



RULES FOR
CLASSIFICATION OF

SHIPS / HIGH SPEED, LIGHT CRAFT AND NAVAL SURFACE CRAFT

NEWBUILDINGS

MATERIALS AND WELDING

PART 2 CHAPTER 2

METALLIC MATERIALS

JANUARY 2005

*This booklet includes the relevant amendments and corrections
shown in the January 2006 version of Pt.0 Ch.1 Sec.3.*

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CHANGES IN THE RULES

General

The present edition of the rules includes additions and amendments decided by the Board as of 29 November 2004, and supersedes the January 2003 edition of the same chapter.

The rule changes come into force 1 July 2005.

This chapter is valid until superseded by a revised chapter. Supplements will not be issued except for an updated list of minor amendments and corrections presented in Pt.0 Ch.1 Sec.3. Pt.0 Ch.1 is normally revised in January and July each year.

Revised chapters will be forwarded to all subscribers to the rules. Buyers of reprints are advised to check the updated list of rule chapters printed in Pt.0 Ch.1 Sec.1 to ensure that the chapter is current.

Main changes

- **Section 4 – Steel Pipes**

— This section has been renamed (former “Steel Tubes, Pipes and Fittings”) and completely revised. The previous rules were based on ISO standards and detailed DNV requirements, while the new rules are based on the most frequently used industry standards like ISO, EN, ASTM, DIN and JTS. Specific DNV requirements have been restricted to cover additional safety measures and matters as deemed necessary by the Society.

Corrections and Clarifications

In addition to the above stated rule requirements, a number of corrections and clarifications have been made in the existing rule text.

Comments to the rules may be sent by e-mail to rules@dnv.com

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SECTION 1 ROLLED STEEL FOR STRUCTURAL APPLICATION

A. General

A 100 Scope

101 This section specifies the requirements for weldable normal strength, high strength and extra high strength hot rolled structural steel plates and sections. These requirements are also applicable to seamless steel tubes and pipes intended for structural application. The requirements are applicable to steel products with a thickness not exceeding 150 mm. For greater thicknesses certain deviations from these requirements may be accepted or required after consideration in each case.

This section covers IACS UR W11 and W16.

For rolled slabs, billets or bars used as substitute for forgings, see Sec.5.

102 Steels differing from the rule requirements in chemical composition, deoxidation practice, condition of supply and mechanical properties may be accepted, subject to special approval by the Society. Such steels shall be given a special designation, see 200.

A 200 Designation of steel grades

201 The steel grades of this Section are divided into strength groups of three ranges:

- Normal strength steels (NS)
- High strength steels (HS)
- Extra high strength Steels (EHS)

202 The alphanumeric designation of the steel grade is NV x y,

where

- NV = designation of a steel grade according to the Society's rules.
 x = a capital letter corresponding to a specified impact toughness test temperature, see Table A1.
 y = a figure designating the strength group according to the specified minimum yield stress, see Table A1. The figure y is omitted for NS steels.

203 Additional symbols following the alphanumeric designation given in 202 may be:

- Z = steel grade of improved through-thickness properties.
 S = especially approved steel, see 100.

A 300 Method of manufacture

301 The steel shall be manufactured by an electric or one of the basic oxygen processes. The use of other processes may be especially approved by the Society.

302 The reduction ratio of thickness from continuously cast slab to plate shall be minimum 5 to 1 unless otherwise approved by the Society.

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

Table A1 Definitions of steel grades

Strength range	Impact testing		Tensile properties	
	Symbol x	Test temperature (°C)	Symbol y	Minimum yield stress (N/mm ²)
NS	A B D E	- 0 -20 -40	Omitted	235
HS	A D E F	0 -20 -40 -60	27 32 36 40	265 315 355 390
EHS	D E F	-20 -40 -60	420 460 500 550 620 690	420 460 500 550 620 690

B. Normal Strength Steel

B 100 Scope

101 Subsection B specifies the requirements for normal strength steel, which is defined as steel with minimum yield stress of 235 N/mm².

