



OFFSHORE STANDARD
DNV-OS-B101

METALLIC MATERIALS

APRIL 2009

DET NORSKE VERITAS

FOREWORD

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

DNV Offshore Codes consist of a three level hierarchy of documents:

- *Offshore Service Specifications*. Provide principles and procedures of DNV classification, certification, verification and consultancy services.
- *Offshore Standards*. Provide technical provisions and acceptance criteria for general use by the offshore industry as well as the technical basis for DNV offshore services.
- *Recommended Practices*. Provide proven technology and sound engineering practice as well as guidance for the higher level Offshore Service Specifications and Offshore Standards.

DNV Offshore Codes are offered within the following areas:

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

Amendments and Corrections

Whenever amendments and corrections to the document are necessary, the electronic file will be updated and a new Adobe PDF file will be generated and made available from the Webshop (<http://webshop.dnv.com/global/>).

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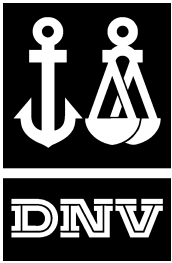
Main changes

- Ch.2 Sec.1: Updating of steel grades in accordance with Ship Rules for steels of normal weldability and in accordance with international standards for steels of increased weldability.
- Ch.2 Sec.2: Totally re-written. More references to international standards. Division of pipes into different categories. Detailed Charpy V-notch requirements to pipes for low-temperature services.
- Ch.2 Sec.3: Revised in accordance with Ship Rules and international standards. Requirements to "Ferritic steel castings for low temperature service" and "Stainless steel castings" have been included.
- Ch.2 Sec.4: Revised in accordance with Ship Rules and international standards. Requirements to "Ferritic steel forgings for low temperature service" and "Stainless steel forgings" have been included.
- Ch.2 Sec.5 and Sec.6: Updated in accordance with international standards.
- Ch.3: No changes to main certification requirements compared to previous edition. However, requirements to Approval of Manufacturer (AoM) have been limited to works delivering steel materials with NV or Works certificates.

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CHAPTER 1

INTRODUCTION

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DET NORSKE VERITAS

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SECTION 1 INTRODUCTION

A. General

A 100 Introduction

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

102 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 or installation.

103 The objectives of this standard are to:

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

A 200 Scope and application

201 The requirements are applicable to:

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

Requirements for copper alloys and iron castings are given in Rules for Classification of Ships, Pt.2 Ch.2.

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

A 300 Material specification

301 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.

302 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.

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

A 400 Pre-qualification of materials and manufacturers

401 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.

402 Requirements for the pre-qualification of manufacturers shall be considered in each case. The consideration shall take into account the complexity and criticality of the product to be

supplied, manufacturer's previous experience and the requirements of this standard.

A 500 Marking

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

502 The type of marking shall be subject to agreement.

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

A 600 Certification

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

B. Normative References

B 100 General

101 The standards in Table B1 include provisions which, through reference in this text, constitute provisions of this offshore standard. Latest issue of the standards shall be used unless otherwise agreed.

102 Other recognised standards may be used provided it can be demonstrated that these meet or exceed the requirements of the standards in Table B1.

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

B 200 Reference documents

201 Applicable reference documents are given in Table B1.

Table B1 Normative references	
No.	Title
ASTM A 275	Standard Test Method for Magnetic Particle Examination of Steel Forgings
ASTM A 388	Standard Practice for Ultrasonic Examination of Heavy Steel Forgings
ASTM E 165	Standard Test Method for Liquid Penetrant Examination
ASTM E 709	Standard Guide for Magnetic Particle Examination
ISO 3452	Non-destructive Testing – Penetrant inspection/testing
ISO 9712	Non-destructive Testing – Qualification and certification of personnel
EN 10204	Metallic Products - Types of inspection documents
EN 473	Qualification and Certification of NDT personnel
EN 10160	Ultrasonic Testing of Steel Flat Product of Thickness Equal or Greater than 6 mm (reflection method)
EN 10228-1/2/3/4	Non-destructive Testing of Steel Forgings
DNV OS-D101	Marine and Machinery Systems and Equipment

C. Definitions

C 100 Verbal forms

101 *Shall*: Indicates requirements strictly to be followed in order to conform to this standard and from which no deviation is permitted.

102 *Should*: Indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others, or that a certain course of action is preferred but not necessarily required. Other possibilities may be applied subject to agreement

103 *May*: Verbal form used to indicate a course of action permissible within the limits of the standard.

104 *Agreement, agreed or by agreement*: Unless otherwise indicated, agreed in writing between manufacturer and purchaser.

C 200 Terms

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

202 *Manufacturer*: The party who is contracted to be responsible for planning, execution and documentation of manufacturing.

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

D. Abbreviations and Symbols

D 100 Abbreviations

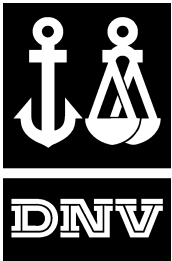
101 Abbreviations used are given in Table D1.

Table D1 Abbreviations	
Abbreviation	Full text
AR	As rolled
EHS	Extra high strength steel
EN	European Norm
HS	High strength steel
IMO	International Maritime Organization
N	Normalised
NR	Normalising rolling
NS	Normal strength steel
QT	Quenched and tempered
TM	Thermo-Mechanical rolling

D 200 Symbols

201 Symbols used are given in Table D2.

Table D2 Symbols	
Symbol	Definition
NV	Designation of a steel grade according to DNV offshore standards
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
W	Letter included to designate a steel grade of improved weldability
Z	Steel grade of improved through-thickness properties
S	Specially accepted steel
R _m	Tensile strength
R _e	Yield stress (yield point)
R _p	Yield strength (proof stress)
R _t	Yield strength (proof stress), total elongation



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CHAPTER 2

TECHNICAL PROVISIONS

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SECTION 1

ROLLED STEEL FOR STRUCTURAL APPLICATION

A. General

A 100 Scope

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

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

103 Steels differing from these requirements in chemical composition, deoxidation practice, condition of supply and mechanical properties may be acceptable, provided that they are specially considered and demonstrated to be suitable.

A 200 Designation of steel grades

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

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

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

- steels of normal weldability
- steels of improved weldability.

The two series are intended for the same applications. However, in addition to leaner chemistry and better weldability the improved weldability grades have extra margins to account for reduced toughness after welding. These grades are also limited to a specified minimum yield stress of 500 N/mm².

203 The alphanumeric designation of the steel grade is:

- NV xy for steels of normal weldability
- NV xWy for steels of improved weldability.

- NV = designation of a steel grade according to the DNV offshore standards
- x = a capital letter corresponding to a specified impact toughness test temperature, see Table A1
- W = letter included to designate a steel grade of improved weldability
- y = a figure designating the strength group according to the specified minimum yield stress. The figure y is omitted for NS steels.

204 Additional symbols following the alphanumeric designation given in 203 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.

Table A1 Definitions of steel grades

Strength group	Impact testing			Tensile properties	
	Symbol x		Test temperature °C)	Symbol y	Minimum yield stress ¹⁾ (N/mm ²)
	Normal weldability	Improved weldability			
NS	A B ²⁾ D E	- BW DW EW	- 0 -20 -40	Omitted	235
HS	A D E F	AW DW EW -	0 -20 -40 -60	27 32 36 40	265 315 355 390
EHS	A D E F	- DW EW -	0 -20 -40 -60	420 460 500 550 620 690	420 460 500 550 620 690
1) For steels of improved weldability the required minimum yield stress is reduced for increasing material thickness.					
2) Charpy V-notch tests are required for thickness above 25 mm but is subject to agreement for thickness of 25 mm or less.					

A 300 Manufacture

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

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

303 Conditions of supply shall be in accordance with 500.

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

A 400 Chemical composition

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

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

403 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.

404 When recycled scrap is used in steelmaking, adequate controls shall be in place to prevent accumulation of harmful

elements in the final product. The content of impurity elements such as tin, antimony and arsenic may be required determined.

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

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

Subject to agreement, the weldability may alternatively be evaluated by calculating the cold cracking susceptibility using the formula:

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

A 500 Condition of supply and heat treatment

501 Conditions of supply shall be in accordance with requirements given in B to D and as defined in 502 to 506. Where alternative conditions are permitted, the manufacturer shall supply materials only in the conditions agreed.

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

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

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

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

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

507 It is the manufacturer's responsibility to ensure that the programmed rolling schedules for NR and TM are adhered to. Production records to this effect shall be made available to the surveyor on request. Where deviation from the programmed rolling schedules occurs, the manufacturer must ensure that each affected rolled piece is tested and that an investigation is carried out according to 304.

A 600 Inspection and tolerances

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

602 Products shall have a workmanlike finish consistent with the method of manufacture and shall be free from cracks, shells and seams. Acceptance criteria for other imperfections such as rolled-in scale, indentations and roll marks, which may

occur under normal manufacturing conditions, shall be EN 10163 Class A for plates and Class D for sections or equivalent standard.

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

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

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

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

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

A 700 Repair

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

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

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

702 Surface defects which cannot be dealt with as in 701 may be repaired by chipping or grinding followed by welding, subject to the purchaser's consent and under his supervision, provided that:

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

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

A 800 Identification

801 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. NV E36. When products comply with the requirements of E, the grade shall include the suffix Z25 or Z35, e.g. NV E36Z25
- identification number, heat number or other marking which will enable the full history of the product to be traced
- if required by the purchaser, his order number or other identification mark.

802 The particulars in 801, but excluding the manufacturer's name or trade mark where this is embossed on finished products, shall be encircled with paint or otherwise marked so as to be easily recognisable.

803 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.

A 900 Certification

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

- purchaser's name, order number and, if known, the vessel identification
- manufacturer's name
- description of products and steel grade
- identification marking of products
- steel making process, heat number and chemical composition
- condition of supply
- results of mechanical tests
- when products comply with the requirements of E, the

- results of through thickness tensile tests and ultrasonic tests
- results of any supplementary and additional test requirements specified.

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

B. Normal Strength Steel**B 100 Scope**

101 These requirements are supplementary to A and apply to normal strength steel, which is defined as steel with specified minimum yield stress of 235 N/mm².

B 200 Chemical composition

201 Requirements for chemical composition and deoxidation practice for normal strength steel are given in Table B1 and Table B2.

