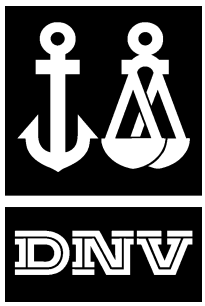

OFFSHORE STANDARD
DNV-OS-B101

METALLIC MATERIALS

JANUARY 2001

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

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METALLIC MATERIALS

CHAPTER 1

INTRODUCTION

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DET NORSKE VERITAS

Veritasveien 1, N-1322 Høvik, Norway Tel.: +47 67 57 99 00 Fax: +47 67 57 99 11

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 facilities.

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 facility. 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	Welding - Grooves for aluminium
EN 10228-1/2/3/4	Non-destructive testing of steel forgings

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*
IMO	International Maritime Organization
EN	European Norm
ICLL	International Convention on Load Lines
CIBS	Classification Information Breakdown Structure

Table D1 Abbreviations (Continued)

Abbreviation	*Full text*
AR	As rolled condition
CR	Controlled rolled
N	Normalised
QT	Quenched and tempered
TMCP	Thermo-mechanically controlled process
NS	Normal strength steel
HS	High strength steel
EHS	Extra high strength steel

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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METALLIC MATERIALS

CHAPTER 2

TECHNICAL PROVISIONS

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DET NORSKE VERITAS

Veritasveien 1, N-1322 Høvik, Norway Tel.: +47 67 57 99 00 Fax: +47 67 57 99 11

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/mm^2.

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.

A 300 Method of manufacture

301 The steel shall be manufactured by an electric or one of the basic oxygen processes.

302 Steels of improved weldability shall be vacuum degassed or ladle refined.

303 The reduction ratio of thickness from continuously cast slab to plate shall be minimum 4 to 1.

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.

304 The applicable rolling methods are defined as follows:

Controlled rolling, CR (Normalised rolling, NR): A rolling procedure in which the final deformation is carried out in the normalising temperature range, resulting in a material condition generally equivalent to that obtained by normalising.

Thermo-mechanical rolling, TM (Thermo-mechanical controlled processing, TMCP): This is a procedure which involves the strict control of both the steel temperature and the rolling reduction. Generally a high proportion of the rolling reduction is carried out close to the Ar3 temperature and may involve the rolling in the dual phase temperature region. TM can include processes with an increasing cooling rate with or without tempering including self-tempering but excluding direct quenching and quenching and tempering.

Unlike controlled rolling (normalised rolling) the properties conferred by TM cannot be reproduced by subsequent normalising or other heat treatment.

B. Normal Strength Steel

B 100 Scope

101 This subsection specifies the requirements for normal strength steel, which is defined as steel with minimum yield stress of 235 N/mm^2.

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 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 and deoxidation practice for normal strength steel of normal weldability

		Grade			
		NV A	NV B	NV D	NV E
Deoxidation		*For t ≤ 50 mm: Any method except rimmed steel For t > 50 mm Killed*	*For t ≤50 mm: Any method except rimmed steel For t > 50 mm Killed*	*For t ≤25 mm: Killed For t > 25 mm: Killed and fine grain treated*	*Killed and fine grain treated*
Chemical composition (ladle analysis) 1)	C maximum (%) 3)	0.21 2)	0.21	0.21	0.18
	Si maximum (%)	-	-	0,10	0.10
	Si maximum (%)	0.50	0.35	0.35	0.35
	Mn minimum (%) 3)	2.5 x C	0.80 4)	0.60	0.70
	P maximum (%)	0.035	0.035	0.035	0.035
	S maximum (%)	0.035	0.035	0.035	0.035
	Al minimum ac.sol. (%) 5)	-	-	0.015 6)	0.015

1) Where necessary, limits should be placed on the amount of residual- or trace elements which may have an adverse effect on the working and use of the steel, e.g. copper and tin.

2) Maximum 0.23% for sections.

3) Carbon plus 1/6 of the manganese content shall not exceed 0.40%.

4) For NV B, when the silicon content is 0.10 or above (killed steel), the minimum manganese content may be reduced to 0.60%.

5) The total content may be determined instead of the acid soluble content. In such cases the total Al content shall not be less than 0.020%. An upper limit may be specified. Other grain refiners may be used upon special consideration.

6) Al is required for thicknesses above 25 mm.

Table B2 Requirements for normal strength steel of improved weldability [1]			
Grade	*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} [6]	0.22		
Tensile test			
Tensile strength(N/mm^2) Yield stress (N/mm^2)	400 – 520		
t ≤ 25 mm	235 minimum		
25 mm < t ≤ 50 mm	215 minimum		
50 mm < t ≤ 75 mm	200 minimum		
75 mm < t ≤ 100 mm	190 minimum		
Elongation, A_5 (%)	22 minimum		
Impact test, Charpy V-notch			
Test temperature (°C)	0	-20	-40
Minimum average energy			
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.

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

Table B3 Condition of supply for normal strength (NS) steel		
Grade	*Thickness, t (mm)*	*Condition of supply [1]*
NV A	t ≤ 50	Any
	50 < t ≤ 150	AR[2] CR, N, TM
NV B	t ≤ 50	Any
	50 < t ≤ 150	AR[2], CR, N, TM
NV D	t ≤ 35	Any
	35 < t ≤ 150	AR[3], CR, N, TM
NV E	t ≤ 150	AR[3], CR[3], N, TM

1) Condition of supply:
AR: As rolled.
N: Normalised.
CR: Controlled rolled.

2) Grades NV A and NV B may be supplied as rolled (AR) subject to special consideration.

3) Subject to special consideration, sections in grade NV D may be supplied as rolled (AR) provided satisfactory results are consistently obtained from Charpy V-notch impact tests. Similarly, sections in grade NV E may be supplied as rolled (AR) or controlled rolled (CR).

Table B4 Mechanical properties for normal strength (NS) steel of normal weldability

Grade	*Yield stress* R_{eH} *minimum* (N/mm^2)	*Tensile strength* R_m (N/mm^2)	*Elongation* A_5 *minimum (%)*	*Test temperature (°C)*	*Average impact energy J minimum*					
					$t \leq 50$		$50 < t \leq 70$		$70 < t \leq 150$	
					Longitudinal	*Transverse*	*Longitudinal*	*Transverse*	*Longitudinal*	*Transverse*
NV A	235	400-520	22[3]	+20	-	-	34[2]	24[2]	41[2]	27[2]
NV B				0	27[1]	20[1]	34	24	41	27
NV D				-20	27	20	34	24	41	27
NV E				-40	27	20	34	24	41	27

1) Charpy V-notch impact tests are generally not required for grade NV B steel with thickness of 25 mm or less.

2) Impact tests for grade NV A over 50 mm thick are not required when the material is produced using fine grain practice and furnished normalised or thermo-mechanically controlled processed.

3) For full thickness flat test specimens with a width of 25 mm and a gauge length of 200 mm the elongation shall comply with the following minimum values:

Thickness, mm	$t \leq 5$	$5 < t \leq 10$	$10 < t \leq 15$	$15 < t \leq 20$	$20 < t \leq 25$	$25 < t \leq 30$	$30 < t \leq 40$	$40 < t \leq 150$
Elongation	14	16	17	18	19	20	21	22

C. High Strength Steel

C 100 Scope

101 Subsection C specifies the requirements for high strength steel, which is defined as steel with minimum yield stress of 265 N/mm^2 and up to and including 390 N/mm^2.

C 200 Chemical composition

201 For steel grades of normal weldability and improved weldability, the chemical composition, deoxidation practice and fine grain treatment shall in general satisfy the requirements in Table C1 and Table C2, respectively. Where additions of any other elements have been made as part of the steelmaking practice, the content shall be indicated.

202 Grades which according to Table C1 and Table C2 are to be fine grain treated shall contain one or more of the elements Al, Nb, Ti and V. Other grain-refining elements (micro-alloying) elements may be used where demonstrated and agreed as acceptable. The combination of grain-refining elements of the various steel grades shall be specially considered. A smaller content of Al than given in the table may be acceptable, subject to agreement.

203 The content of all elements specified shall be determined for each cast, by ladle analysis, and shall be stated on the material certificate. The determination of Al, Nb, Ti and V may be omitted for grades that are not fine-grain treated.