102 Additional requirements for steel with guaranteed through thickness properties - 'Z' grade steel, are detailed in subsection E.

B 200 Chemical composition

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

B 300 Heat treatment, condition of supply

301 Normal strength steel shall be delivered in a condition complying with the requirements given in Table B2.

B 400 Mechanical properties

401 Normal strength steel shall comply with the mechanical properties specified in Table B3.

Table B1 Chemical composition and deoxidation practice for normal strength steel

		Grade			
		NV A	NV B	NV D	NV E
Deoxidation		For t ≤ 50 mm: Any method except rimmed steel ¹⁾ 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) ^{2) 3)}	C maximum (%) ⁵⁾	0.21 ⁴⁾	0.21	0.21	0.18
	Si minimum (%)	-	-	0.10	0.10
	Si maximum (%)	0.50	0.35	0.35	0.35
	Mn minimum (%) ⁵⁾	2.5 x C	0.80 ⁶⁾	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. (%) ⁷⁾	-	-	0.015 ⁸⁾	0.015
<p>1) For sections up to 12.5 mm thickness, rimmed steel may be accepted subject to special approval by the Society.</p> <p>2) When any grade of steel is supplied in the thermo-mechanically controlled processed condition, deviations in the specified chemical composition may be allowed or required by the Society.</p> <p>3) The Society may limit the amount of residual and or trace elements which may have an adverse effect on the working and use of the steel, e.g. copper and tin.</p> <p>4) Maximum 0.23% for sections.</p> <p>5) Carbon plus 1/6 of the manganese content shall not exceed 0.40%.</p> <p>6) For NV B, when the silicon content is 0.10 or above (killed steel), the minimum manganese content may be reduced to 0.60%.</p> <p>7) 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 approval by the Society.</p> <p>8) Al is required for thicknesses above 25 mm.</p>					

Table B2 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
<p>1) Condition of supply: AR: As rolled. N: Normalised. CR: Controlled rolled. TM: Thermo-mechanically controlled processed (TMCP)</p> <p>2) Grades NV A and NV B may be supplied as rolled (AR) subject to special approval by the Society.</p> <p>3) Subject to special approval by the Society, 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).</p>		

Table B3 Mechanical properties for Normal Strength (NS) steel										
Grade	Yield stress R_{eH} minimum (N/mm ²)	Tensile strength R_m (N/mm ²)	Elonga- tion A_5 mini- mum (%)	Test tem- perature (°C)	Average impact energy J minimum					
					$t \leq 50$		$50 < t \leq 70$		$70 < t \leq 150$	
					Longitudi- nal	Transverse	Longitudi- nal	Transverse	Longitudi- nal	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 B steel with thickness of 25 mm or less.										
2) Impact tests for Grade 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/mm² and up to and including 390 N/mm².

102 It should be noted that the fatigue strength of welded joints of high strength steels may not be higher than that of a welded joint in normal strength steel.

103 Additional requirements for steel with guaranteed through thickness properties - 'Z' grade steel, are detailed in subsection E.

C 200 Chemical composition

201 The chemical composition, deoxidation practice and fine grain treatment are in general to satisfy the requirements in Table C1. 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 shall 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 after agreement with the Society. The combination of grain-refining elements of the various steel grades is subject to approval by the Society.

A smaller content of Al than given in the table may be accept-

ed, subject to special approval.

203 The content of all elements specified shall be determined for each cast, by ladle analysis, and shall be stated on the 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 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 C2.

The formula given in D200 (P_{cm}) may also be used for evaluating weldability instead of the carbon equivalent at the discretion of the Society.