B 300 Heat treatment, condition of supply

301 Normal strength steel shall be delivered in a condition complying with the requirements given in Table B3.

B 400 Mechanical properties

401 Normal strength steel shall comply with the mechanical properties specified in Table B2 and Table B4 for steel grades of improved weldability and normal weldability respectively.

402 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 B5.

403 Additional requirements concerning through thickness properties (Z-ductility), are given in E400 for steel grades of improved weldability and, where specified, for grades of normal weldability.

Table B1 Chemical composition limits ¹⁾ and deoxidation practice for normal strength steel							
Grade	C ²⁾	Si	Mn ²⁾	P	S	Al	Deoxidation practice
NV A	0.21 ³⁾	0.50	Min. 2.5 × C	0.035	0.035	-	For t ≤ 50 mm: Any method except rimmed steel ⁴⁾ For t > 50 mm: Killed
NV B	0.21	0.35	Min. 0.80 ⁵⁾	0.035	0.035	-	For t ≤ 50 mm: Any method except rimmed steel For t > 50 mm: Killed
NV D	0.21	0.10-0.35	Min. 0.60	0.035	0.035	-	For t ≤ 25 mm: Killed
NV E	0.18	0.10-0.35	Min. 0.70	0.035	0.035	Min. 0.020 ⁶⁾	For t > 25 mm: Killed and fine grain treated Killed and fine grain treated

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

Table B2 Requirements for normal strength steel of improved weldability ¹⁾

Grade	NV BW	NV DW	NV EW
Deoxidation	Killed and fine grain treated		
Chemical composition (ladle analysis, maximum weight % unless range stated)			
C	0.12		
Si	0.10 – 0.50		
Mn	0.60 – 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 (N/mm ²)	400 – 520		
Yield stress (N/mm ²) t ≤ 25 mm 25 mm < t ≤ 50 mm 50 mm < t ≤ 75 mm 75 mm < t ≤ 100 mm	235 minimum 215 minimum 200 minimum 190 minimum		
Elongation, A ₅ (%)	22 minimum		
Impact test, Charpy V-notch			
Test temperature (°C)	0	-20	-40
Minimum average energy (J)			
Transverse	40		
Minimum single value (J)			
Transverse	28		
Minimum average through thickness ductility Z _z (%)	35		
1) When scrap material is being used in steel production, the amount of the following residual elements shall be determined and reported and the levels shall not exceed: 0.03% As, 0.01% Sb, 0.02% Sn, 0.01% Pb, 0.01% Bi and 0.005% Ca.			
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.			

Table B3 Conditions of supply for normal strength steel

Grade	Thickness, t (mm)	Plates	Sections
NV A, NV B	t ≤ 50	AR, NR, N, TM	AR, NR, N, TM
	50 < t ≤ 150	AR ¹⁾ , NR, N, TM	AR ¹⁾ , NR, N, TM
NV D	t ≤ 35	AR, NR, N, TM	AR, NR, N, TM
	35 < t ≤ 150	NR, N, TM	AR ¹⁾ , NR, N, TM
NV E	t ≤ 150	N, TM	AR ¹⁾ , NR ¹⁾ , N, TM
1) Products may be supplied in this condition when especially approved.			

Table B4 Mechanical properties for normal strength steel

Grade	Yield stress R_{eH} minimum (MPa)	Tensile strength R_m (MPa)	Elongation A_5 minimum (%)	Impact energy, longitudinal minimum (J)			
				Temperature (°C)	$t \leq 50$ (mm)	$50 < t \leq 70$ (mm)	$70 < t \leq 150$ (mm)
NV A	235	400-520	22 ³⁾	+20	-	34 ²⁾	41 ²⁾
NV B				0	27 ¹⁾	34	41
NV D				-20	27	34	41
NV E				-40	27	34	41

- 1) Impact tests are not required for grade B steel with thickness of 25 mm or less.
- 2) Impact tests for grade A over 50 mm thickness are not required when the material is produced using fine grain practice and supplied in either N or TM conditions.
- 3) For full thickness flat test pieces with width 25 mm and gauge length 200 mm, the minimum elongation (%) is reduced to the following values:

Table B5 Test units for impact testing of normal strength steel

Grade	Thickness, t (mm)	Plates	Sections
NV A	$t \leq 50$	Not required	Not required
	$50 < t \leq 150$	50 tonnes	Not required
NV B	$t \leq 25$	Not required	Not required
	$25 < t \leq 150$	50 tonnes ^{1) 2)}	50 tonnes ²⁾
NV D	$t \leq 150$	50 tonnes ^{1) 2)}	50 tonnes ²⁾
NV E	$t \leq 150$	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.

C 200 Chemical composition

201 For steel grades of normal weldability and improved weldability, the chemical composition, shall comply with the requirements in Table C1 and Table C2, respectively. The steel grades shall be killed and fine grain treated except for NV A27S in thickness up to and including 25 mm which may be semi-killed or killed without fine grain treatment.

202 For TM steels the carbon equivalent calculated from above formula shall comply with the requirements given in Table C3.

C 300 Condition of supply

301 High strength steel shall be delivered in a condition complying with the requirements given in Table C4.

C 400 Mechanical properties

401 High strength steel shall comply with the mechanical properties specified in Table C2 and Table C5 for steel grades of improved weldability and normal weldability respectively.

402 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 C6.

403 Additional requirements concerning through thickness properties (Z-ductility) are given in E400 for steel grades of improved weldability and, where specified, for grades of normal weldability.

C. High Strength Steel**C 100 Scope**

101 These requirements are supplementary to A and apply to high strength steel, which is defined as steel with specified minimum yield stress of 265 N/mm² and up to and including 390 N/mm².

Table C1 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₎	N
NV A27S, NV D27S, NV E27S	0.18	0.50	0.70- 1.60	0.035	0.035	0.20	0.08	0.40	0.35	Min. 0.020	0.02 - 0.05	0.05 - 0.10	0.007 - 0.05	-
NV A32, NV D32, NV E32, NV A36, NV D36, NV E36, NV A40, NV D40, NV E40	0.18	0.50	0.90- 1.60 ²⁾	0.035	0.035	0.20	0.08	0.40	0.35	Min. 0.020	0.02 - 0.05	0.05 - 0.10	0.007 - 0.05	-
NV F27S, NV F32, NV F36, NV F40	0.16	0.50	0.90- 1.60	0.025	0.025	0.20	0.08	0.80	0.35	Min. 0.020	0.02 - 0.05	0.05 - 0.10	0.007 - 0.05	0.009 ⁵⁾

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

Table C2 Requirements for high strength steels of improved weldability ¹⁾

Grade	NV AW27 NV DW27 NV EW27	NV AW32 NV DW32 NV EW32	NV AW36 NV DW36 NV EW36
Deoxidation	Killed and fine grain treated		
Chemical composition (ladle analysis, maximum weight % unless range stated)			
C	0.12		
Si	0.10 – 0.50		
Mn	0.90 – 1.60		
P	0.020		
S	0.008		
Cu	0.35		
Cr	0.20		
Ni	0.70		
Mo	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 (N/mm ²)	400 – 530	440 – 590	490 – 630
Yield stress (N/mm ²)			
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 NV AW Grade NV DW Grade NV EW		0 – 20 – 40	
Minimum average energy (J)			
Transverse	40	44	50
Minimum single value (J)			
Transverse	28	31	35
Minimum average through thickness ductility Z _z (%)	35		
1) When scrap material is being used in steel production, the amount of the following residual elements shall be determined and reported and the levels shall not exceed: 0.03% As, 0.01% Sb, 0.02% Sn, 0.01% Pb, 0.01% Bi and 0.005% Ca.			
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.			

Table C3 Maximum carbon equivalent values for high strength steel supplied in TM condition

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

Table C4 Conditions of supply for high strength steel

Grade	Grain refining element	Thickness, <i>t</i> (mm)	Plates	Sections
NV A27S, NV A32, NV A36	Al or Al+Ti	$t \leq 20$	AR, NR, N, TM	AR, NR, N, TM
		$20 < t \leq 35$	AR ¹⁾ , NR, N, TM	AR, NR, N, TM
		$35 < t \leq 150$	NR, N, TM, QT	AR ¹⁾ , NR, N, TM, QT
	Any, except Al or Al+Ti	$t \leq 12.5$	AR, NR, N, TM	AR, NR, N, TM
		$12.5 < t \leq 150$	NR, N, TM, QT	AR ¹⁾ , NR, N, TM, QT
NV A40	Any	$t \leq 12.5$	AR, NR, N, TM	AR, NR, N, TM
		$12.5 < t \leq 150$	NR, N, TM, QT	NR, N, TM, QT
NV D27S, NV D32, NV D36	Al or Al+Ti	$t \leq 20$	AR, NR, N, TM	AR, NR, N, TM
		$20 < t \leq 25$	AR ¹⁾ , NR, N, TM	AR, NR, N, TM
		$25 < t \leq 150$	NR, N, TM, QT	AR ¹⁾ , NR, N, TM, QT
	Any, except Al or Al+Ti	$t \leq 12.5$	AR, NR, N, TM	AR, NR, N, TM
		$12.5 < t \leq 150$	NR, N, TM, QT	AR ¹⁾ , NR, N, TM, QT
NV D40	Any	$t \leq 150$	NR, N, TM, QT	NR, N, TM, QT
NV E27S, NV E32, NV E36	Any	$t \leq 50$	N, TM, QT	AR ¹⁾ , NR ¹⁾ , N, TM, QT
		$50 < t \leq 150$	N, TM, QT	NR ¹⁾ , N, TM, QT
NV F27S, NV F32, NV F36	Any	$t \leq 150$	N, TM, QT	NR ¹⁾ , N, TM, QT
NV E40, NV F40	Any	$t \leq 150$	N, TM, QT	N, TM, QT

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

Table C5 Mechanical properties for high strength steel

Grade	Yield stress R_{eH} minimum (MPa)	Tensile strength R_m (MPa)	Elongation A_5 minimum (%)	Impact energy, longitudinal minimum (J)			
				Temperature (°C)	$t \leq 50$ (mm)	$50 < t \leq 70$ (mm)	$70 < t \leq 150$ (mm)
NV A27S NV D27S NV E27S NV F27S	265	400-530	22 ¹⁾	0 -20 -40 -60	27	34	41
NV A32 NV D32 NV E32 NV F32	315	440-570	22 ¹⁾	0 -20 -40 -60	31	38	46
NV A36 NV D36 NV E36 NV F36	355	490-630	21 ¹⁾	0 -20 -40 -60	34	41	50
NV A40 NV D40 NV E40 NV F40	390	510-660	20 ¹⁾	0 -20 -40 -60	41	45	55

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

Table C6 Test units for impact testing of high strength steel

Grade	Plates	Sections
Grades A and D of all strength levels	50 tonnes ^{1) 2)}	50 tonnes ²⁾
Grades E and F of all strength levels	Each piece	25 tonnes ³⁾

1) Maximum 25 tonnes for plates over 50 mm in thickness supplied in NR condition.
2) Maximum 25 tonnes for plates and sections supplied in AR condition.
3) Maximum 15 tonnes for sections supplied in AR or NR condition.