204 When required, the carbon equivalent value for steel of normal weldability shall be calculated from the ladle analysis using the following formula:

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

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

The formula given in D200 (P_{cm}) may also be used for evaluating weldability for steel of normal weldability instead of the carbon equivalent where appropriate.

C 300 Heat treatment, 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 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 C1 Chemical composition and deoxidation practice for high strength (HS) steel of normal weldability		
Grade	NV A27 NV D27 NV E27 NV A32 NV D32 NV E32 NV A36 NV D36 NV E36 NV A40 NV D40 NV E40	NV F32 NV F36 NV F40
Deoxidation	*Killed and fine grain treated*	
Chemical composition (ladle analysis)		
C maximum (%)	0.18	0.16
Si (%)	0.10 - 0.50	0.10 - 0.50
Mn (%)	0.9 - 1.6 2)	0.9 - 1.6 2)
P maximum (%)	0.035	0.025
S maximum (%)	0.035	0.025
Cu maximum (%)	0.35	0.35
Cr maximum (%)	0.20	0.20
Ni maximum (%)	0.40	0.80
Mo maximum (%)	0.08	0.08
Al ac.sol. (%)	0.015 - 0.08 3)	0.015 - 0.08 3)
Al total (%)	0.020 - 0.085 3)	0.020 - 0.085 3)
Nb (%)	0.02 - 0.05 3)	0.02 - 0.05 3)
V (%)	0.05 - 0.10 3)	0.05 - 0.10 3)
Ti maximum (%)	0.02	0.02
N maximum (%)	-	0.009 (0.012 if Al is present

1) NV A27 is acceptable semi-killed or killed without fine grain treatment for thicknesses up to and including 25 mm.

2) For thicknesses up to and including 12.5 mm the minimum Mn-content may be reduced to 0.70%. For NV A27, NV D27 and NV E27 it may be reduced to 0.70% regardless of thickness.

3) The steel shall contain Al, Nb, V or other suitable grain refining elements, either singly or in any combination. When used singly the steel shall contain the specified minimum content of the grain refining element. When used in combination, the specified minimum content of at least one grain refining element is applicable.

Table C2 Requirements for high strength steels of improved weldability [1]				
1	*Grade*	NV AW27 NV DW27 NV EW27	NV AW32 NV DW32 NV EW32	NV AW36 NV DW36 NV EW36
2	*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} [6)]		0.22		
4	Tensile test			
Tensile strength (N/mm^2) Yield stress (N/mm^2)		400 – 530	440 – 590	490 – 620
t ≤ 25 mm 25 mm < t ≤ 50 mm 50 mm < t ≤ 75 mm 75 mm < t ≤ 100 mm		265 245 230 220	315 295 280 270	355 335 320 310
Elongation, A_5 (%)		22	22	21
5	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
6	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.

6) Pcm = C + Si/30 + (Mn + Cu + Cr)/20 + Ni/60 + Mo/15 + V/10 +5B

Table C3 Carbon equivalent for high strength steels of normal weldability up to 150 mm in thickness produced by TMCP			
Grade	*Carbon equivalent, maximum (%)*		
	t ≤50 (mm)	*50 < t ≤100 (mm)*	*100 < t ≤150 (mm)*
NV A27, D27, E27	-	-	-
NV A32, D32, E32, F32	0.36	0.38	0.40
NV A36, D36, E36, F36	0.38	0.40	0.42
NV A40, D40, E40, F40	0.40	-	-

Table C4 Condition of supply for High Strength (HS) steel

Grade	*Grain refining elements*	*Thickness, t (mm)*	*Condition of supply* [1]
NV A27 NV A32 NV A36	Nb and/or V	t ≤ 12.5 12.5 < t ≤ 150	Any AR [3], CR, N, QT, TM
	Al only or with Ti	t ≤ 20 20 < t ≤ 35 35 < t ≤ 150	Any Any [2] AR [3], CR, N, QT, TM
NV A40	Any	t ≤ 12.5 12.5 < t ≤ 150	Any CR, N, QT, TM
NV D27 NV D32 NV D36	Nb or V	t ≤ 12.5 12.5 < t ≤ 150	Any AR [3], CR, N, QT, TM
	Al only or with Ti	t ≤ 20 20 < t ≤ 25 25 < t ≤ 150	Any Any [2] AR [3], CR, N, QT, TM
NV D40	Any	t ≤ 150	CR, N, QT, TM
NV E27 NV E32 NV E36	Any	t ≤ 150	CR [3], N, QT, TM
NV E40	Any	t ≤ 150	N, QT, TM
NV F32 NV F36	Any	t ≤ 150	CR [4], N, QT, TM
NV F40	Any	t ≤ 150	N, QT, TM

1) Condition of supply:
AR: As rolled condition.
N: Normalised.
QT: Quenched and tempered.
CR: Controlled rolled.

2) As rolled (AR) subject to special consideration and approval.

3) Subject to special consideration and approval, sections in grades NV A27, NV A32, NV A36, NV D27, NV D32 and NV D36 may be supplied as rolled (AR) provided satisfactory results are consistently obtained from Charpy V-notch impact tests. Similarly sections in grades NV E27, NV E32 and NV E36 may be supplied as rolled (AR) or controlled rolled (CR).

4) Subject to special consideration, sections in grades F32 and F36 may be supplied controlled rolled (CR).

Table C5 Mechanical properties for high strength (HS) steel of normal weldability

Grade	*Yield stress* R_{eH} *minimum* (N/mm^2)	*Tensile strength* R_m (N/mm^2)	*Elongation* A_5 *minimum (%)*	*Test temperature (°C)*	*Average impact energy J minimum*					
					t ≤ 50 (mm)		*50 < t ≤ 70 (mm)*		*70 < t ≤ 150 (mm)*	
					Longitudinal	*Transverse*	*Longitudinal*	*Transverse*	*Longitudinal*	*Transverse*
NV A27 NV D27 NV E27	265	400 – 530	22 [1]	0 – 20 – 40	27	20	34	24	41	27
NV A32 NV D32 NV E32 NV F32	315	440 – 590	22 [1]	0 – 20 – 40 – 60	31	22	38	26	46	31
NV A36 NV D36 NV E36 NV F36	355	490 – 620	21 [1]	0 – 20 – 40 – 60	34	24	41	27	50	34
NV A40 NV D40 NV E40 NV F40	390	510 – 650	20 [1]	0 – 20 – 40 – 60	41	27	45	30	55	37

1) For full thickness flat test specimens with a width of 25 mm and a gauge length of 200 mm the elongation shall comply with the following minimum values:

Thickness (mm)	*t ≤ 5*	*5 < t ≤ 10*	*10 < t ≤ 15*	*15 < t ≤ 20*	*20 < t ≤ 25*	*25 < t ≤ 30*	*30 < t ≤ 40*	*40 < t ≤ 150*
Elongation: (%)								
A27, D27 and E27	15	16	17	18	19	20	21	22
A32, D32, E32 and F32	14	16	17	18	19	20	21	22
A36, D36, E36 and F36	13	15	16	17	18	19	20	21
A40, D40, E40 and F40	12	14	15	16	17	18	19	20

D. Extra High Strength Steel

D 100 Scope

101 Subsection D specifies the requirements for extra high strength steel, which is defined as steel with minimum yield stress of 420 N/mm^2 and up to and including 690 N/mm^2.

D 200 Chemical composition

201 The chemical composition, deoxidation practice and fine grain treatment shall in general satisfy the requirements in Table D1 and Table D2 for steel grades of normal weldability and improved weldability respectively.

Where any other elements have been added as part of the steel-making practice, the content shall be indicated.

202 All extra high strength steel grades shall be fine grain treated, and are therefore to contain one or more of the elements Al, Nb, Ti and V. Other grain-refining elements (micro-alloying) elements may be used after special consideration and agreement. The combination of grain-refining elements of the various steel grades shall be specially documented.

203 The content of all elements specified shall be determined by ladle analysis for each cast, and shall be stated on the certificate.

204 When the weldability is to be evaluated from the chemical composition, the following formula shall be used for steel of normal weldability unless agreed otherwise:

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

D 300 Heat treatment, condition of supply

301 Extra high strength steel shall unless otherwise agreed, be delivered in a condition complying with the requirements given in Table D3.

D 400 Mechanical properties

401 Extra high strength steel shall comply with the mechanical properties specified in Table D2 and Table D4 for steel grades of improved weldability and normal weldability respectively.