C 300 Heat treatment, condition of supply

301 High strength steel shall be delivered in a condition complying with the requirements given in Table C3.

C 400 Mechanical properties

401 High strength steel shall comply with the mechanical properties specified in Table C4.

Table C1 Chemical composition and deoxidation practice for high strength (HS) steel

<i>Grade</i>	<i>NV A27S NV D27S NV E27S NV A32 NV D32 NV E32 NV A36 NV D36 NV E36 NV A40 NV D40 NV E40</i>	<i>NV F32 NV F36 NV F40</i>
Deoxidation	Killed and fine grain treated ¹⁾	
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)
<p>1) NV A 27S is accepted semi-killed or killed without fine grain treatment for thicknesses up to and including 25 mm.</p> <p>2) For thicknesses up to and including 12.5 mm the minimum Mn-content may be reduced to 0.70%. For NV A 27S, NV D 27S and NV E 27S it may be reduced to 0.70% regardless of thickness.</p> <p>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.</p>		

Table C2 Carbon equivalent for high strength steels up to 150 mm in thickness produced by TMCP

<i>Steel Grade</i>	<i>Carbon equivalent, maximum (%)</i>		
	<i>t ≤ 50 mm</i>	<i>50 < t ≤ 100 mm</i>	<i>100 < t ≤ 150 mm</i>
NV A27S, NV D27S, NV E27S	-	-	-
NV A32, NV D32, NV E32, NV F32	0.36	0.38	0.40
NV A36, NV D36, NV E36, NV F36	0.38	0.40	0.42
NV A40, NV D40, NV E40, NV F40	0.40	-	-

Table C3 Condition of supply for high strength (HS) steel			
<i>Grade</i>	<i>Grain refining elements</i>	<i>Thickness, t mm</i>	<i>Condition of supply ¹⁾</i>
NV A27S NV A32 NV A36	Nb and/or V	$t \leq 12.5$ $12.5 < t \leq 150$	Any AR ³⁾ , CR, N, QT, TM
	Al only or with Ti	$t \leq 20$ $20 < t \leq 35$ $35 < t \leq 150$	Any Any ²⁾ AR ³⁾ , CR, N, QT, TM
NV A40	Any	$t \leq 12.5$ $12.5 < t \leq 150$	Any CR, N, QT, TM
NV D27S NV D32 NV D36	Nb or V	$t \leq 12.5$ $12.5 < t \leq 150$	Any AR ³⁾ , CR, N, QT, TM
	Al only or with Ti	$t \leq 20$ $20 < t \leq 25$ $25 < t \leq 150$	Any Any ²⁾ AR ³⁾ , CR, N, QT, TM
NV D40	Any	$t \leq 150$	CR, N, QT, TM
NV E27S NV E32 NV E36	Any	$t \leq 150$	CR ³⁾ , N, QT, TM
NV E40	Any	$t \leq 150$	N, QT, TM
NV F32 NV F36	Any	$t \leq 150$	CR ⁴⁾ , N, QT, TM
NV F40	Any	$t \leq 150$	N, QT, TM
<p>1) Condition of supply: AR: As rolled condition. N: Normalised. QT: Quenched and tempered. CR: Controlled rolled. TM: Thermo-mechanically controlled processed (TMCP).</p> <p>2) As rolled (AR) subject to special approval of the Society.</p> <p>3) Subject to special approval by the Society, sections in grades NV A27S, NV A32, NV A36, NV D27S, 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 E27S, NV E32 and NV E36 may be supplied as rolled (AR) or controlled rolled (CR).</p> <p>4) Subject to special approval by the Society, sections in grades NV F32 and NV F36 may be supplied controlled rolled (CR).</p>			