D. Extra High Strength Steel

D 100 Scope

101 These requirements are supplementary to A and apply to extra high strength steels, which is defined as steel with specified minimum yield stress of 420 N/mm² and up to and including 690 N/mm².

The steel grades shall be killed and fine grain treated.

D 200 Chemical composition

201 The chemical composition shall satisfy the requirements

in Table D1 and Table D2 for steel grades of normal weldability and improved weldability respectively.

D 300 Heat treatment, condition of supply

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

D 400 Mechanical properties

401 Extra high strength steel shall comply with the mechanical

properties specified in Table D2 and Table D3 for steel grades of improved weldability and normal weldability respectively.
The extent of tensile and impact testing shall be each piece.

402 Additional requirements for through thickness properties (Z-ductility) are given in E400 for steel grades of improved weldability and, where specified, for grades of normal weldability.

Table D1 Chemical composition limits ¹⁾ for extra high strength steel														
<i>Grade</i>	<i>C</i>	<i>Si</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Cr</i> ²⁾	<i>Mo</i> ²⁾	<i>Ni</i> ²⁾	<i>Cu</i> ²⁾	<i>Al</i> ^{3) 4)}	<i>Nb</i> ⁴⁾	<i>V</i> ⁴⁾	<i>Ti</i> ⁴⁾	<i>N</i>
Grade A of all strength levels	0.21	0.10-0.55	1.70	0.035	0.035	0.20	0.08	0.40	0.35	Min. 0.020	0.02-0.05	0.05-0.10	0.007-0.05	-
Grades D and E of all strength levels	0.20	0.10-0.55	1.70	0.030	0.030	0.20	0.08	0.40	0.35	Min. 0.020	0.02-0.05	0.05-0.10	0.007-0.05	-
Grade F of all strength levels	0.18	0.10-0.55	1.60	0.025	0.025	0.20	0.08	0.80	0.35	Min. 0.020	0.02-0.05	0.05-0.10	0.007-0.05	0.009 ⁵⁾
¹⁾ Composition in percentage mass by mass maximum unless shown as a range or as a minimum. ²⁾ The limits given do not apply when elements are intentionally added. ³⁾ Total content. Acid soluble content, if determined instead, shall be minimum 0.015%. ⁴⁾ The steel shall contain Al, Nb, V or Ti, either singly or in any combination. When used singly, the steel shall contain the specified minimum content of the element. When Al and Nb are used in combination, the minimum total Al content shall be 0.015% and the minimum Nb content shall be 0.010%. When Al and V are used in combination, the minimum total Al content shall be 0.015% and the minimum V content shall be 0.030%. The total content of Nb+V+Ti shall not exceed 0.12%. ⁵⁾ 0.012% if Al is present.														

Table D2 Requirements for extra high strength steels of improved weldability ¹⁾			
<i>Grade</i>	<i>NV DW420 NV EW 20</i>	<i>NV DW460 NV EW460</i>	<i>NV DW500 NV EW500</i>
<i>Deoxidation</i>	<i>Killed and fine grain treated</i>		
Chemical composition (ladle analysis, maximum weight % unless range stated)			
C	0.12		
Si	0.10 – 0.50		
Mn	1.65		
P	0.020		
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		
<i>Tensile test</i>			
Tensile strength(N/mm ²)	530 – 680	570 – 720	610 – 770
Yield stress (N/mm ²)			
t ≤ 50 mm	420	460	500
50 mm < t ≤ 75 mm	400	440	480
75 mm < t ≤ 100 mm	380	420	460
Elongation, A ₅ (%)	20	19	18
<i>Impact test, Charpy V-notch</i>			
Test temperature (°C)			
Grade DW	-20		
Grade EW	-40		
Minimum average energy (J)			
Transverse	60		
Minimum single value (J)			
Transverse	42		
Minimum average through thickness ductility Z _x (%)	35		

Table D2 Requirements for extra high strength steels of improved weldability 1) (Continued)

1) When scrap material is being used in steel production, the amount of the following residual elements shall be determined and reported and the levels shall not exceed: 0.03% As, 0.01% Sb, 0.02% Sn, 0.01% Pb, 0.01% Bi and 0.005% Ca.
2) Al:N ≥ 2:1 (not applicable for titanium killed steel).
3) (Nb+V) _{max} : 0.09%.
4) (Nb+V+Ti) _{max} : 0.13%.
5) Boron (maximum 30 ppm) may be added subject to agreement.

Table D3 Mechanical properties for extra high strength steel

Grade	Yield stress R_{eH} minimum (MPa)	Tensile strength R_m (MPa)	Elongation A_5 minimum (%)	Impact energy, transverse minimum (J)	
				Temperature (°C)	$t \leq 150$ (mm)
NV A420 NV D420 NV E420 NV F420	420	530-680	18 ¹⁾	0 -20 -40 -60	28
NV A460 NV D460 NV E460 NV F460	460	570-720	17 ¹⁾	0 -20 -40 -60	31
NV A500 NV D500 NV E500 NV F500	500	610-770	16 ¹⁾	0 -20 -40 -60	33
NV A550 NV D550 NV E550 NV F550	550	670-830	16 ¹⁾	0 -20 -40 -60	37
NV A620 NV D620 NV E620 NV F620	620	720-890	15 ¹⁾	0 -20 -40 -60	41
NV A690 NV D690 NV E690 NV F690	690	770-940	14 ¹⁾	0 -20 -40 -60	46

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

Thickness, mm	$t \leq 10$	$10 < t \leq 15$	$15 < t \leq 20$	$20 < t \leq 25$	$25 < t \leq 40$	$40 < t \leq 50$	$t > 50$
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

E. Testing

E 100 Test material and test pieces for mechanical testing

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

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

103 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 approximately one-quarter width from an edge, see Fig. 1a.

— *Flats with a width < 600 mm, bulb flats and other sections*
The test material shall be taken at approximately one-third of the width from an edge, see Figures 1b, 1c, 1d and 1e. For channels and beams, an alternative position is shown in Fig. 1d.

— *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 Fig. 1f.

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

Longitudinal: longitudinal axis of test piece parallel to the principal direction of rolling.

Transverse: longitudinal axis of test piece perpendicular to the principal direction of rolling.

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

— *Plates and wide flats with a width ≥ 600 mm*

Tensile test pieces shall be transverse. Impact test pieces shall be longitudinal, except that for extra high strength steel, transverse tests are required.

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

— *Bars and other similar products*

Tensile and impact test pieces shall be longitudinal.

106 The preparation of test pieces and the procedures used for mechanical testing shall comply with the relevant requirements of Sec.6. See also 107 and 108.

107 For impact test pieces, the notch shall be cut in a face of the test piece which was originally perpendicular to a rolled surface.

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

E 200 Tensile testing

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

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

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

204 When no distinct yield is observed during tensile testing, $R_{p0.2}$ or $R_{t0.5}$ shall be determined.

E 300 Impact testing

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

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

302 For thicknesses equal to or below 50 mm, the impact test pieces shall be taken not less than 2 mm below the surface. For plate thicknesses exceeding 50 mm, impact test pieces shall be situated so that the distance between the centre-line of the test piece and the plate surface is not less than 1/4 of the plate thickness.

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

the required values of the standard test piece.

304 The average energy value from each set of three impact tests and the single values shall comply with the appropriate requirements of Table B4, Table C5, and Table D3 for steel grades of normal weldability. For steel grades of improved weldability, requirements are given in Table B2, Table C2 and Table D2 as appropriate. Further, only one individual value within each set may be below the specified minimum average value, but not lower than 70% of this value.

E 400 Testing of through thickness properties

Scope

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

402 Provision is made for two quality classes Z25 and Z35 based on specified minimum values for reduction of area in a through thickness tensile test. Quality class Z25 is intended for normal ship applications and Z35 for more severe applications.

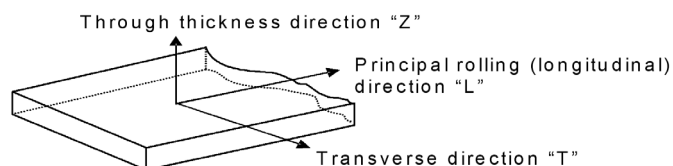


Figure 1
Through thickness tensile testing

Manufacture

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

Chemical composition

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

Test material

405 Test material shall be taken close to the longitudinal centreline from one end of each rolled piece representing the test unit, see Fig.3 and Table E1.