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 and deoxidation practice for extra high strength (EHS) steel of normal weldability

		Grade					
		NV A 20 NV D420 NV E420 NV F420	NV A460 NV D460 NV E460 NV F460	NV A500 NV D500 NV E500 NV F500	NV A550 NV D550 NV E550 NV F550	NV A620 NV D620 NV E620 NV F620	NV A690 NV D690 NV E690 NV F690
Deoxidation		*Killed and fine grain treated*					
Chemical Composition (ladle analysis) [1]		A grades:		D and E grades:		F grades:	
	C maximum (%)	0.21		0.20		0.18	
	Si (%)	0.10 - 0.55		0.10 - 0.55		0.10 - 0.55	
	Mn maximum (%)	1.7		1.7		1.6	
	P maximum (%)	0.035		0.030		0.025	
	S maximum (%)	0.035		0.030		0.025	
	B maximum (%)	0.005		0.005		0.005	
	N maximum (%)	0.020		0.020		0.020	
	Al ac.sol. (%)	0.015 - 0.08 [2]		0.015 - 0.08 [2]		0.015 - 0.08 [2]	
	Al total (%)	0.020 - 0.085 [2]		0.020 - 0.085 [2]		0.020 - 0.085 [2]	
	Nb (%)	0.02 - 0.05 [2]		0.02 - 0.05 [2]		0.02 - 0.05 [2]	
	V (%)	0.04 - 0.10 [2]		0.04 - 0.10 [2]		0.04 - 0.10 [2]	
	Ti maximum (%)	0.02		0.02		0.02	

1) The limits given in the table are regarded as over-all limits. The chemical composition shall comply with the approved specification of the steel grade in question.

2) The steel shall contain Al, Nb, V or other suitable grain refining elements, either singly or in any combination. When used singly. the steel shall contain the specified minimum content of the grain refining element. When used in combination, the specified minimum content of at least one grain refining element is applicable.

Table D2 Requirements for extra high strength steels of improved weldability [1]			
1 Grade	NV DW420 NV EW 20	NV DW460 NV EW460	NV DW500 NV EW500
2 Deoxidation	*Killed and fine grain treated*		
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} [6]	0.22		
4 Tensile test			
Tensile strength(N/mm^2) Yield stress (N/mm^2)	530 – 680	570 – 720	610 – 770
t ≤ 50mm 50mm < t ≤ 75mm 75mm < t ≤ 100mm	420 400 380	460 440 420	500 480 460
Elongation, A_5 (%)	20	19	18
5 Impact test, Charpy V-notch			
Test temperature (°C)			
Grade DW Grade EW	-20 -40		
Minimum average energy (J)			
Transverse	60		
Minimum single value (J)			
Transverse	42		
6 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) $(Nb+V)_{max}$: 0.09%.

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

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

6) $P_{cm} = C + Si/30 + (Mn + Cu + Cr)/20 + Ni/60 + Mo/15 + V/10 + 5B$.

Table D3 Condition of supply for extra high strength (EHS) steel			
Grade	*Grain refining elements*	*Thickness, t (mm)*	*Condition of supply [1]*
NV A420, NV A460, NV A500, NV A550, NV A620, NV A690	Any	t ≤ 150	N, QT, TM

NV D420, NV D460, NV D500, NV D550, NV D620, NV D690	Any	t ≤ 150	N, QT, TM
NV E420, NV E460, NV E500, NV E550, NV E620, NV E690	Any	t ≤ 150	N, QT, TM
NV F420, NV F460, NV F620, NV F690	Any	t ≤ 150	N, QT, TM

1) Condition of supply
N: Normalised.
QT: Quenched and tempered.
CR: Controlled rolled.
TM: Thermo mechanically controlled processed (TMCP).

Table D4 Mechanical properties for extra high strength (EHS) steel of normal weldability

Steel grade	*Yield stress ReH* [1] *minimum (N/mm²)*	*Tensile strength R_m (N/mm)*	*Elongation A_5 minimum (%)*	*Test temperature (°C)*	*Average impact energy J minimum*	
					t ≤ 150	
					Longitudinal	*Transverse*
NV A420 NV D420 NV E420 NV F420	420	530 - 680	18	0 – 20 – 40 – 60	42	28
NV A460 NV D460 NV E460 NV F460	460	570 - 720	17	0 – 20 – 40 – 60	46	31
NV A500 NV D500 NV E500 NV F500	500	610 - 770	16	0 – 20 – 40 – 60	50	33
NV A550 NV D550 NV E550 NV F550	550	670 - 830	16	0 – 20 – 40 – 60	55	37
NV A620 NV D620 NV E620 NV F620	620	720 - 890	15	0 – 20 – 40 – 60	62	41
NV A690 NV D690 NV E690 NV F690	690	770 - 940	14	0 – 20 – 40 – 60	69	46

1) Where the yield stress R_{eH} does not mark in the tensile test, $R_{p\,0.2}$ or $R_{t0.5}$ is applicable.

2) For full thickness flat test specimens with a width of 25 mm and a gauge length of 200 mm the elongation shall comply with the following minimum values:

Thickness (mm)	*t ≤ 10*	*10 < t ≤ 15*	*15 < t ≤ 20*	*20 < t ≤ 25*	*25 < t ≤ 40*	*40 < t ≤ 50*
Elongation:						
A420, D420, E420 and F420	11	13	14	15	16	17
A460, D460, E460 and F460	11	12	13	14	15	16
A500, D599, E500 and F500	10	11	12	13	14	15
A550, D550, E550 and F550	10	11	12	13	14	15
A620, D620, E620 and F620	9	11	12	12	13	14
A690, D690, E690 and F690	9	10	11	11	12	13

E. Testing

E 100 Test material

101 All material in a test unit presented for acceptance tests shall be of the same product form for example plates, flats, sections, and so forth, from the same cast and in the same condition of supply.

The test samples shall be fully representative of the material and, where relevant, shall not be cut from the material until heat treatment has been completed.

The test pieces shall not be separately heat treated in any way.

102 The test samples for tensile and impact test pieces shall be taken from the following positions:

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

The test samples shall be taken from one end at a position approximately midway between the axis in the direction of rolling and the edge of the rolled product (see Fig.1a). Unless otherwise agreed, the tensile test pieces shall be prepared with their longitudinal axes transverse to the final direction of rolling.

— *Flats with a width < 600 mm, bulb flats and other sections:*

The test samples shall be taken from one end at a position approximately one third from the outer edge (see Fig.1b, Fig.1c, Fig.1d and Fig.1e) or in the case of small sections, as near as possible to this position. In the case of channels, beams or bulb angles, the test samples may alternatively be taken from a position approximately one quarter of the

width from the web centre line or axis (see Fig.1d). The tensile test pieces may be prepared with their longitudinal axes either parallel or transverse to the final direction of rolling.

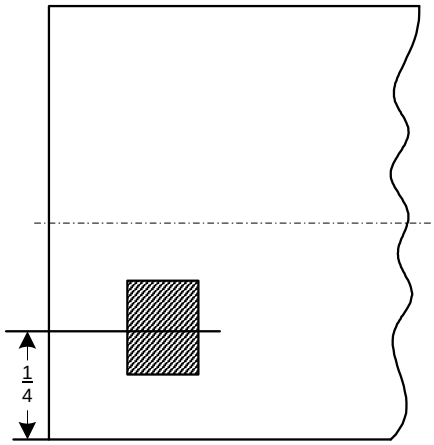
For small sizes, the tensile test pieces may consist of a suitable length of the full cross-section of the product.

— *Bars and other similar products:*

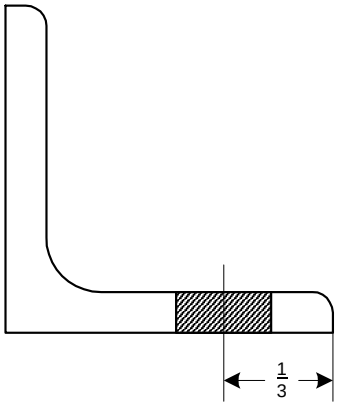
The test samples shall be taken so that the longitudinal axes of the test pieces are parallel to the direction of rolling and are as near as possible to the following:

— for non-cylindrical sections, at one third of the half diagonal from the outside (see Fig.1e),
— for cylindrical sections, at one third of the radius from the outside (see Fig.1f).