Table C4 Mechanical properties for high strength (HS) steel

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 A27S NV D27S NV E27S	265	400 - 530	22 ¹⁾	0 -20 -40	27 ²⁾	20	34	24	41	27
NV A32 NV D32 NV E32 NV F32	315	440 - 570	22 ¹⁾	0 -20 -40 -60	31 ²⁾	22	38	26	46	31
NV A36 NV D36 NV E36 NV F36	355	490 - 630	21 ¹⁾	0 -20 -40 -60	34 ²⁾	24	41	27	50	34
NV A40 NV D40 NV E40 NV F40	390	510 - 660	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: 2) For grades NV A27S, NV A32 and NV A36 steels a relaxation in the number of impact tests for acceptance purposes may be permitted by special agreement with the Society provided that satisfactory results are obtained from occasional check tests.										
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 (%)										
NV A27S, NV D27S, NV E27S	15	16	17	18	19	20	21	22		
NV A32, NV D32, NV E32, NV F32	14	16	17	18	19	20	21	22		
NV A36, NV D36, NV E36, NV F36	13	15	16	17	18	19	20	21		
NV A40, NV D40, NV E40, NV 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/mm² and up to and including 690 N/mm².

102 It should be noted that the fatigue strength of welded joints of extra high strength steels may not be greater than that of a welded joint in lower strength steels.

103 Additional requirements for steel with guaranteed through thickness properties - 'Z' grade steel, are detailed in subsection E.

D 200 Chemical composition

201 The chemical composition, deoxidation practice and fine grain treatment are in general to satisfy the requirements in Table D1.

Where additions of any other elements have been made as part of the steelmaking 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 agreement with the Society. The combination of grain-refining elements of the various steel grades is subject to approval by the Society.

A smaller content of Al than given in the table may be accepted, subject to special approval. When used in combination, the specified minimum content of at least one element is applicable.

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

204 When the weldability shall be evaluated from the chemical composition, the following formula shall be used if not otherwise agreed:

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

D 300 Heat treatment, condition of supply

301 Extra high strength steel shall be delivered in a condition complying with the requirements given in Table D2.

D 400 Mechanical properties

401 Extra high strength steel shall comply with the mechanical properties specified in Table D3.

402 Drop weight testing and/or fracture mechanics testing may be required where found appropriate by the Society.

Table D1 Chemical composition and deoxidation practice for extra high strength (EHS) steel

		Grade					
		NV A420	NV A460	NV A500	NV A550	NV A620	NV A690
		NV D420	NV D460	NV D500	NV D550	NV D620	NV D690
		NV E420	NV E460	NV E500	NV E550	NV E620	NV E690
		NV F420	NV F460	NV F500	NV F550	NV F620	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 Condition of supply for extra high strength (EHS) steel

Grade	Grain refining elements	Thickness, t mm	Condition of supply ^{1) 2)}
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 F500, NV F550, NV F620, NV F690	Any	t ≤ 150	N, QT, TM
1) Condition of supply: N: Normalised. QT: Quenched and temper. CR: Controlled rolled. TM: Thermo mechanically controlled processed (TMCP).			
2) For specified yield stress above 500 N/mm ² only quenching and tempering is applicable.			

Table D3 Mechanical properties for extra high strength (EHS) steel							
Steel grade	Yield stress $R_{eH}^{1)}$ minimum (N/mm ²)	Tensile strength R_m (N/mm ²)	Elongation A_5 minimum (%)	Test temperature (°C)	Average impact energy (J) minimum		
					$t \leq 150$		
					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 the 0.2% proof stress $R_{p0.2}$ 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)		10 < t ≤ 15	15 < t ≤ 20	20 < t ≤ 25	25 < t ≤ 40	40 < t ≤ 50	50 < t ≤ 150
Elongation							
NV A420, NV D420, NV E420, NV F420	11	13	14	15	16	17	18
NV A460, NV D460, NV E460, NV F460	11	12	13	14	15	16	17
NV A500, NV D599, NV E500, NV F500	10	11	12	13	14	15	16
NV A550, NV D550, NV E550, NV F550	10	11	12	13	14	15	16
NV A620, NV D620, NV E620, NV F620	9	11	12	12	13	14	15
NV A690, NV D690, NV E690, NV F690	9	10	11	11	12	13	14

E. Steel Plates and Wide Flats with Specified Minimum Through Thickness Properties ("Z" Quality)

E 100 Scope

101 These requirements supplement those given in subsection A to D for material with a thickness greater than or equal to 15mm and intended to have a specified minimum ductility in the through thickness or "Z" direction. See Figure 1.