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

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

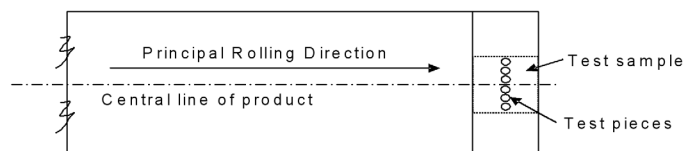


Figure 2
Plate and wide flat sampling position

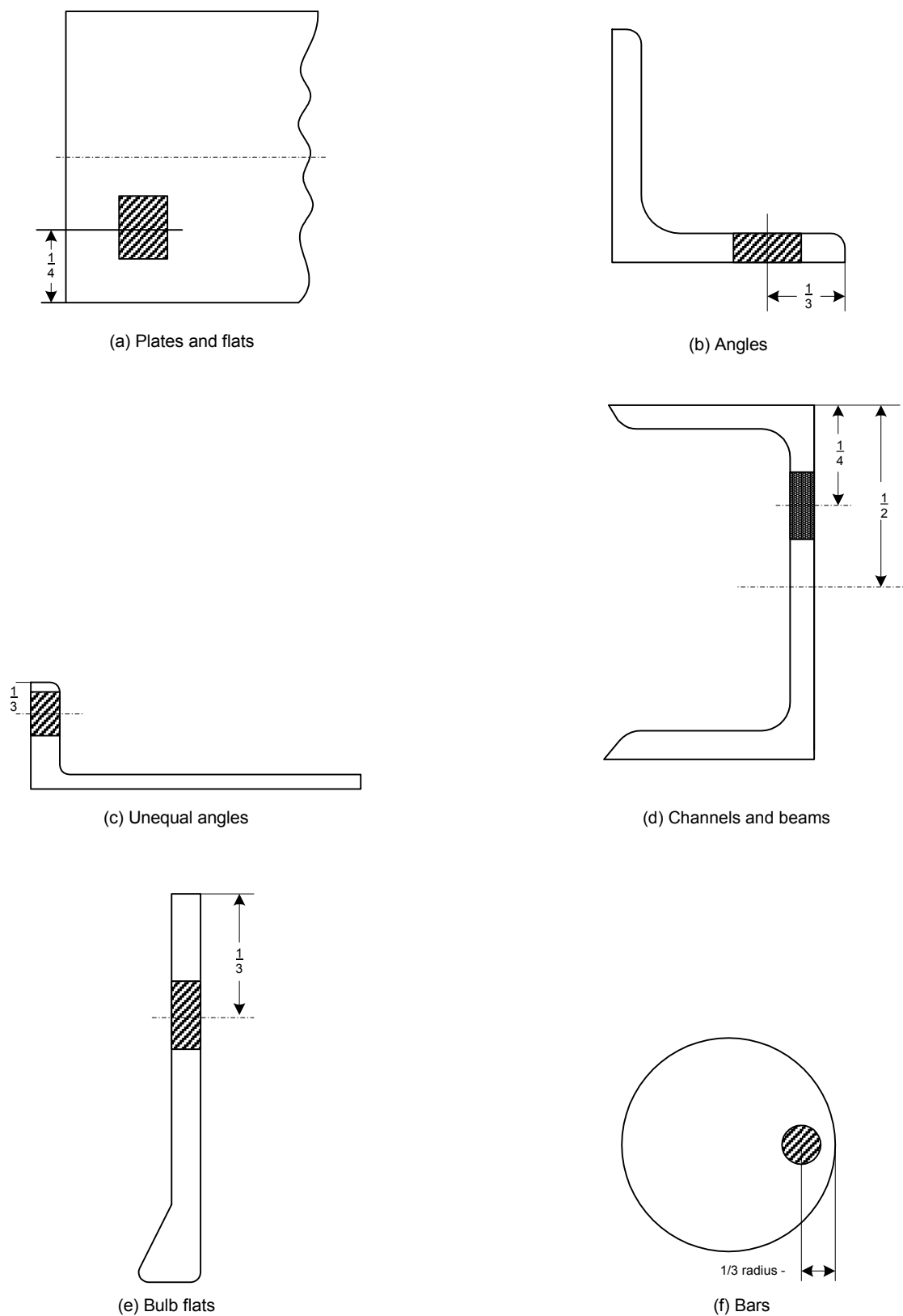


Figure 3
Position of test specimen

Table E1 Test unit (batch) size dependent on product and sulphur content

Product	$S > 0.005\%$	$S \leq 0.005\%$
Plates	Each piece (parent plate)	Maximum 50 t of products of the same heat, thickness and condition of supply
Wide flats of nominal thickness ≤ 25 mm	Maximum 10 t of products of the same heat, thickness and condition of supply	Maximum 50 t of products of the same heat, thickness and condition of supply
Wide flats of nominal thickness > 25 mm	Maximum 20 t of products of the same heat, thickness and condition of supply	Maximum 50 t of products of the same heat, thickness and condition of supply

Mechanical testing

408 The average reduction of area value of three test pieces shall be determined and meet the specified minimum average value given in Table E2. One individual value may be below the specified minimum average value, provided that it is not less than the specified minimum individual value.

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

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

410 Where batch testing is permitted and the conditions for acceptance after retest in 409 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.

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

Table E2 Reduction of Area Acceptance Values

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

Ultrasonic testing

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

SECTION 2 STEEL PIPES

A. General Requirements

A 100 Scope

101 This sub-section specifies the general requirements for steel pipes to be used in the construction of piping for pressure, cargo, and process systems. Provision is made for carbon and carbon-manganese, alloy, and stainless steels. Separate requirements for steel piping fittings are given in F.

102 Pipes shall be in accordance with recognised standards, as given in B to E, provided that additionally supplementary requirements equivalent to specific requirements in B to E are also met. Recognition of other standards is subject to agreement.

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

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

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

A 200 Manufacture

201 Pipes shall be manufactured as specified in B to E. The terms “hot finished” and “cold finished” apply to the condition of the pipe before it is heat treated.

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

A 300 Chemical composition

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

302 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.

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

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

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

A 400 Heat treatment

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

A 500 Mechanical testing

501 Pipes shall be sampled and subjected to testing in accordance with the requirements of the relevant standard. Unless stricter requirements are specified in the standard, the size of a test unit (batch) shall be restricted to maximum 400 pipes and as given in 502 and 503.

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

503 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.

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

A 600 Leak tightness testing

601 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. Unless stricter requirements are specified in the standard, the testing shall be as given in 602.

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

A 700 Inspection

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

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

A 800 Repair

801 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.

A 900 Identification

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

A 1000 Certification

1001 The manufacturer shall provide the type of inspection certificate required in the relevant design and construction rules giving the following particulars for each test unit which has been accepted:

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

B. Pressure Pipes

B 100 Scope

101 These requirements are supplementary to A and apply to carbon and carbon-manganese and alloy steel pipes for use in pressure systems.

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

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

In addition, those standards given in D and E may be used.

B 200 Manufacture

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

- hot finished seamless
- cold finished seamless
- electric resistance or induction welded, see A202
- cold finished electric resistance or induction welded, see A202
- electric fusion welded, see A202.

C. Stainless Steel Pipes

C 100 Scope

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

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

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

C 200 Manufacture

201 Pipes shall be manufactured by any of the following methods:

- hot finished seamless
- cold finished seamless
- electric resistance or induction welded, see A202
- cold finished electric resistance or induction welded, see A202
- electric fusion welded, see A202.

C 300 Mechanical testing

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

C 400 Corrosion testing

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

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

D. Pipes for Low-temperature Service

D 100 Scope

101 These requirements are supplementary to A 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.

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

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

D 200 Manufacture

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

- hot finished seamless
- cold finished seamless
- electric resistance or induction welded, see A202
- cold finished electric resistance or induction welded, see A202
- electric fusion welded, see A202.

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

D 300 Mechanical testing

301 Requirements for Charpy V-notch impact testing dependent of steel type and minimum design temperature are given in Table D1.

Table D1 Charpy V-notch impact properties			
Steel type	Min. design temperature (°C)	Charpy V-notch	
		Test temperature (°C)	Average energy (J)
C and C-Mn	-55	1)	27
2 ¼ Ni	-65	-70	34
3 ½ Ni	-90	-95	34
9 Ni	-165	-196	41
1) The test temperature shall be 5°C below the design temperature or -20°C whichever is lower.			

E. Boiler and Superheater Tubes

E 100 Scope

101 These requirements are supplementary to A and apply to carbon and carbon-manganese and alloy steel tubes for use in boilers, superheaters and heat exchangers.

102 Austenitic stainless steels may also be used for this type of service. Where such applications are proposed, see A105.

103 Suitable pipe grades shall be selected from the following

recognised standards:

- ISO 9329 Part 2, ISO 9330 Part 2
- EN 10216 Part 2, EN 10217 Part 2
- ASTM A178, A209, A210, A213
- DIN 17175, DIN 17177
- JIS G3461, JIS G3462.

E 200 Manufacture

201 Pipes shall be manufactured by any of the following methods:

- hot finished seamless
- cold finished seamless
- electric resistance or induction welded, see A202
- cold finished electric resistance or induction welded, see A202.

F. Piping Fittings

F 100 Scope

101 This sub-section specifies the requirements for steel piping fittings such as elbows, bends, tees, reducers and caps - for the applications covered in B to E. Detachable pipe couplings and flanges are excluded from these requirements.

102 Fittings shall be in accordance with recognised standards, as given in 103. Recognition of other standards is subject to agreement.

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

- EN 10253
- ASTM A234, A403, A420, A744, A815, A960, A961
- DIN 2605, DIN 2609, DIN 2615, DIN 2616, DIN 2617
- JIS B2312, JIS B2313, JIS B2316.

104 Where required by the relevant design and construction parts of the rules, fittings shall comply with the requirements of Ch.1 Sec.1 and Sec.6 and this sub-section.

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

F 200 Materials and manufacture

201 Materials for fittings shall consist of plates, seamless or welded pipes.

202 Fittings shall be manufactured by forming operations such as pressing, bending or fusion welding.

F 300 Testing and inspection

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

F 400 Certification

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

- purchaser's name, order number and vessel identification, where known
- manufacturer's name
- description of fittings and material quality
- identification marking of fittings
- heat number and chemical composition
- results of mechanical tests and technological tests
- results of any supplementary and additional test requirements specified.

SECTION 3 STEEL FORGINGS

A. General Requirements

A 100 Scope

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

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

103 As an alternative to 102, materials which comply with national or proprietary specifications may be accepted provided such specifications give reasonable equivalence to the requirements of A or are especially agreed upon. As a minimum the following particulars shall be specified: manufacturing process, chemical composition, heat treatment, mechanical properties and non-destructive testing.

A 200 Grading system

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

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

Guidance note:

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

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A 300 Manufacture

301 The steel used in the manufacture of forgings shall be made by a process approved by the purchaser. All forgings shall be made from killed steel.

302 For forgings with specified minimum ultimate tensile strength 800 N/mm² 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.

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

304 The material shall be progressively hot worked by hammer or press, and shall be forged as close as practical to the finished shape and size, see also 504. Shaping of forgings by flame cutting, scarfing or arc-air gouging shall be undertaken in accordance with recognised good practice and, unless otherwise approved, shall be carried out before the final heat treatment.

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

- for forgings made from ingots or from forged blooms or billets, 3:1 where $L > D$ and 1.5:1 where $L < D$
- for forgings made from rolled products, 4:1 where $L > D$ and 2:1 where $L < D$
- for forgings made by upsetting, the length after upsetting shall be not more than one-third of the length before upsetting or, in the case of an initial forging reduction of at least 1.5:1, not more than one-half of the length before upsetting
- for rolled bars (see A101), 6:1.