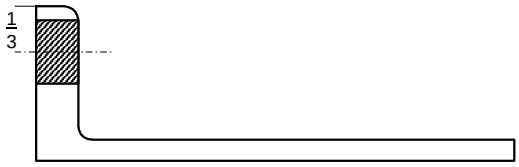
103 Samples for testing of through thickness properties shall be agreed as appropriate.



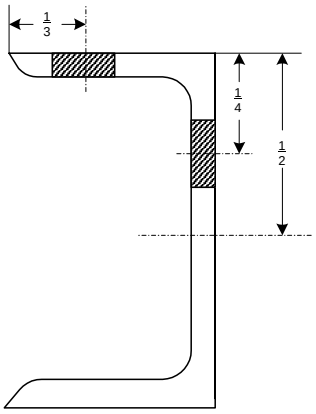
(a) Plates and flats



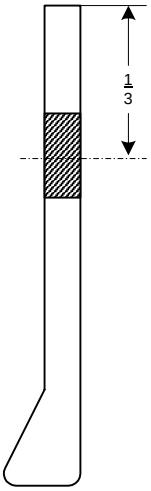
(b) Angles



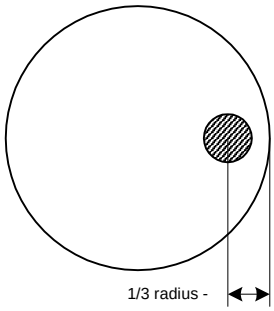
(c) Unequal angles



(d) Channels and beams



(e) Bulb flats



(f) Bars

Figure 1
Position of test specimen

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.

205 For thermo-mechanically controlled processed steel, accelerated cooled, additional testing in the simulated stress relieved condition may be required.

206 The procedures used for all tensile tests shall generally be in accordance with the requirements of Sec.6. However,

recognised international standards may be used subject to agreement.

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 The maximum size of a test unit shall be as specified in Table E1. One set of three test pieces is to be taken from one of the thickest products of each specified test unit or part thereof.

303 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.

304 Where it is impossible to use a standard impact test piece of 10 mm x 10 mm, the largest possible of the following pieces shall be used: 10 mm x 7.5 mm or 10 mm x 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.

305 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 D4 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.

306 The procedures used for all impact tests shall generally be in accordance with the requirements of Sec.6. However, recognised international standards may be used subject to agreement.

E 400 Testing of through thickness properties

401 Steel specified with improved through thickness properties (Z-steel) shall be tested by tensile pieces taken in the thickness direction of the product. The test sampling shall be performed as follows (see also Sec.6):

Plates:	One set of three pieces shall be taken from one end of each rolled length.
Wide flats:	Products of the same cast, thickness and heat treatment shall be divided into test units of 10 t, or, where their thickness exceeds 25 mm, of 20 t. From one sample product of each test unit at least one set of test pieces shall be taken.

Table E1 Extent of impact testing at delivery

Strength range	*Grades (NV)*	*Thickness, t (mm)*	*Test unit maximum*	
			Plate	*Sections*
NS-steel	A	t ≤ 50 50 < t ≤ 150	Not required 50 t	Not required
	B, BW	t ≤ 25 25 < t ≤ 150	50 t [1] 50 t [2] [3]	50 t [1] 50 t [3]
	D, DW	t ≤ 150	50 t [2] [3]	50 t [3]
	E, EW	t ≤ 150	Each piece	25 t [4]
HS-steel	A, AW	t ≤ 150	Maximum 50 [2] [3]	50 t [3]
	D, DW	t ≤ 150	Maximum 50 t [2] [3]	50 t [3]
	E, EW	t ≤ 150	Each piece	25 t [4]
	F	t ≤ 150	Each piece	25 t [4]
EHS-steel	A	t ≤ 150	Each piece	Each piece
	D, DW	t ≤ 150	Each piece	Each piece
	E, EW	t ≤ 150	Each piece	Each piece
	F	t ≤ 150	Each piece	Each piece

1) Subject to agreement for normal weldability grades.

2) When steel plates over 50 mm in thickness are supplied in the controlled rolled (CR) condition, the frequency of impact test shall be made for each batch of 25 tonnes or fraction thereof.

3) When, subject to agreement, material is supplied in the as rolled (AR) condition, the frequency of impact tests shall be increased to one set from each batch of 25 tonnes or fraction thereof. Similarly grade NV A steel over 50 mm in thickness may be supplied in the as rolled condition. In such case one set of three Charpy V-notch test specimens shall be taken from each batch of 50 tonnes or fraction thereof.

4) When subject to agreement, sections other than grades NV E40 and NV F40 are supplied in the as rolled condition, one set of impact tests shall be taken from each batch of 15 tonnes or fraction thereof.

402 The minimum average reduction of area of each set of three specimens shall be at least 25%. Only one individual value within each set may be below 25% but not less than 20%. For steel grades of improved weldability the corresponding requirements are 35% and 20%.

403 When a set of tests fails to meet the requirements in 402 three additional test pieces may be taken from the same test sample for retesting and evaluated together with the previous test results as one set of six test pieces. The average reduction of area shall not be less than 25%. Totally, two individual values may be less than 25% but only one value may be less than 20%. For steel grades of improved weldability the corresponding requirements are 35% and 20%.

404 Z-steel shall be subjected to ultrasonic examination according to an agreed standard (e.g. EN 10160), with established accepted criteria.

405 Steel grades of normal weldability processed to obtain improved through thickness properties and complying with the requirements given in 402, 403 and 404 shall be marked with the suffix Z in addition to the material grade designation, for example NV DZ, NV E36Z.

E 500 Inspection tolerances

501 Surface inspection and checking of dimensions are the responsibility of the manufacturer, who shall verify that the requirements to quality and dimensional tolerances are fulfilled prior to despatch. The manufacturer is also responsible for compliance with the general requirements concerning freedom from harmful internal defects.

Subsequent identification that a material is defective shall not absolve the manufacturer from this responsibility.

502 Plates and other products of extra high strength steel shall be subjected to a thorough visual inspection of both sides by the manufacturer to ensure freedom from defects and harmful imperfections. Examination by means of suitable non-destructive methods such as magnetic particle and/or ultrasonic examination may be required.

503 The maximum permissible under thickness tolerance for hull structural plates, wide flats and welded profiles is -0.3 mm.

The permissible under thickness tolerance for hull structural rolled profiles shall be in accordance with the requirements of a recognised international or national standard.

The acceptable under thickness tolerances stated in this standard are to be considered as the lower limit of a «plus-minus» range of thickness tolerance which could be found in the normal production of a conventional rolling mill manufacturing material, on average, to the nominal thickness.

A more stringent under thickness tolerance than given may be agreed upon in each case.

The thickness shall be measured at random locations whose distance from a longitudinal edge shall be at least 10 mm. Local surface depressions resulting from imperfections and ground areas resulting from the elimination of defects may be disregarded provided the imperfections or grinding are in accordance with recognised national or international standards.

For seamless structural tubes the tolerances for outer diameter, wall thickness and out-of roundness shall be defined and agreed upon prior to starting the production.

F. Repairs

F 100 Surface defects

101 Surface defects in structural steel may be removed by local grinding, provided that:

— the thickness shall in no place be reduced to less than 93% of the nominal thickness, but in no case by more than 3 mm, and
— the sum of all ground areas does not exceed 10% of the total area in question.

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

102 Surface defects which cannot be dealt with as above may be repaired by chipping or grinding followed by welding, subject to compliance with the requirements given below.

— After removal of the defect, and before welding, the thickness of the piece shall in no place be reduced by more than 20%. The welding shall be carried out according to an approved procedure with approved electrodes. The weld shall be ground smooth to the correct nominal thickness.
— The weld repair shall be subject to adequate non-destructive examination.
— The piece shall normally be subject to adequate heat treatment subsequent to the final grinding. In general the heat treatment shall be the same as prescribed for the steel grade in question.

SECTION 2
STEEL TUBES AND PIPES

A. General

A 100 Scope

101 This section covers seamless and welded steel tubes and pipes intended for pressure, boiler, heat exchanger, superheater, chemicals and low temperature services.

A 200 General principles

201 The products shall be in accordance with relevant and recognised national or international standards agreed upon before manufacturing starts in addition to satisfy the general requirements given in 300 to 1000.

202 Tubes and pipes intended as strength members of structures shall satisfy the material requirements for the structure in question, for example hull material.