102 The use of such material known as "Z" quality steels is recommended for structural details subject to strains in the through thickness direction to minimise the possibility of lamellar tearing during fabrication. Two 'Z' quality steels are specified, Z25 for normal ship applications and Z35 for more severe applications.

Through thickness properties are characterised by specified values for reduction of area in a through thickness tensile test.

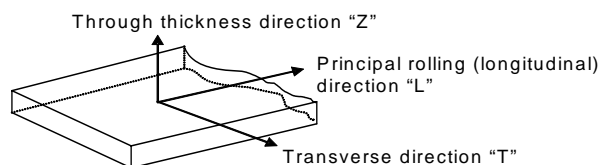


Fig. 1
Through thickness tensile testing

E 200 Manufacture

201 All the materials shall be manufactured at works approved by the Society for "Z" quality steels.

E 300 Chemical Composition

301 In addition to the requirements of the appropriate steel specification given in subsection B to D, the maximum sulphur content shall be 0.008% determined by the ladle analysis.

E 400 Test Material

401 In addition to the requirements of the appropriate steel

specification given in subsection B to D, preparation of test pieces and testing procedures shall be as given below.

402 For plates and wide flats, one test sample shall be taken close to the longitudinal centreline of one end of each rolled piece representing the batch, see Table E1 and Figure 2.

Table E1 Batch size dependent on product and sulphur content		
Product	$S > 0.005\%$	$S \leq 0.005\%$
Plates	Each piece (parent plate)	Maximum 50 t of products of the same cast, thickness and heat treatment
Wide flats of nominal thickness ≤ 25 mm	Maximum 10 t of products of the same cast, thickness and heat treatment	Maximum 50 t of products of the same cast, thickness and heat treatment
Wide flats of nominal thickness > 25 mm	Maximum 20 t of products of the same cast, thickness and heat treatment	Maximum 50 t of products of the same cast, thickness and heat treatment

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

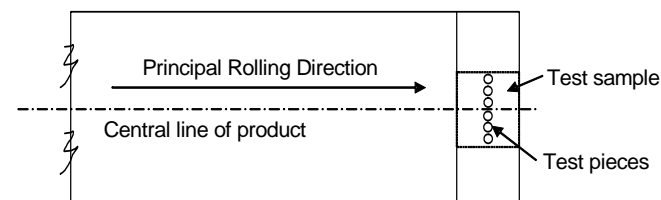


Fig. 2
Plate and wide flat sampling position.

E 500 Mechanical testing

501 Round test pieces shall be prepared in accordance with a recognised national standard.

502 The test is considered invalid and further replacement test is required if the fracture occurs in the weld or heat affected zone.

The minimum average value for the reduction of area of at least three test pieces is given in Table E2. Only one individual value may be below the minimum average but not less than the minimum individual value shown for the appropriate grade, see Figure 3.

A value less than the minimum individual value is a cause for rejection.

Table E2 – Reduction of Area Acceptance Values		
Grade	Z25	Z35
Minimum average	25%	35%
Minimum individual	15%	25%

E 600 Re-test procedure

601 Figure 3 shows the three cases where a retest situation is permitted. In these instances three more tensile tests shall be taken from the remaining test sample. The average of all 6 tensile tests shall be greater than the required minimum average with no greater than two results below the minimum average.

In the case of failure after re-test, either the batch represented by the piece is rejected or each piece within the batch is tested.

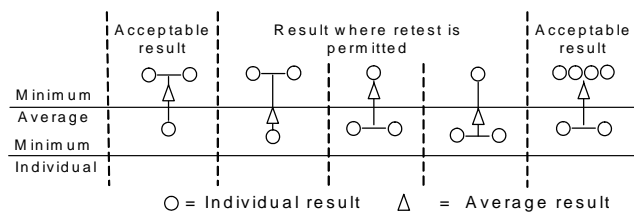


Fig. 3
Diagram showing acceptance and rejection and retest criteria

E 700 Non-destructive testing

701 Ultrasonic testing is required and shall be performed in accordance with EN 10160 1999 Level S2/E3 or ASTM A 578 Level C.