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

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

307 For clean steel forgings, the steels shall have a degree of cleanliness as given in Table A1 when tested according to ISO 4967 method A. Samples shall be obtained from forged or rolled product representative of each heat. Additionally, the contents of the elements sulphur, phosphorus, and oxygen shall be restricted to maximum 0.005%, 0.015%, and 25 ppm, respectively.

Table A1 Cleanliness requirements		
<i>Inclusion group</i>	<i>Series</i>	<i>Limiting value</i>
Type A	Fine	1
	Thick	1
Type B	Fine	1.5
	Thick	1
Type C	Fine	1
	Thick	1
Type D	Fine	1
	Thick	1
Type DS	N.A.	1

A 400 Chemical composition

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

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

403 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.

A 500 Heat treatment

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

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

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

504 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.

505 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.

506 If a forging is locally reheated or any straightening operation is performed after the final heat treatment, consideration shall be given to a subsequent stress relieving heat treatment.

A 600 Test material and test pieces for mechanical testing

601 Test material, from which test pieces are taken, shall be integral with the forging except as provided in 603. 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.

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

603 Where batch testing is permitted according to 700, 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.

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

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

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

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

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

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

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

A 700 Test units and number of tests

701 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.

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

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

704 Rolled bars (see 101) may be batch tested and the test unit shall consist of either:

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

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

706 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.

707 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.

A 800 Mechanical properties

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

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

A 900 Inspection

901 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.

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

903 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.

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

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

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

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

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

906 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 condition for subsequent processing and final MT or PT by the purchaser, the manufacturer should perform suitable intermediate inspections taking into consideration the quality level required in finished condition.

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

908 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.

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

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

A 1000 Repair

1001 Defects may be removed by grinding or by chipping and grinding provided the component dimensions are acceptable and the repair is made in accordance with any applicable requirements of the relevant construction rules. See also 1002. The resulting grooves shall have a bottom radius of approxi-

mately three times the groove depth and shall be blended into the surrounding surface so as to avoid any sharp contours. Complete elimination of the defective material shall be verified by magnetic particle testing or liquid penetrant testing.

1002 Unless otherwise approved for hull forgings, the permissible depth of grinding shall be in accordance with IACS Recommendation No. 68.

1003 Repair welding of forgings may be permitted subject to prior agreement of the purchaser. In such cases, full details of the extent and location of the repair, the proposed welding procedure, heat treatment and subsequent inspection procedures shall be submitted for the acceptance.

1004 The forging manufacturer shall maintain records of repairs and subsequent inspections traceable to each forging repaired. The records shall be presented to the purchaser on request.

A 1100 Identification

1101 Each forging which has been tested and inspected with satisfactory results shall be suitably identified by the manufacturer with the following:

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

1102 In the case of forgings of the same type less than 115 kg in mass, modified arrangements for identification may be agreed upon.

A 1200 Certification

1201 The manufacturer shall provide the type of inspection certificate required in the relevant construction rules giving the following particulars for each test unit which has been accepted:

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

B. Forgings for Hull Structures and Equipment

B 100 Scope

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

B 200 Chemical composition

201 The chemical composition shall comply with the overall limits given in Table B1 or, where applicable, the requirements of the agreed specification.

B 300 Heat treatment

301 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.

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

B 400 Mechanical testing

401 Longitudinal tests shall be made but, at the discretion of the manufacturer, transverse tests may be used.

402 The mechanical properties shall comply with the values given in Table B2 appropriate to the specified minimum tensile strength or, where applicable, the requirements of the

agreed specification.

403 Forgings may be supplied to any specified minimum tensile strength within the general limits given in Table B2 but subject to any restrictions of the relevant construction rules. Where it is proposed to use a steel with a specified minimum tensile strength intermediate to those given in Table B2, corresponding minimum values for the other properties may be obtained by interpolation.

B 500 Inspection

501 Magnetic particle or liquid penetrant testing shall be carried out on forgings intended for rudder stocks and pintles with diameter larger than 100 mm, see A906.

502 Ultrasonic testing shall be carried out on forgings intended for rudder stocks and pintles with diameter larger than 200 mm.

Table B1 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 - 1.50	0.035	0.035	0.30	0.15	0.40	0.30	0.85
Alloy	0.25	0.45	0.30 - 1.00	0.035	0.030	Minimum 0.40 4)	Minimum 0.15 4)	Minimum 0.40 4)	0.30	-

1) Composition in percentage mass by mass maximum unless shown as a range or as a minimum.

2) Forgings not intended for welding may be supplied to the composition limits given in DNV Ship Rules Pt2 Ch.2 Sec.5 Table C1.

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.

Table B2 Mechanical properties for steel forgings for hull structures and equipment

Steel type	Tensile strength R_m minimum (N/mm ²)	Yield stress R_e minimum (N/mm ²)	Elongation A_5 minimum (%)		Reduction of area Z minimum (%)		Charpy V-notch ¹⁾		
			l	t	l	t	Temperature (°C)	Energy (J)	
								l	t
C and C-Mn	400	200	26	19	50	35	0	27	18
	440	220	24	18	50	35	0	27	18
	480	240	22	16	45	30	0	27	18
	520	260	21	15	45	30	0	27	18
	560	280	20	14	40	27	0	27	18
	600	300	18	13	40	27	0	27	18
Alloy	550	350	20	14	50	35	0	32	22
	600	400	18	13	50	35	0	32	22
	650	450	17	12	50	35	0	32	22

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

l = longitudinal, t = transverse

C. Ferritic Steel Forgings for Low Temperature Service

C 100 Scope

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

C 200 Chemical composition

201 The chemical composition shall comply with the overall limits given in Table C1 or, where applicable, the requirements of the agreed specification.

202 Where carbon and carbon-manganese steel is fine grain treated with niobium, vanadium or titanium, either singly or in any combination, the content of Nb shall be within 0.01 to

0.05%, V shall be 0.05% maximum and Ti shall be 0.02% maximum.

C 300 Heat treatment

301 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.

302 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.

C 400 Mechanical properties

401 The mechanical properties shall comply with the values given in Table C2 or, where applicable, the requirements of the

agreed specification.

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

C 500 Inspection

501 Quenched and tempered forgings are subject to magnetic particle testing, see A906 and the relevant construction rules.

502 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.

C 600 Pressure testing

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

Table C1 Chemical composition limits ¹⁾ for ferritic steel forgings for low temperature service

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

1) Composition in percentage by mass maximum unless shown as a range or as a minimum.

2) Elements are considered as residual elements unless shown as a range or as a minimum.

3) Aluminium total content. Other grain refining elements may be used for carbon and carbon-manganese steel, see 200.

Table C2 Mechanical properties for ferritic steel forgings for low temperature service

Steel type	Grade	Yield stress R_e or $R_{p0.2}$ minimum (N/mm ²)	Tensile strength R_m (N/mm ²)	Elongation A_5 minimum (%)	Reduction of area Z minimum (%)	Charpy V-notch	
						Temperature (°C)	Energy (J)
C and C-Mn	450L	240	450 - 600	22	40	-60 ¹⁾	27
	490L	275	490 - 640	20	40	-60 ¹⁾	27
3 ½ Ni	-	275	490 - 640	20	35	-95	34
5 Ni	-	380	540 - 690	20	35	-110	34
9 Ni	-	480	640 - 790	18	35	-196	34

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

D. Stainless Steel Forgings

D 100 Scope

101 These requirements are supplementary to A and apply to austenitic stainless steel forgings intended for use in the construction of cargo tanks and piping systems for liquefied gases and chemicals.

102 Steel forgings shall be in accordance with recognised standards, e.g. EN 10222, ASTM A 336 and JIS G 3214 provided that supplementary requirements contained herein are also met. Recognition of other standards is subject to agreement.

D 200 Manufacture

201 Steel shall be manufactured by an electric or one of the basic oxygen processes or any other process involving secondary refining subject to agreement.

D 300 Mechanical properties

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

D 400 Inspection

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

E. Other Application Areas

E 100 General

101 Reference is made to Rules for Classification of Ships, Pt.2 Ch.2 Sec.5 for requirements for forgings in other application areas such as machinery, gearing and pressure vessels.

SECTION 4 STEEL CASTINGS

A. General Requirements

A 100 Scope

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

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

103 As an alternative to 102, materials which comply with national or proprietary specifications may be accepted provided such specifications give reasonable equivalence to the requirements of Sec.4 or are approved for each specific application. As a minimum the following particulars shall be specified: manufacturing process, chemical composition, heat treatment, mechanical properties and non-destructive testing.

A 200 Grading system

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

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

Guidance note:

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

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A 300 Manufacture

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

302 Where flame cutting, scarfing or arc-air gouging to remove surplus metal is undertaken, the affected areas shall be either machined or ground smooth.

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

A 400 Chemical composition

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

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

403 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.

A 500 Heat treatment

501 All castings shall be heat treated as specified in the sub-

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

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

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

504 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 approved.

A 600 Test blocks and test pieces for mechanical testing

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

602 In the case of castings of the same type under 1 000 kg in finished mass, the test blocks may alternatively be cast separately provided they are cast from the same heat of steel as the production castings represented and heat treated with the castings. Separately cast test blocks shall receive substantially the same casting practices as the castings represented.

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

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

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

A 700 Test units and number of tests

701 For castings with finished mass 1 000 kg or more, each casting shall be regarded as the test unit.

702 For castings of the same type less than 1 000 kg in mass, batch testing is permitted and each heat in each heat treatment charge shall be regarded as the test unit.

703 At least one set of mechanical tests is required for each test unit, except as specified in 704 and 705.

704 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.

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

A 800 Mechanical properties

801 The mechanical properties specified in the subsequent subsections refer to test pieces machined from integrally cast or separately cast test blocks and not to the castings themselves.

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

A 900 Inspection

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

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

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

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

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

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

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

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

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

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

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

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

906 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, the foundry should perform suitable intermediate inspections taking into consideration the quality level required in finished condition.

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907 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.

908 Where UT is specified, the tests shall be carried out after the final heat treatment when the casting surface has been brought to a condition suitable for UT. RT may also be accepted and generally applies to castings with thickness less than 50 mm.

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

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

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

911 The foundry shall maintain records of own inspections including dimensional measurements traceable to each casting. The records shall be presented to the purchaser on request. The foundry is also to provide the surveyor 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.