A 300 Quality

301 The pipes and tubes shall have smooth internal and external surfaces consistent with the method of manufacture.

302 The pipes and tubes shall have a workmanlike finish but small imperfections are permissible, provided that the thickness remains within the tolerance limits. Small laps, cracks, slivers, scratches or other surface defects may be removed by grinding within the minimum permissible wall thickness.

Repair of defects by welding is not acceptable.

The pipes and tubes shall be reasonably straight. Tubes and pipes shall be delivered with nominally square-cut ends, free from excessive burrs.

A 400 Dimensional tolerances

401 The tolerances on the outside diameter and the wall thickness of tubes and pipes shall be subject to agreement.

A 500 Chemical composition

501 The requirements for the chemical composition of ladle samples shall be in accordance with the agreed standard.

If a product analysis is taken, the analysis shall be within the permissible deviations from the specified ladle composition.

A 600 Heat treatment

601 Tubes and pipes shall be supplied in the heat treatment conditions as agreed upon between the contracting parties.

A 700 Mechanical properties

701 The number of tests to be performed and the results of all mechanical tests agreed upon shall comply with the requirements given in the agreed standard.

702 Impact testing of austenitic stainless steels is required only for design temperatures below –105°C. Test temperature shall be –196°C.

A 800 Test material

801 Tubes and pipes shall be presented for test in batches. A batch is formed by tubes of the same size, the same steel grade, the same manufacturing process and the same heat treatment conditions. The size of a batch shall be in accordance with Table A1 or the agreed standard.

802 The procedures used for all tests shall be in accordance with the appropriate requirements of Sec.6.

Table A1 Number of tubes per batch

Outside diameter range (mm)	*Number of tubes per batch* [1)]
$D \leq 114.3$	400
$114.3 < D \leq 323.9$	200
$D > 323.9$	100

1) Any residual fraction of the batch is considered as a batch.

A 900 Hydraulic test

901 Each tube and pipe shall be subjected to a hydraulic test at the manufacturer's work. Test procedures shall be as specified in the agreed standard.

A 1000 Re-testing

1001 If one or more of the sample method tests prove unsatisfactory, the tube or pipe in question shall be rejected and twice as many new pipes or tubes of the batch in question shall be selected for testing. All these tests shall show satisfactory results. If not, the whole batch shall be rejected and a renewed heat treatment of the batch and subsequent re-testing of the material is required. The tests shall be executed in the same way as for the first time. All results shall be satisfactory, otherwise the whole batch shall be rejected.

SECTION 3
STEEL FORGINGS

A. General Requirements

A 100 Scope

101 Subsection A specifies the general requirements for steel forgings to be used in the construction of hull structures and equipment.

102 Where required by the relevant design and fabrication parts of the DNV Offshore Standards, steel forgings shall comply with the requirements of Ch.1 Sec.1 and Sec.6, the general requirements of this subsection and the appropriate specific requirements of subsequent subsections. 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 also be accepted provided such specifications give reasonable equivalence to the requirements of this section or are agreed upon for each specific application. As a minimum the following particulars shall be specified: manufacturing process, chemical composition, heat treatment, mechanical properties and non-destructive testing.

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.

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

A 300 Information to be supplied by the purchaser

301 Where relevant the following information shall be supplied by the purchaser to the forge at the time of enquiry and order:

a) description of the forging by drawing

b) dimensions, dimensional tolerances, including machining allowances

c) material specification and grade

d) details of any requirements additional to or stricter than those given in this section.

A 400 Manufacture

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

402 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 cleanness. Other processes may be accepted provided adequate cleanliness is documented.

403 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 segregations in the finished forgings.

404 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. Shaping of forgings by flame cutting, scarfing or arc-air gouging shall be undertaken only by agreement.

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

— for forgings made from ingot or from forged blooms or billets, 3:1 where $L > D$ and 1.5:1 where $L \leq D$
— for forgings made from rolled products, 4:1 where $L > D$ and 2:1 where $L \leq D$
— for forgings made by upsetting, the length after upsetting shall not be 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, 6:1.

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

406 For certain components, where grain flow is specified in the most favourable direction with regard to the mode of stressing in service, the proposed method of manufacture requires acceptance by the purchaser. In such cases, tests will be required to demonstrate that satisfactory mechanical properties and grain flow are obtained.

407 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.

A 500 Chemical composition

501 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.

502 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.

503 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 600 Heat treatment

601 All forgings shall be heat treated for mechanical properties as specified in subsequent subsection. 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.

602 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.

603 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.

604 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

605 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 reheat treated.

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

A 700 Test material and test pieces for mechanical testing

701 Test material, from which test pieces are taken, shall be integral with the forging except as provided in 703. Test material shall be provided by prolongations 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.

702 Except for closed die forgings or for componenets which shall be carburised or for hollow forgings where the ends shall be subequently 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.

703 Where batch testing is permitted according to 800, 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.

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

705 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.

706 Unless otherwise agreed, the longitudinal axis and mid-length 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.

707 Longitudinal tests shall be made except that rings, hollow forgings which are expanded, and disks shall be tested in the tangential direction.

708 The preparation of test pieces and the procedures used for mechanical testing are to comply with the relevant requirements of Sec.6.

A 800 Test units and number of tests

801 Normalised or solution heat treated forgings with mass 1000 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.

802 Normalised or solution heat treated forgings with mass up to 1000 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.

803 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.

804 Rolled bars may be batch tested and the test unit shall consist of either:

a) material from the same rolled ingot or bloom provided that where this is cut into individual lengths, these are all heat treated in the same furnace charge, or

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

805 Unless otherwise specified in subsequent sub-sections, 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.

806 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.

807 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 900 Mechanical properties

901 The material shall meet the mechanical properties specified in subsequent subsection.

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

A 1000 Inspection

1001 All finished forgings shall be visually inspected on accessible surfaces. Where applicable, this is to include the inspection of internal surfaces and bores. The surfaces shall be adequately prepared for inspection. Black forgings shall be suitably descaled by either shotblasting or flame descaling methods.

1002 Forgings shall be presented to the purchaser for visual inspection.

1003 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.

1004 Forgings are subject to non-destructive testing where specified in 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): 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.

1005 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.

1006 Where MT or PT is specified, the tests shall be carried out after the final heat treatment and when the surface is in the final condition. 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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1007 Where UT is specified, the tests shall be carried out after the final heat treatment and 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.

1008 Where a forging is delivered in the as-forged condition for subsequent machining, the manufacturer shall ensure that a suitable ultrasonic test is carried out to verify the internal quality.

1009 The extent of non-destructive testing and acceptance criteria shall be agreed with the purchaser.

1010 The forging manufacturer shall maintain records of inspections including dimensional measurements traceable to each forging. The records shall be presented to the purchaser on request. The forging manufacturer shall also provide the purchaser with a statement confirming that non destructive tests have been carried out with satisfactory results including information on the test standard and the extent of testing.

A 1100 Repair

1101 Defects may be removed by grinding or by chipping and grinding. The resulting grooves shall have a bottom radius of approximately three times the groove depth and shall be blended into the surrounding surface so as to avoid any sharp contours. Complete elimination of the defective material shall be verified by magnetic particle testing or liquid penetrant testing.

1102 The permissible depth of grinding shall be agreed with the purchaser.

1103 Repair welding of forgings may be permitted subject to agreement. 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.

1104 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.

B. Forgings for Hull Structures and Equipment

B 100 Scope

101 These requirements are supplementary to A and apply to steel forgings 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 limits given in Table B1 or, where applicable, the requirements of the agreed specification.

202 For forgings to be welded, the maximum carbon equivalent (CE) shall not exceed 0.52% when calculated in accordance with CE = C+Mn/6+Cr/5+Mo/5+V/5+Ni/15+Cu/15.

B 300 Heat treatment

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

a) Normalised.

b) Normalised and tempered at a temperature of not less than 550°C.

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 carried out, 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 standard. 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.