Ultrasonic should be carried out on each piece in the final supply condition and with a probe frequency of 4 MHz.

E 800 Marking

801 Products complying with these requirements shall be marked in accordance with the appropriate steel requirement given in A to D and in addition with the notation Z25 or Z35 added to the material grade designation, e.g. NV E36 Z25.

E 900 Certification

901 The following information is required to be included on the certificate in addition to the appropriate steel requirement given in A to D.

- Through thickness reduction in area (%)
- Steel grade with Z25 or Z35 notation

F. Testing

F 100 Test material

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

The test samples shall be fully representative of the material and, where appropriate, 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 Unless otherwise agreed, 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.4a). 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 Figs. 4b, 4c, 4d and 4e) 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. 4d). 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. 4e),
- for cylindrical sections, at one third of the radius from the outside (see Fig. 4f).

103 Samples for testing of through thickness properties shall be agreed upon by the Society.

F 200 Tensile testing

201 The dimensions of the tensile test pieces shall be in accordance with Ch.1 Sec.2. Generally for plates, wide flats and sections 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, etc. test pieces may consist of a suitable length of the full cross section of the product.

202 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 is only to represent material from the same heat treatment batch.

204 When no distinct yield is observed during tensile testing, the stress at 0.2% non-proportional elongation 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 be in accordance with the requirements of Ch.1.

F 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 steel plates and wide flats over 600 mm where the pieces shall be taken with their axes transverse to the main rolling direction. The steel works is, however, to 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 Except where otherwise specified or especially agreed by the Society, the maximum size of a test unit shall be as specified in Table F1. One set of three test pieces shall 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 cut with their edge within 2 mm from the as-rolled 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 10x10 mm, the larger of the following pieces shall be used: 10x7.5 mm or 10x5 mm. The 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 tables B3, C4 and D3 respectively. 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 be in accordance with the requirements of Ch.1.

Table F1 Extent of impact testing at delivery

Strength range	Grades	Thickness, <i>t</i> (mm)	Test unit maximum	
			Plate	Sections
NS steel	A	$t \leq 50$ $50 < t \leq 150$	Not required 50 t	Not required
	B	$t \leq 25$ $25 < t \leq 150$	Not required 50 t ^{1) 2)}	Not required 50 t ²⁾
	D	$t \leq 150$	50 t ^{1) 2)}	50 t ²⁾
	E	$t \leq 150$	Each piece	25 t ³⁾
HS steel	A	$t \leq 150$	Maximum 50 t ^{1) 2)}	50 t ²⁾
	D	$t \leq 150$	Maximum 50 t ^{1) 2)}	50 t ²⁾
	E	$t \leq 150$	Each piece	25 t ³⁾
	F	$t \leq 150$	Each piece	25 t ³⁾
EHS steel	D	$t \leq 150$	Each piece	Each piece
	E	$t \leq 150$	Each piece	Each piece
	F	$t \leq 150$	Each piece	Each piece

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

2) When, subject to special approval of the Society, material is supplied in the as rolled (AR) condition, the frequency of impact testing 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.

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

F 400 Inspection - tolerances

401 Surface inspection and checking of dimensions are the responsibility of the manufacturer who shall verify that the requirements concerning 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.

Acceptance by the Society of material which is later found to be defective does not absolve the manufacturer from this responsibility.

402 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.

403 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 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 conventional rolling mill manufacturing material, on average, to the nominal thickness.

The shipbuilder and shipowner may mutually agree in individual cases whether, for commercial reasons, they wish to specify a more stringent under thickness tolerance than given.

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 eliminations of defects may be disregarded provided the imperfections or grinding are in accordance with accepted national or international standards.

404 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.