A 1000 Repair

1001 Defects may be removed by grinding or by chipping and grinding to a depth of 10% of the section thickness or 15 mm, whichever is smaller. The resulting grooves shall have a bottom radius of approximately three times the groove depth and shall be blended into the surrounding surface so as to avoid any sharp contours. Flame-scarfing or arc-air gouging may also be used provided that the surfaces of the resulting grooves are subsequently ground smooth. Complete elimination of the defective material shall be verified by MT or PT.

1002 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 1001) 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.

1003 Weld repairs are classified as major or minor. A weld repair is considered major when:

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

All other weld repairs are considered minor.

1004 Major weld repairs require the approval of the purchaser before the repair is commenced. Proposals for major weld repairs shall be accompanied by sketches or photographs showing the extent and positions of the repairs. A grain refining heat treatment shall be given to the whole casting prior to major repairs, unless otherwise approved.

1005 Minor weld repairs do not require the approval of the

purchaser before the repair is commenced but must be recorded on sketches showing the extent and positions of the repairs. The records shall be presented to the purchaser on request.

1006 All weld repairs shall be done by qualified welders using qualified procedures.

1007 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.

1008 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. Subject to agreement, however, 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.

1009 On completion of heat treatment the weld repairs and adjacent material shall be ground smooth. All weld repairs are subject to non-destructive testing as required by 900.

1010 The foundry shall maintain records of welding, subsequent heat treatment and inspections traceable to each casting repaired. The records shall be presented to the surveyor on request.

A 1100 Identification

1101 Each casting which has been tested and inspected with satisfactory results shall be suitably identified by the manufacturer with the following:

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

1102 In the case of castings of the same type less than 230 kg in mass, modified arrangements for identification may be agreed upon.

A 1200 Certification

1201 The manufacturer shall provide the type of inspection certificate required in the relevant construction rules giving the following particulars for each test unit of castings which has been accepted:

- purchaser's name, order number and vessel identification, where known
- manufacturer's name
- description of castings and steel quality
- identification marking of castings
- steel making process, heat number and chemical composition
- details of heat treatment, including temperatures and holding times

- results of mechanical tests
- results of non-destructive tests, where applicable
- test pressure, where applicable
- results of any supplementary and additional test requirements specified.

B. Castings for Hull Structures and Equipment

B 100 Scope

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

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

B 200 Chemical composition

201 The chemical composition shall comply with the overall limits given in Table B1 or, where applicable, the requirements of the agreed specification.

B 300 Heat treatment

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

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

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

B 400 Mechanical properties

401 The mechanical properties shall comply with the values given in Table B2 or, where applicable, the requirements of the approved specification.

402 Where it is proposed to use a steel with a specified minimum tensile strength intermediate to those given in Table B2, corresponding minimum values for the other properties may be obtained by interpolation.

B 500 Inspection

501 The castings are subject to magnetic particle (see A906) and ultrasonic testing.

Table B1 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 - 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 - 1.70	0.035	0.030	Minimum 0.40 ⁵⁾	Minimum 0.15 ⁵⁾	Minimum 0.40 ⁵⁾	0.30	0.12	-

- 1) Composition in percentage by mass maximum unless shown as a range or as a minimum.
2) Castings not intended for welding may be supplied to the composition limits given in DNV Ship Rules Pt.2 Ch.2 Sec.7 Table C1.
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.
6) Al can be used for grain refining but the content to be less than 0.08%.

Table B2 Mechanical properties for steel castings for hull structures and equipment

Steel type	Steel grade	Yield stress R_e minimum (N/mm ²)	Tensile strength R_m minimum (N/mm ²)	Elongation A_5 minimum (%)	Reduction of area Z minimum (%)	Charpy V-notch ¹⁾	
						Temperature (°C)	Energy (J)
C and C-Mn	410 W	235	410	24	40	0	27
	450 W	255	450	22	35	0	27
	480 W	275	480	20	30	0	27
Alloy	550 W	355	550	18	30	0	32
	620 W	430	620	16	30	0	32

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

C. Ferritic Steel Castings for Low Temperature Service

C 100 Scope

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

C 200 Chemical composition

201 The chemical composition shall comply with the limits given in Table C1 or, where applicable, the requirements of the agreed specification.

C 300 Heat treatment

301 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.

C 400 Mechanical properties

401 The mechanical properties shall comply with the values given in Table C2 or, where applicable, the requirements of the agreed specification.

C 500 Inspection

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

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

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

C 600 Pressure testing

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

Table C1 Chemical composition limits ¹⁾ for ferritic steel castings for low temperature service

Steel type	C	Si	Mn	P	S	Cr ²⁾	Mo ²⁾	Ni	Cu ²⁾	V ²⁾	Total residuals
C and C-Mn	0.25	0.60	1.60	0.035	0.035	0.40	0.15	0.80	0.30	0.03	0.60
2 ½ Ni	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
3 ½ Ni	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

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

Table C2 Mechanical properties for ferritic steel castings for low temperature service

Steel type	Grade	Yield stress R_e or $R_{p0.2}$ minimum (N/mm ²)	Tensile strength R_m (N/mm ²)	Elongation A_5 minimum (%)	Charpy V-notch	
					Temperature (°C)	Energy (J)
C and C-Mn	450L	240	450 - 600	22	-60 ¹⁾	27
	490L	275	490 - 640	20	-60 ¹⁾	27
2 ½ Ni	-	275	490 - 640	20	-70	34
3 ½ Ni	-	275	490 - 640	20	-95	34

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

D. Stainless Steel Castings

D 100 Scope

101 These requirements are supplementary to the requirements in A and apply to stainless steel castings for use in piping systems for liquefied gases and chemicals.

D 200 Chemical composition

201 The chemical composition shall comply with the overall limits given in Table D1 or, where applicable, the requirements of the agreed specification.

D 300 Heat treatment

301 Austenitic stainless steel castings shall be supplied in the solution treated condition.

D 400 Mechanical properties

401 The mechanical properties shall comply with the values given in Table D2 or, where applicable, the requirements of the agreed specification.

D 500 Inspection

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

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

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

Table D1 Chemical composition limits ¹⁾ for stainless steel castings

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

1) Composition in percentage mass by mass maximum unless shown as a range or as a minimum.

2) Niobium content shall be minimum 8 times the Carbon content and maximum 1.00%.

Table D2 Mechanical properties for stainless steel castings

Steel type	Proof stress $R_{p0.2}$ minimum ¹⁾ (N/mm ²)	Tensile strength R_m minimum (N/mm ²)	Elongation A_5 minimum (%)	Charpy V-notch	
				Temperature (°C)	Energy (J)
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 CrNiMo 19 11 2 (316)	180	440	30		
GX 5 CrNiMo 19 11 3 (317)	180	440	30		

1) The minimum $R_{p1.0}$ value is 25 N/mm² higher.

2) Impact tests may be omitted if the design temperature is above -105°C.

E. Other Application Areas

E 100 General

101 Reference is made to Rules for Classification of Ships,

Pt.2 Ch.2 Sec.7 for requirements for castings in other application areas such as machinery, propellers and pressure vessels.

SECTION 5 ALUMINIUM ALLOYS

A. Wrought Aluminium Alloys

A 100 Scope

101 This subsection specifies the requirements for aluminium alloy plates, sections, tubes 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.

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

103 As an alternative to 102, 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 approved for each specific application. Generally, such materials shall comply with the appropriate requirements of Ch.1 Sec.1 and Sec.6.

A 200 Aluminium grades and temper conditions

201 The alloy grades are listed in Table A1. 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.

202 5000 series alloys shall be supplied in any of the temper conditions given in Table A2 and Table A3, as applicable. 6000 series alloys shall be supplied in any of the temper conditions given in Table A3.

203 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.

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

A 300 Manufacture

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

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

A 400 Chemical composition

401 The chemical composition of each heat shall be determined by the manufacturer on a sample taken preferably during the pouring of the heat. The chemical composition shall comply with the limits given in Table A1.

402 Other alloys or alloys which do not fully comply with Table A1, 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.

A 500 Test material and test pieces for mechanical testing

501 For rolled products, the test material shall be taken at one third of the width from a longitudinal edge. The test pieces are normally to be cut with their longitudinal axis transverse to

the final rolling direction. If the width is insufficient to obtain transverse tests, longitudinal tests will be permitted.

502 For extruded products, the test material shall be taken in the range 1/3 to 1/2 of the distance from the edge to the centre of the thickest part of the section. The test pieces are normally to be cut with their longitudinal axes parallel to the extruding direction.

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

A 600 Test units and number of tests

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

602 For rolled products, one tensile test is required for each 2 000 kg, or fraction thereof, in each test unit. For single plates or for coils weighing more than 2 000 kg, only one tensile test per plate or coil is required.

603 For extruded products with a nominal mass of less than 1 kg/m, one tensile test is required for each 1 000 kg, or fraction thereof, in each test unit. For nominal masses between 1 and 5 kg/m, one tensile test is required for each 2 000 kg, or fraction thereof, in each test unit. Where the nominal mass exceeds 5 kg/m, one tensile test is required for each 3 000 kg, or fraction thereof, in each test unit.

A 700 Mechanical properties

701 The mechanical properties shall comply with the values given in Table A2 and Table A3, as applicable. Other temper conditions with related mechanical properties may be accepted by agreement.

A 800 Press weld testing

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

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

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

A 900 Corrosion testing

901 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.

902 The manufacturers shall establish the relationship between microstructure and resistance to corrosion. A reference photomicrograph taken at $500\times$ shall be established for each of the alloy-tempers and thickness ranges relevant. The reference photographs shall be taken from samples which have exhibited no evidence of exfoliation corrosion and a pitting rating of PB or better, when subjected to the test described in ASTM G66 (ASSET). The samples shall also have exhibited resistance to inter-granular corrosion at a mass loss no greater than 15 mg/cm^2 , when subjected to the test described in ASTM G67.

903 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 purchaser. Production practices shall not be changed after approval of the reference micrographs.

904 For test unit acceptance, metallographic examination of one sample selected from mid width at one end of a coil or random sheet or plate shall be carried out. A longitudinal section perpendicular to the rolled surface shall be prepared. The microstructure shall be compared to the reference photomicrograph of acceptable material. If the microstructure shows evidence of continuous grain boundary network of aluminium-magnesium precipitates in excess of the reference photomicrographs, the test unit shall either be rejected or tested for exfoliation-corrosion resistance and inter-granular corrosion resistance. The corrosion tests shall be in accordance with ASTM G66 and G67 or equivalent standards. If the results from testing satisfy the acceptance criteria stated in 902 the test unit is accepted, else it is rejected.