502 Ultrasonic testing shall be carried out on forgings 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

Steel type	*C*	*Si*	*Mn*	*P*	*S*	*Cr* [2]	*Mo* [2]	*Ni* [2]	*Cu* [2]	*V* [2]	*Total residuals*
C and C-Mn	0.23[3]	0.45	0.30-1.70	0.040	0.035	0.30	0.10	0.40	0.30	0.05	0.80
Alloy	0.25[3]	0.45	0.30-1.00	0.035	0.030	minimum 0.40 [4]	minimum 0.15 [4]	minimum 0.40 [4]	0.30	0.05	1.0

1) Composition in percentage mass by mass maximum unless shown as a range or as a minimum.
2) Elements are considered as residual elements unless shown as a range or as a minimum.
3) An increase is permitted up to maximum 0.30% for forgings not intended for welding.
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/mm²)	*Yield stress* R_e *minimum* (N/mm²)	*Elongation* A_5 *minimum* (%)		*Reduction of area* *Z minimum* (%)		*Charpy V-notch* [2]		
							Temperature (°C)	*Energy* (J)	*Temperature* (°C)
			Longitudinal	*Transverse*	*Longitudinal*	*Transverse*		*Longitudinal*	*Transverse*
C and C-Mn	400	210	26	19	50	35	0	27	18
	440	230	24	18	50	35	0	27	18
	480	250	22	16	45	30	0	27	18
	520	270	21	15	45	30	0	27	18
	560	290	20	14	40	27	0	27	18
	600	310	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) Testing at +20°C may be accepted subject to compliance with a specified minimum average energy of 45 J longitudinal or 30 J transverse for all grades.

C. Other Application Areas

C 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 Subsection A specifies the general requirements for steel castings to be used in the construction of hull structures and equipment.

102 Where required by the relevant design and fabrication 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 this subsection and the appropriate specific requirements of subsequent subsections. 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 also be accepted provided such specifications give reasonable equivalence to the requirements of this section or are agreed upon for each specific application. As a minimum the following particulars shall be specified: manufacturing process, chemical composition, heat treatment, mechanical properties and non-destructive testing.

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 Information to be supplied by the purchaser

301 Where relevant the following information shall be supplied by the purchaser to the foundry at the time of enquiry and order:

a) Description of the casting by pattern number and/or drawing.

b) Dimensions, dimensional tolerances, including machining allowances.

c) Material specification and grade.

d) Details of any requirements additional to or stricter than those given in this section.

A 400 Manufacture

401 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. All castings shall be made from killed steel.

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

403 Where two or more castings 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.

A 500 Chemical composition

501 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.

502 When multiple heats are tapped into a common ladle, the ladle analysis shall apply and be within the specified limits.

503 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.

504 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 600 Heat treatment

601 All castings shall be heat treated 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.

602 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.

603 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.

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

A 700 Test blocks and test pieces for mechanical testing

701 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.

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

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

704 The dimensions of test blocks shall be in accordance with recognised standards but in all cases shall have a thickness of not less than 28 mm. The test pieces shall be taken with their axis at least 14 mm from the cast surface.

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

A 800 Test units and number of tests

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

802 For castings of the same type under 1000 kg in mass, batch testing is permitted and each heat in each heat treatment charge shall be regarded as the test unit.

803 At least one set of mechanical tests is required for each test unit, except as specified in 804 and 805.

804 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.

805 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 900 Mechanical properties

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

902 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 shall meet the specified requirements.

A 1000 Inspection

1001 All finished castings shall be visually inspected on accessible surfaces. Where applicable, this is to 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.

1002 Castings shall be presented to the purchaser for visual inspection. The purchaser may require areas to be etched for the purpose of investigating weld repairs.

1003 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.

1004 Castings are subject to non-destructive testing where specified in 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 is to 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.

1005 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.

1006 Where MT or PT is specified, the tests shall be carried out after the final heat treatment and when the surface is in the final condition. 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 is responsible for the final surface condition except where indications are caused by the subsequent processing.

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1007 The castings are subject to MT or PT in the following areas:

a) At fabrication weld preparations and over a band width of 30 mm from welding edges.
b) At positions where repair welds are made.
c) At all accessible fillets and abrupt changes of section.
d) At positions where surplus metal has been removed by flame cutting, scarfing or arc-air gouging.

1008 Where UT is specified, the tests shall be carried out after the final heat treatment and 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.

1009 Unless otherwise agreed the castings are subject to UT or RT in the following areas:

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

1010 Acceptance criteria for non-destructive testing shall be agreed with the purchaser.

1011 The foundry shall maintain records of inspections traceable to each casting. The records shall be presented to the purchaser on request. The foundry shall also provide the purchaser with a statement confirming that non destructive tests have been carried out with satisfactory results including information on test standard and the extent of testing.

A 1100 Repair

1101 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.

1102 Where the repair entails removal of more than 10% of the wall thickness or 15 mm, whichever is smaller, the defective area shall 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.

1103 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
— the area of the groove based on length times width exceeds 0.125 m^2
— castings have leaked on hydrostatic testing.

All other weld repairs are considered minor.

1104 Major weld repairs require the acceptance by 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 agreed.

1105 Minor weld repairs do not require the acceptance of 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.

1106 All weld repairs shall be done by qualified welders using qualified procedures.

1107 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 accepted 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.

1108 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 prior approval, however, local stress relieving may be accepted for minor repairs. Special consideration may be given by the purchaser 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 procedures is such that residual stresses and hardness are minimised.

1109 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 1000.

1110 The foundry shall maintain records of welding, subsequent heat treatment and inspections traceable to each casting repaired. The records shall be presented to the purchaser on request.

B. Castings for Hull Structures and Equipment

B 100 Scope

101 These requirements are supplementary to subsection 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 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 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:

a) Fully annealed.
b) Normalised.
c) Normalised and tempered at a temperature of not less than 550°C.
d) Quenched and tempered at a temperature of not less than 550°C.

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 agreed specification.

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

B 500 Inspection

501 The castings are subject to magnetic particle and ultrasonic testing.

Table B1 Chemical composition limits[1] for steel castings for hull structures and equipment

Steel type	*C*	*Si*	*Mn*	*P*	*S*	*Cr* [2]	*Mo* [2]	*Ni* [2]	*Cu* [2]	*V* [2]	*Total residuals*
C and C-Mn	0.23 [3]	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 [4]	minimum 0.15 [4]	minimum 0.40 [4]	0.30	0.12	-

1) Composition in percentage mass by mass maximum unless shown as a range or as a minimum.
2) Elements are considered as residual elements unless shown as a range or as a minimum.
3) An increase is permitted up to maximum 0,30% provided that the manganese content is reduced to maximum 1.20%.
4) One or more of the elements shall comply with the minimum content.

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)	*Charpy V-notch* [1] *Energy* (J)
C and C-Mn	NV 410 W	235	410	24	40	0	27
	NV 450 W	255	450	22	35	0	27
	NV 480 W	275	480	20	30	0	27
Alloy	NV 550 W	355	550	18	30	0	32
	NV 620 W	430	620	16	30	0	32

1) Testing at +20°C may be accepted subject to compliance with a specified minimum average energy of 45 J for all grades.

C. Other Application Areas

C 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 Subsection A specifies the requirements for aluminium alloy plates, sections, tubes and bars to be used in aluminium structures. 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 this offshore standard, 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 accepted 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. Temper designations are given in Table A2. The numerical designation (grade) of aluminium alloys and temper designations are based on those of the Aluminium Association.

202 5000 series alloys, capable of being strain hardened, shall be supplied in any of the temper conditions given in Table A3 and Table A4, as applicable. 6000 series alloy, capable of being age hardened, shall be supplied in any of the temper conditions given in Table A4.

203 The prime alloy selection for main structure components should be alloy 5083 for plates and alloy 6005 or 6082 for profiles. The other alloys listed should be used for secondary applications. For weld filler material alloy 5183 should be the prime selection. For structures submerged in seawater the alloy 5083 should be used. The use of 6000 series aluminium alloys in direct contact with seawater may be restricted depending on application and corrosion protection system. The use of these alloys shall be subject to agreement in each case.

204 The number of alloys, tempers and type of filler materials to be selected for one structure should be limited to ease material purchasing and fabrication, and to avoid exchange of material by mistake.

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 workmanlike finish and shall be free from internal and surface defects of such nature as would be harmful in service.

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 and agreement in each case. Special tests and/or other relevant information, for instance, 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 shall normally 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 shall normally be cut with their longitudinal axes parallel to the extruding direction except that transverse tests are required for closed profile extrusions.

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 shall in addition be from the same furnace charge.