G. Repairs

G 100 Surface defects

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

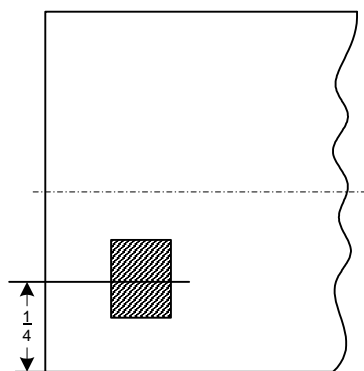
- the thickness is in no place reduced to less than 93% of the nominal thickness, but in no case by more than 3 mm
- each single ground area does not exceed 0.25 m² and
- all ground areas do not exceed 2% of the total surface in question.

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

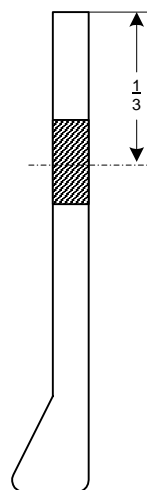
The repairs shall be agreed with the surveyor in each case, and shall be carried out under the surveyor's supervision unless otherwise agreed.

102 Surface defects which cannot be dealt with as above may, subject to the surveyor's consent, be repaired by chipping or grinding followed by welding under his supervision, provided the requirements given below are complied with.

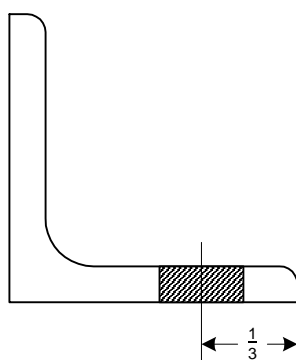
- after removal of the defect, and before welding, the thickness of the piece is in no place to be reduced by more than 20%. The welding shall be carried out according to an approved procedure with approved electrodes. The weld shall be ground smooth to the correct nominal thickness
- the weld repair shall be subjected to adequate non-destructive examination
- the piece is normally to be subjected 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.



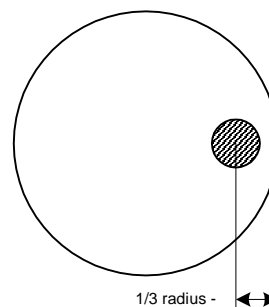
(a) Plates and flats



(e) Bulb flats



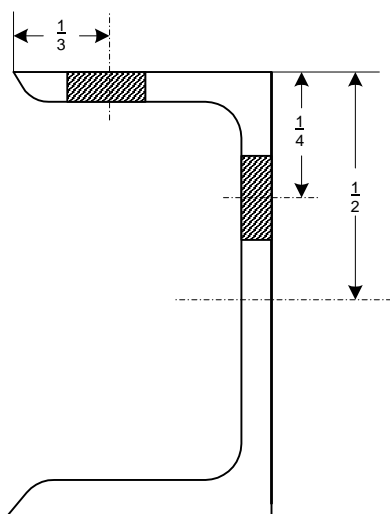
(b) Angles



(f) Bars



(c) Unequal angles



(d) Channels and beams

Fig. 4
Position of test specimen

SECTION 2

ROLLED STEEL FOR BOILERS, PRESSURE VESSELS AND SPECIAL APPLICATIONS

A. General

A 100 Scope

101 This section specifies the requirements for rolled steel intended for use in the construction of boilers and pressure vessels and of tanks and process equipment for low temperature service. Mechanical properties at high temperatures for design purposes are stated. The rules also apply to rolled austenitic and ferritic-austenitic (duplex) stainless steel.

A 200 Method of manufacture

201 The steel shall be manufactured by an electric or one of the basic oxygen processes. The use of other processes may be especially approved by the Society.

202 The reduction ratio of thickness from continuously cast slab to plate shall be minimum 5 to 1 unless otherwise approved by the Society.