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

A 1000 Inspection and tolerances

1001 Surface inspection and verification of dimensions are the responsibility of the manufacturer.

1002 Permissible under-thickness tolerances for rolled and extruded products are given in Table A4 and Table A5, respec-

tively. Dimensional tolerances other than those given shall comply with a recognised standard.

1003 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.

A 1100 Repair

1101 Surface imperfections may be removed by machining or grinding provided the final dimensions are within the tolerances. Repair by welding is not permitted.

A 1200 Identification

1201 Each item which has been tested and inspected with satisfactory results shall be suitably identified by the manufacturer with the following:

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

1202 Where a number of items are securely fastened together in bundles, only the top item of each bundle need to be branded. Alternatively, a durable label may be attached to each bundle.

A 1300 Certification

1301 The manufacturer shall provide the type of inspection certificate required in the relevant construction rules giving the following particulars for each test unit which has been accepted:

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

For Temper descriptions reference is made to the standards in A 201.

Table A1 Chemical composition limits ¹⁾ for wrought aluminium alloys

Grade	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Other elements ²⁾	
									Each	Total
NV-5052	0.25	0.40	0.10	0.10	2.2 – 2.8	0.15 – 0.35	0.10	-	0.05	0.15
NV-5059	0.45	0.50	0.25	0.6 – 1.2	5.0 – 6.0	0.25	0.40 – 0.9	0.20	0.05 ⁵⁾	0.15 ⁵⁾
NV-5083	0.40	0.40	0.10	0.40 – 1.0	4.0 – 4.9	0.05 – 0.25	0.25	0.15	0.05	0.15
NV-5086	0.40	0.50	0.10	0.20 – 0.7	3.5 – 4.5	0.05 – 0.25	0.25	0.15	0.05	0.15
NV-5154A	0.50	0.50	0.10	0.50	3.1 – 3.9	0.25	0.20	0.20	0.05	0.15
NV-5383	0.25	0.25	0.20	0.7 – 1.0	4.0 – 5.2	0.25	0.40	0.15	0.05 ⁴⁾	0.15 ⁴⁾
NV-5454	0.25	0.40	0.10	0.50 – 1.0	2.4 – 3.0	0.05 – 0.20	0.25	0.20	0.05	0.15
NV-5456	0.25	0.40	0.10	0.50-1.0	4.7-5.5	0.05-0.20	0.25	0.20	0.05	0.15
NV-5754	0.40	0.40	0.10	0.50 ³⁾	2.6 – 3.6	0.30 ³⁾	0.20	0.15	0.05	0.15
NV-6005A	0.50 – 0.9	0.35	0.30	0.50 ⁶⁾	0.40 – 0.7	0.30 ⁶⁾	0.20	0.10	0.05	0.15
NV-6060	0.30 – 0.6	0.10 – 0.30	0.10	0.10	0.35 – 0.6	0.05	0.15	0.10	0.05	0.15

Table A1 Chemical composition limits ¹⁾ for wrought aluminium alloys (Continued)

Grade	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Other elements ²⁾	
									Each	Total
NV-6061	0.40 - 0.8	0.7	0.15 - 0.40	0.15	0.8 - 1.2	0.04 - 0.35	0.25	0.15	0.05	0.15
NV-6063	0.20 - 0.6	0.35	0.10	0.10	0.45 - 0.9	0.10	0.10	0.10	0.05	0.15
NV-6082	0.7 - 1.3	0.50	0.10	0.40 - 1.0	0.6 - 1.2	0.25	0.20	0.10	0.05	0.15

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

Table A2 Mechanical properties for rolled aluminium alloys B101Ch2.fm

Grade	Temper	Thickness, t(mm)	Yield strength $R_{p0.2}$ min. or range (MPa)	Tensile strength R_m min. or range (MPa)	Elongation ¹⁾	
					$A_{50 \text{ mm}}$ min. (%)	A_{5d} min. (%)
NV-5052	0	$t \leq 50$	65	165 – 215	19	18
	H32	$t \leq 6$	130	210 – 260	10	
		$6 < t \leq 50$	130	210 – 260	12	12
	H34	$t \leq 6$	150	230 – 280	7	
		$6 < t \leq 50$	150	230 – 280	9	9
NV-5059	0	$t \leq 50$	160	330		24
	H116	$t \leq 20$	270	370	10	10
		$20 < t \leq 50$	260	360	10	10
	H321	$t \leq 20$	270	370	10	10
		$20 < t \leq 50$	260	360	10	10
NV-5083	0	$t \leq 50$	125	275 – 350	16	14
	H112	$t \leq 50$	125	275	12	10
	H116	$t \leq 50$	215	305	10	10
	H321	$t \leq 50$	215 - 295	305 – 385	12	10
NV-5086	0	$t \leq 50$	95	240 – 305	16	14
	H112	$t \leq 12.5$	125	250	8	
		$12.5 < t \leq 50$	105	240		9
	H116	$t \leq 6.3$	195	275	8	
		$6.3 < t \leq 50$	195	275	10	9
NV-5154A	0	$t \leq 50$	85	215 – 275	17	16
	H32	$t \leq 6$	180	250 – 305	8	
		$6 < t \leq 50$	180	250 – 305	10	9
	H34	$t \leq 50$	200	270 – 325	8	7
NV-5383	0	$t \leq 50$	145	290		17
	H116	$t \leq 50$	220	305	10	10
	H321	$t \leq 50$	220	305	10	10
NV-5454	0	$t \leq 50$	85	215 – 285	17	16
	H32	$t \leq 6$	180	250 – 305	8	
		$6 < t \leq 50$	180	250 – 305	10	9
	H34	$t \leq 50$	200	270 – 325	8	7
NV-5456	0	$t \leq 6.3$	130 - 205	290 – 365	16	
		$6.3 < t \leq 50$	125 - 205	285 – 360	16	14
	H116	$t \leq 30$	230	315	10	10
		$30 < t \leq 40$	215	305		10
	H321	$40 < t \leq 50$	200	285		10
		$t \leq 12.5$	230 - 315	315 – 405	12	
		$12.5 < t \leq 40$	215 - 305	305 – 385		10
		$40 < t \leq 50$	200 - 295	285 – 370		10
NV-5754	0	$t \leq 50$	80	190 – 240	18	17
	H32	$t \leq 50$	130	220 – 270	10	9
		$t \leq 6$	160	240 – 280	8	
	H34	$6 < t \leq 50$	160	240 – 280	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.

Table A3 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⁾	
					$A_{50\text{ mm}}$ min. (%)	A_{5d} min. (%)
NV-5059	H112	$t \leq 50$	200	330	10	10
NV-5083	0	$t \leq 50$	110	270 - 350	14	12
	H111	$t \leq 50$	165	275	12	10
	H112	$t \leq 50$	110	270	12	10
NV-5086	0	$t \leq 50$	95	240 – 315	14	12
	H111	$t \leq 50$	145	250	12	10
	H112	$t \leq 50$	95	240	12	10
NV-5383	0	$t \leq 50$	145	290	17	17
	H111	$t \leq 50$	145	290	17	17
	H112	$t \leq 50$	190	310	13	13
NV-6005A	T4	$t \leq 50$	90	180	15	13
	T5	$t \leq 50$	215	260	9	8
	T6	$t \leq 10$	215	260	8	6
		$10 < t \leq 50$	200	250	8	6
NV-6060	T4	$t \leq 50$	60	120	16	14
	T5	$t \leq 50$	100	140	8	6
	T6	$t \leq 50$	140	170	8	6
NV-6061	T4	$t \leq 50$	110	180	15	13
	T5	$t \leq 50$	205	240	6	7
	T6	$t \leq 50$	240	260	10	8
NV-6063	T4	$t \leq 50$	65	130	14	12
	T5	$t \leq 50$	110	150	8	7
	T6	$t \leq 50$	170	205	10	9
NV-6082	T4	$t \leq 0$	110	205	14	12
	T5	$t \leq 50$	230	270	8	6
	T6	$t \leq 5$	250	290	6	
		$5 < t \leq 50$	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.

Table A4 Under-thickness tolerances for rolled products (mm)

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

Table A5 Under-thickness tolerances for extrusions (mm)

Nominal thickness range, t (mm)	Open profiles, sections circumscribed by a circle of diameter, d (mm)			Closed profiles
	$d \leq 250$	$250 < d \leq 400$	$d > 400$	
$3.0 \leq t < 6.0$	0.25	0.35	0.40	0.25
$6.0 \leq t < 50.0$	0.30	0.40	0.45	0.30

SECTION 6 TESTING PROCEDURES

A. General

A 100 Scope

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

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

A 200 Definitions relevant to testing

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

202 *Sample product:* A single forging, casting, plate, tube or other wrought product selected from a test unit.

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

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

A 300 Testing machines

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

A 400 Preparation of test pieces

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

402 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.

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

B. Test Methods

B 100 Tensile testing at ambient temperature

101 Symbols related to tensile testing.

R_m = tensile strength
 R_e = yield stress (yield point)
 R_p = yield strength (proof stress)
 R_t = yield strength (proof stress), total elongation
 A = percentage elongation after fracture

Z = percentage reduction of area.

102 Upper yield stress (R_{eH}) is the highest value of stress measured at the commencement of plastic deformation at yield; often this value is represented by a pronounced peak stress. The test shall be carried out with an elastic stress rate not exceeding 30 N/mm² per sec.

103 When no well-defined yield phenomena exists, either the yield strength at 0.2% non-proportional elongation ($R_{p0.2}$) or the yield strength at 0.5% total elongation ($R_{t0.5}$) shall be determined according to the applicable specification. The test shall be carried out with an elastic stress rate not exceeding 30 N/mm² per sec.

104 For determination of tensile strength (R_m) of ductile materials, the speed of the testing machine during the tensile test shall not exceed that corresponding to a strain-rate at maximum load of 40%/min. For brittle materials, like cast iron the elastic stress rate shall not exceed 2.5 N/mm² per sec.

105 The elongation generally means elongation determined on a proportional gauge length $5.65 \sqrt{S_0}$, or 5 d and has the designation A_5 .