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

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

A 700 Mechanical properties

701 The mechanical properties shall comply with the values given in Table A3 and Table A4, as applicable. Other temper conditions with related mechanical properties may be accepted subject to consideration and agreement in each case.

A 800 Press weld testing

801 Proper fusion of press welds for closed profile extrusions shall be verified by macrosection tests or drift expansion tests. Other tests may be accepted after consideration. Every profile shall be sampled, except where the profile is 6.0 m long or shorter, in which case every fifth profile shall be sampled. Every sample profile shall be tested at both ends.

802 Where verification is by macrosection 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 lest 60°. The test is considered

to be unacceptable if it fails with a clean split along the weld line.

A 900 Inspection, tolerances

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

902 Permissible under-thickness tolerances for rolled and extruded products are given in Table A5 and Table A6, respectively. Dimensional tolerances other than those given shall comply with a recognised standard.

903 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 1000 Repair

1001 Slight surface imperfections may be removed by machining or grinding provided the final dimensions are within the tolerances. Repair by welding is not permitted.

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-5154A	0.50	0.50	0.10	0.50	3.1-3.9	0.25	0.20	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-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-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-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-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-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-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
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-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-6082	0.7-1.3	0.50	0.10	0.40-1.0	0.6-1.2	025	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 Temper descriptions and designations			
Temper description			*Temper*
Tempers achieved by fabrication, annealing, cold working, or cold working plus partial annealing or stabilising	As fabricated, cold worked without specified mechanical property limits		F
	Annealed, soft		0
	Strain hardened to specified strength	1/8 hard	H11
		1/4 hard	H12
		1/2 hard	H14
	Strain hardened and partially annealed (p.a.) to specified strength	1/8 hard, p.a.	H21
		1/4 hard, p.a.	H22
		1/2 hard, p.a.	H24
	Strain hardened and stabilised to specified strength	1/4 hard, stabilised	H32
		1/2 hard, stabilised	H34
	Special tempers		
	- Less strain hardened than H11, e.g. by straightening or stretching		H111
	- No controlled strain hardening, but there are mechanical property limits		H112
	- Treatment against exfoliation corrosion		H116
	- Strain hardened less than required for a controlled H32 temper		H321
Heat treated tempers	Unstable condition after solution heat treatment		W
	Solution heat treated, naturally aged		T4
	Cooled from an elevated temperature shaping process, artificially aged		T5
	Solution heat treated, artificially aged		T6
	Solution heat treated, artificially overaged		T7

Table A3 Mechanical properties for rolled aluminium alloys

Grade	*Temper*	*Yield Strength* $R_{p0.2}$ *minimum* *(N/mm²)*	*Tensile Strength* *Rm minimum or range* *(N/mm²)*	*Elongation* [1]	
				$A_{50\ mm}$ *minimum (%)*	A_{5d} *minimum (%)*
NV-5052	0 or H111	65	165-215	19	18
	H32	130	210-260	12 [2]	12
	H34	150	230-280	9 [3]	9
NV-5154A	0 or H111	85	215-275	17	16
	H32	180	250-305	10 [4]	9
	H34	200	270-325	8	7
NV-5754	0 or H111	80	190-240	18	17
	H32	130	220-270	10	9
	H34	160	240-280	10 [4]	8
NV-5454	0 or H111	85	215-285	17	16
	H32	180	250-305	10 [4]	9
	H34	200	270-325	8	7
NV-5086	0 or H111	100	240-310	17	16
	H112	125 [5]	250 [5]	8	9
	H32 or H321	185	275-335	10 [4]	9
	H34	220	300-360	8	7
NV-5083	0 or H111	125	275-350	16	15
	H112	125	275	12	10
	H116	215	305	12 [2]	10
	H32 or H321	215	305-380	10 [4]	9
NV-5383	0 or H111	145	290		17
	H116 or H321	220	305		10
NV-5059	0 or H111	160	330		24
	H116 or H321	270 [6]	370 [6]		10

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

2) 10% for thicknesses up to and including 6.0 mm.

3) 7% for thicknesses up to and including 6.0 mm.

4) 8% for thicknesses up to and including 6.0 mm.

5) Yield strength minimum 105 N/mm^2 and tensile strength minimum 240 N/mm^2 for thicknesses over 12.5 mm.

6) Yield strength minimum 260 N/mm^2 and tensile strength minimum 360 N/mm^2 for thicknesses over 20 mm.

Table A4 Mechanical properties for extruded aluminium alloys

	Grade	*Temper*	*Yield Strength* $R_{p0.2}$ *minimum* (N/mm²) [2]	*Tensile Strength* R_m *minimum or range* (N/mm²) [2]	*Elongation* [1]	
					$A_{50\ mm}$ *minimum* (%)	A_{5d} *minimum* (%)
Open profiles	NV-5083	0 or H111	110	270	12	10
		H112	125	270	12	10
	NV-5086	0 or H111	95	240-320	18	15
		H112	95	240	12	10
	NV-5383	0 or H111	145	290		17
		H112	190	310		13
	NV-5059	H112	200	330		10
	NV-6060	T4	60	120	16	14
		T5	100	140	8	6
		T6	140	170	8	6
	NV-6061	T4	110	180	15	13
		T5	205	240	6	7
		T6	240	260	10	8
	NV-6063	T4	65	130	14	12
		T5	110	150	8	7
		T6	170	205	10	9
	NV-6005A	T4	90	180	15	13
		T5 or T6	215	260	8	6
	NV-6082	T4	110	205	14	12
		T5 [2]	230	270	8	-
		T6 [2]	250	290	8	-
		T6 [3]	260	310	10	8
Closed profiles	NV-6060	T5	135	175		5
	NV-6061	T5 or T6	205	245		4
	NV-6005A	T5 or T6	215	250		5
	NV-6082	T5 or T6	240	290		5

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

2) Property limits apply for thicknesses up to and including 5.0 mm.

3) Property limits apply for thicknesses over 5.0 mm.

Table A5 Under-thickness tolerances for rolled products in 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 A6 Under-thickness tolerances for extrusions in 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 procedures when testing ferrous and non-ferrous metals.

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.

B. Test Methods

B 100 Testing machines

101 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.

B 200 Tensile testing at ambient temperature

201 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.

202 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 $N/mm^2/s$.

203 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 $N/mm^2/s$.

204 For determination of tensile strength (Rm) 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%/minute. For brittle materials, such as cast iron the elastic stress rate shall not exceed 2.5 $N/mm^2/s$.

205 The elongation generally means elongation determined on a proportional gauge length $5.65\sqrt{S_o}$, 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_o as appropriate. In this case the required elongation A_o is calculated from the following formula:

$$A_o = 2A_5\left(\frac{\sqrt{S_o}}{L_o}\right)^{0.40}$$

A_5 = the required elongation in % for test piece with gauge length
S_o = the cross-sectional area of the test piece in question
L_o = 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: 25 d
Flat test piece: b + a.

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

The following symbols are used:

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

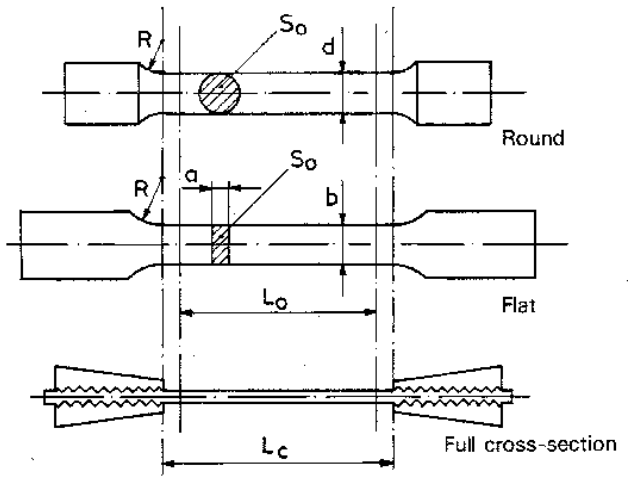

Figure 1
Tensile test pieces

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

208 For plates with thickness t = 3 mm or more, test pieces according to alternative A, B or C below shall be used.

Alternative A, flat test piece:

a = t
b = 25 mm
L_o = 200 mm
L_c ≅ 225 mm
R = 25 mm.

Alternative B, flat test piece:

a = t
b = 25 mm
L_o = $5.65\sqrt{S_o}$
L_c ≅ $L_o + 2\sqrt{S_o}$
R = 25 mm.

Alternative C, round test piece:

d = 14 mm
L_o = 70 mm
L_c ≅ 85 mm
R = 10 mm.

The round test piece shall be located with its centre t/4 from the plate surface or as close to this position as possible.

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

a = t
b = 12.5 mm
L_o = 50 mm
L_c ≅ 75 mm
R = 25 mm.

210 For forgings, bars and cast steel round test pieces normally with dimensions as specified below, shall be used:

d = 14 mm
L_o = 70 mm
L_c ≅ 85 mm
R = 10 mm, except generally for materials with a specified minimum elongation A_5 = 10%, where R shall be 20 mm.

If for special reasons, other dimensions shall be used, they will have to conform with the following geometrical relationship:

L_o = 5 d
L_c ≅ L_o + d
R = 10 mm, except for materials with a specified minimum elongation A_5 = 10%, where R shall be 1.5 d.

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

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

Alternative A:

Full cross-section test pieces with plugged ends.

L_o = $\sqrt{S_o}$
L_c ≅ L_o + D

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

Alternative B: *Strip*

a = wall thickness of the tube
b = 12 mm
L_o = $\sqrt{S_o}$
L_c ≅ L_o + 2b

B 300 Bend testing

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

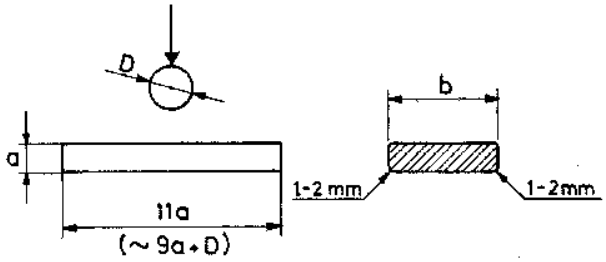

Figure 2
Bend test piece

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

a = as rolled thickness t of material
b = 30 mm.

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

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

a = 20 mm
b = 25 mm.

B 400 Impact testing

401 Impact testing shall be carried out as Charpy V-notch test according to the specification in question. Each value for absorbed energy shall be determined as the average of one set of 3 impact test pieces.

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

403 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/s. 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 may also be applied.).

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 + 0.5% of the machine's maximum striking energy. Impact test machines with a striking energy of less than 290 J may also be applied. 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.

404 Dimensions and tolerances for Charpy V-notch test pieces shall comply with the specifications given in 405. The test samples may be flame-cut but the notch shall not be nearer to a flame-cut edge than 25 mm. The prescribed dimensions shall be accurately and systematically checked. The notch shall be made in a single cut by a special milling cutter. The cutter shall always 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 not be used for more than 100 test pieces between each checking. There shall be no indications, scratches or marks left in the base of the notch after machining. The plane of symmetry of the notch shall be at right angle to the longitudinal axis of the test piece.

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

Table B1 Charpy V-notch test pieces

Dimensions	*Nominal*	*Tolerances*
Length	55 mm	0.60 mm
Width – standard test piece – subsize test piece – subsize test piece – subsize test piece	 10 mm 7.5 mm 5 mm 2.5 mm	 ± 0.11 mm ± 0.11 mm ± 0.06 mm ± 0.06 mm
Thickness	10 mm	± 0.06 mm
Angle of notch	45°	± 2°
Depth below notch	8 mm	± 0.05 mm
Root radius	0.25mm	± 0.025mm
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°	± 2°

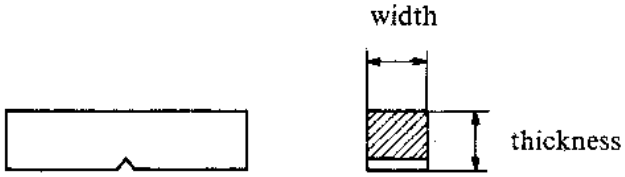

Figure 3
Charpy V-notch test piece

406 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. For tubes and pipes also a subsize test piece with width 2.5 mm shall be used if necessitated by the dimensions.

407 The temperature of the test piece at the moment of breaking shall be the specified temperature within ± 2°C. Test temperature shall be stated on 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 s after withdrawal from the bath.

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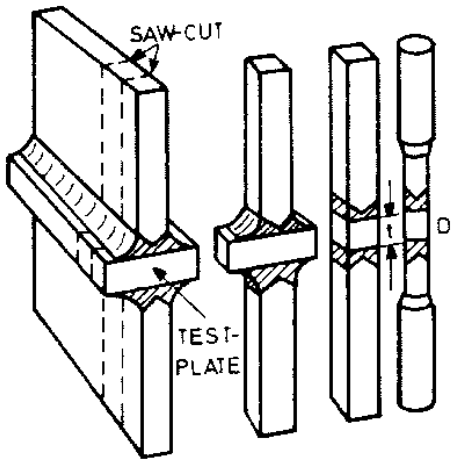

Figure 4
Example of test piece for Z-direction tensile testing for plate thickness t > 40 mm

B 500 Z-direction ductility testing

501 The test is applicable to materials exceeding 15 mm thickness.

502 For plate thickness up to 40 mm the full plate thickness shall be tested by making welded extensions on the plate to be tested. Welding shall be carried out by suitable methods giving a sufficiently strong bond without excessive penetration in the plate. Friction welding, manual metal arc welding, using properly handled low hydrogen electrodes, and stud welding are preferred methods, see Figure 4.

503 For plate thicknesses exceeding 20 mm, the test pieces may be made without welded extensions provided that minimum 6 mm on either side is used for heads or other means of fastening the test piece in the tensile machines (see Figure 5).

504 The relation between material thickness, t, and test piece diameter, D, is as follows:

t ≤ 16 mm: D = 6 mm
t > 16 mm: D = 10 mm.

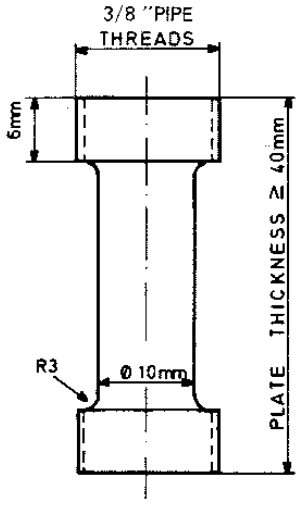

Figure 5
Example of test piece for Z-direction tensile testing for plate thickness t > 40 mm

505 A test sample sufficient for the preparation of six pieces shall be taken from one end of each rolled piece. The sample shall be cut from the mid-end position of the product. For rolled pieces with mass more than 20 tonnes, one test sample shall be taken from each end. Three pieces from each test sample shall be prepared for testing while the rest of the pieces remain for possible retests.

506 If it is not possible to trace individual single plates to the original mother plate, each single plate shall be tested taking 3 pieces of each.

507 The reduction of areas, Z_z, is defined by the relationship:

$$Z_z = \frac{S_o - S}{S_o} \ 100\%$$

S_o = original cross-sectional area of test piece

$$= \frac{\pi}{4} D$$

S = cross-sectional area at fracture, due to the anisotropy of the plate material, the fracture surface is often approximately elliptical rather than circular. When this is the case, the area shall be calculated as

$$S = \frac{\pi}{4}\left(\frac{a + b}{2}\right)^2$$

where a and b are the long and theshort axis of the «ellipse», respectively.

B 600 Determination of grain size

601 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.

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 and preparation of test specimens

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.

302 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.

303 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.

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

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

CONTENTS PAGE

DET NORSKE VERITAS

Veritasveien 1, N-1322 Høvik, Norway Tel.: +47 67 57 99 00 Fax: +47 67 57 99 11

SECTION 1
CERTIFICATION AND CLASSIFICATION

A. General

A 100 Introduction

101 As well as representing DNV's recommendations of 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 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 Materials shall be manufactured at works which have been approved by DNV. A list of approved manufacturers is published separately.

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 manufacturer 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:

a) Manufacturer's name or trade mark.

b) Material grade.

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

d) If required by the purchaser, his order number or other identification 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 requirements of Ch.1 and Ch.2.

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:

a) Purchaser's name and order number and if known the unit identification for which the material is intended.

b) Manufacturer's name.

c) Description of the product, dimensions, weight etc.

d) Identification of specification or grade of material.

e) Identification of the cast and product.

f) Ladle analysis for specified elements.

g) Results of all specified inspections and mechanical tests.

h) 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.