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

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

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

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

L_0 = the gauge length in question

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

- round test piece: 1.25 d
- flat test piece: b + a

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

The following symbols are used:

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

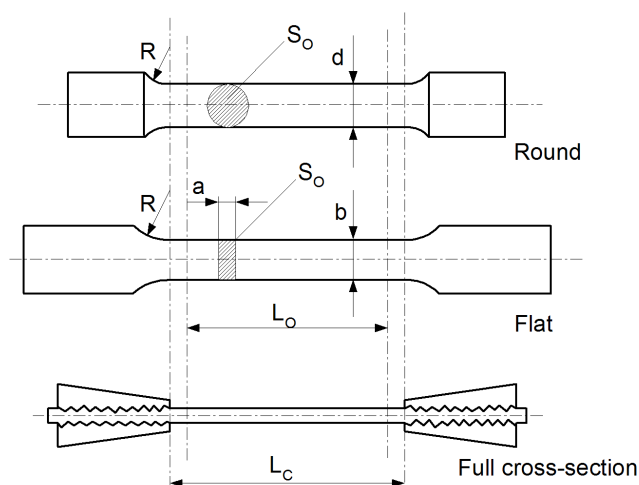


Figure 1
Tensile test pieces.

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

The parallel test length shall be parallel within acceptable tolerances. Tolerances according to ISO 82-1974 will be accepted.

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

Alternative A, proportional flat test piece:

$$\begin{aligned} a &= t \\ b &= 25 \text{ mm} \\ L_o &= 5.65 \sqrt{S_o} \\ L_c &\cong L_o + 2 \sqrt{S_o} \end{aligned}$$

$$R = 25 \text{ mm}$$

Alternative B, non-proportional flat test piece:

$$\begin{aligned} a &= t \\ b &= 25 \text{ mm} \\ L_o &= 200 \text{ mm} \\ L_c &\cong 225 \text{ mm} \\ R &= 25 \text{ mm} \end{aligned}$$

Alternative C, proportional round test piece:

$$\begin{aligned} d &= 10 \text{ mm to } 20 \text{ mm, preferably } 14 \text{ mm} \\ L_o &= 5d \\ L_c &\geq L_o + d/2 \\ R &= 10 \text{ mm} \end{aligned}$$

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

$$\begin{aligned} a &= t \\ b &= 12.5 \text{ mm} \\ L_o &= 50 \text{ mm} \\ L_c &\cong 75 \text{ mm} \\ R &= 25 \text{ mm} \end{aligned}$$

110 For forgings, bars, cast steel and nodular cast iron, proportional round test piece according to alternative C in 108

shall be used. The test piece for materials with a specified minimum elongation $A_5 \leq 10\%$ shall have transition radius $R \geq 1.5d$.

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

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

113 For grey cast iron the test piece shall have dimensions as stipulated in Fig. 2.

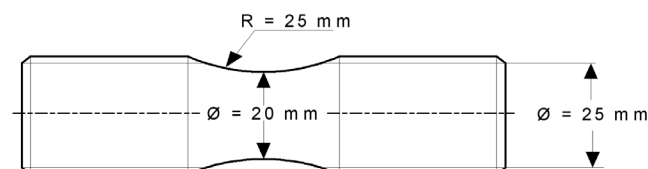


Figure 2
Grey cast iron test piece.

114 For tubes, test piece according to alternative A or B below shall be used.

Alternative A:

Full cross-section test pieces with plugged ends.

$$\begin{aligned} L_o &= 5.65 \sqrt{S_o} \\ L_c &\cong L_o + D \end{aligned}$$

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

Alternative B:

Strip

$$\begin{aligned} a &= \text{wall thickness of the tube} \\ b &= 12 \text{ mm} \end{aligned}$$

$$\begin{aligned} L_o &= 5.65 \sqrt{S_o} \\ L_c &\cong L_o + 2b \end{aligned}$$

B 200 Bend testing

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

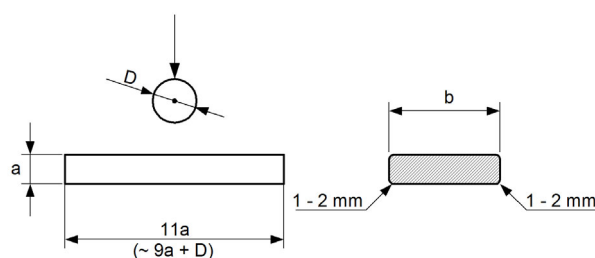


Figure 3
Bend test piece

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

$$\begin{aligned} a &= \text{as rolled thickness } t \text{ of material} \\ b &= 30 \text{ mm} \end{aligned}$$

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

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

$$\begin{aligned} a &= 20 \text{ mm} \\ b &= 25 \text{ mm} \end{aligned}$$

B 300 Impact testing

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

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

303 The Charpy impact test machine shall be of a type having a gap of 40 mm, a striking velocity between 4.5 and 7 m/sec. and a striking energy of 290 ± 10 J for a standard test. 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 scale of the machine shall be calibrated to an accuracy of $\pm 0.5\%$ of the machine's maximum striking energy. Impact test machines with a striking energy of less than 290 J are acceptable. In such cases, KV shall be supplemented with an index giving the striking energy.

For example, KV145 indicates that a striking energy of 145 J has been used.

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

305 Dimensions and tolerances for Charpy V-notch test pieces shall be as given in Table B1.

Table B1 Charpy V-notch test pieces.		
Dimensions	Nominal	Tolerances
Length	55 mm	0.60 mm
Width		
- standard test piece	10 mm	± 0.11 mm
- subsize test piece	7.5 mm	± 0.11 mm
- subsize test piece	5 mm	± 0.06 mm
Thickness	10 mm	± 0.06 mm
Angle of notch	45°	$\pm 2^\circ$
Depth below notch	8 mm	± 0.05 mm
Root radius	0.25 mm	± 0.025 mm
Distance of notch from ends of test piece	27.5 mm	± 0.42 mm
Angle between plane of symmetry of notch and longitudinal axis of test piece	90°	$\pm 2^\circ$

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

307 The temperature of the test piece at the moment of breaking shall be the specified temperature within $\pm 2^\circ\text{C}$.

Test temperature shall be stated in the certificate.

Guidance note:

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

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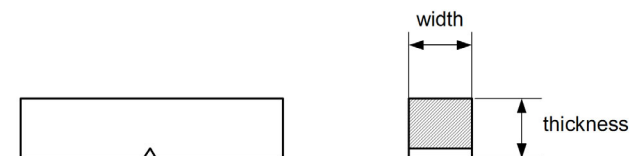


Figure 4
Charpy V-notch test piece

B 400 Determination of grain size

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

C. Miscellaneous

C 100 Chemical composition

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

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

C 200 Heat treatment

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

202 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.

Temperature uniformity of heat treatment furnace shall be verified by the manufacturer.

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

C 300 Selection of test material

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

C 400 Testing

401 The appropriate tests specified in this section shall be carried out at the place of manufacture before materials are dispatched. If the necessary facilities are not available at the manufacturer's works, the testing shall be carried out at a recognised testing laboratory.

402 In the event of any material proving unsatisfactory during subsequent processing or fabrication, such material shall be rejected, notwithstanding any previous certification. The purchaser may require further tests of materials from affected test units.

C 500 Retesting

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

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

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

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

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

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

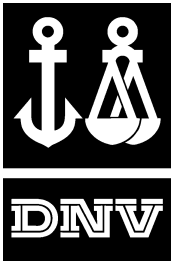
C 600 Non-destructive testing

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

C 700 Correction of defects

701 When unacceptable defects are found, these shall be removed by appropriate methods and rectified in accordance with the applicable requirements of this standard. Shallow grooves or depression resulting from the removal of defects may, by agreement, be accepted provided that they will cause no appreciable reduction in the strength of the material and that they are suitably smoothed and contoured.

702 Repair of defects by welding shall only be carried out when permitted by the appropriate specific requirements. Proposals to repair a defective material by welding shall be submitted to the purchaser for acceptance before this work is commenced. Such proposals shall include appropriate details of the extent and position of defects. The manufacturer may be required to carry out welding procedure qualification tests to demonstrate that satisfactory mechanical properties can be obtained.



CHAPTER 3

CERTIFICATION AND CLASSIFICATION

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SECTION 1

CERTIFICATION AND CLASSIFICATION

A. General

A 100 Introduction

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

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

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

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

A 200 Assumptions

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

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

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

B. Specific Certification or Classification Requirements

B 100 General

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

B 200 Information to be supplied by the purchaser

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

B 300 Approval of manufacturers

301 All steel materials delivered with NV or works certificate shall be made at works approved by DNV.

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

Approved manufacturers are published on DNV Exchange on the Internet.

302 In order to be approved, the manufacturer shall demonstrate and submit documentation to the effect that the necessary manufacturing, testing and inspection facilities are available and are supervised by qualified personnel. The man-

ufacturer shall also carry out a test programme and submit the results.

303 Detailed programmes for approval testing are given in Standards for Certification No.2.9.

For steel grade NVBW and $t \leq 25$ mm, impact testing performed during AoM may replace the testing required in Ch.2 Sec.1, Table A1.

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

B 400 Survey during manufacture

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

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

B 500 Selection of test material and testing

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

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

B 600 Identification of materials

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

602 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 brand, as furnished by the surveyor, and the following particulars:

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

603 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.

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

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

B 700 Certification of materials

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

ments of Ch.1 and Ch.2.

Certification of materials shall be documented as given in DNV-OSS 101 Ch.1 Sec.4 A1008.

702 As an alternative to 701, certification may be based on a Manufacturing Survey Arrangement (MSA), subject to approval by DNV.

703 Normally, separate inspection certificates are issued for each grade of material and each product form. The inspection certificate shall include the following particulars:

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

704 Where applicable, the manufacturer shall provide the surveyor with inspection certificates for all accepted materials giving at least the particulars detailed in 703. Before the inspection certificates are signed by the surveyor, the manufacturer shall furnish him with a written declaration stating that the material has been made by an approved process and that it has been subjected to and has withstood satisfactorily the required tests. The following form of declaration will be accepted if stamped or printed on each inspection certificate with the name of the works and signed by an authorised representative of the manufacturer: "We hereby certify that the material has been made by an approved process and has been satisfactorily tested in accordance with DNV Offshore Standards".

705 When a material is not produced at the works at which it is rolled or forged, a certificate shall be supplied by the maker stating the process of manufacture, the cast number and the chemical composition of ladle samples. The works at which the material was produced must be approved.