B. Steel for Boilers and Pressure Vessels

B 100 Steel grades

101 Requirements regarding carbon and carbon-manganese steels are specified for the as rolled condition in thicknesses up to 25 mm and for the normalised condition in thicknesses up to 100 mm. Requirements are also given for alloy steels in thicknesses up to 100 mm.

As alternatives to the steel grades specified below, materials complying with relevant standards may be accepted, subject to approval in each case.

102 The designations for carbon and carbon-manganese steel grades are built up as follows:

The letters NV are followed by three figures which stand for the specified minimum tensile strength in N/mm².

Further, there is a single figure referring to the impact test temperature:

The figures 0.1 and 2 mean impact testing at +20°, 0° and – 20°C respectively.

The suffix letters are symbolizing the heat treatment and deoxidation practice. The suffix A means as rolled, N means normalised, QT means quenched and tempered and F means fine grain treated steels.

Where controlled rolling is used as a substitute for normalising, the suffix CR shall be used instead of N.

Example:

NV 360—1FN means a steel grade with specified minimum tensile strength 360 N/mm² impact tested at 0°C, fine grain treated and normalised.

B 200 Chemical composition

201 The chemical composition shall satisfy the requirements specified in Table B1 for carbon and carbon-manganese steels and in Table B2 for alloy steels.

202 The content of all elements given in the specification including grain refining elements shall be determined and entered on the certificate. The content of residual elements shall be checked by random tests as agreed upon with the surveyor.

203 Where Al is replaced by other grain refining elements, the minimum contents of such elements shall be:

- Nb, minimum 0.02%
- V, minimum 0.05%.

204 For carbon and carbon-manganese steels, the carbon equivalent shall be calculated from the ladle analysis using the following formula when applicable:

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

B 300 Mechanical properties

301 The mechanical properties of the material shall comply with the requirements specified in the following tables:

Table B3: Carbon and carbon-manganese steels, as rolled

Table B4: Carbon and carbon-manganese steels, normalised or controlled rolled

Table B5: Alloy steels

The values for tensile strength, yield stress and elongation specified in the tables refer to testing at room temperature.

302 Values for lower yield stress or 0.2% proof stress at high temperatures are given in Table B6. The values are intended for design purposes and verification is not required.

If the material is produced in compliance with a recognised standard where the lower yield stress or 0.2% proof stress at high temperatures is higher than stated in Table B6, these higher values will be accepted, provided that tensile tests at high temperatures, in compliance with E300, are carried out with satisfactory results.

The tensile test at high temperatures may be dispensed with if the steelmaker can demonstrate to the satisfaction of the Society that the specified minimum mechanical properties at high temperatures can be consistently obtained in the running production.

303 Estimated average values for stress to rupture in 100,000 and 200,000 hours are given in Table B7 for design purposes.

B 400 Heat treatment

401 The materials shall be supplied in the heat treatment conditions stated in Table B8, except that materials which shall be heat treated after hot or cold forming may be supplied in the as rolled condition, subject to the customer's consent. In such cases heat treatment and subsequent mechanical testing shall be carried out after forming.

402 The designation of controlled rolled- and thermo-mechanically treated steel grades shall be given the suffix CR and TM respectively instead of N.

Table B1 Carbon and carbon-manganese steels for boilers and pressure vessels. Chemical composition

Grade	Chemical composition, (%)								Deoxidation
	<i>C</i> <i>maximum</i>	<i>Si</i>	<i>Mn</i>	<i>P</i> <i>maximum</i>	<i>S</i> <i>maximum</i>	<i>Al</i> _{ac.sol}	<i>N</i> <i>maxi- mum</i>	<i>Residual elements, maximum</i>	
NV 360 - 0A, - 0N	0.17	≤ 0.35	0.40 - ²⁾ 1.00	0.035	0.030	≤ 0.010	0.009 ¹⁾	6)	Semikilled or killed
NV 360 - 1 FN	0.17	≤ 0.35	0.40 - ²⁾ 1.00	0.035	0.030	0.015 - ⁵⁾ 0.080	0.015	6)	Killed fine grained
NV 410 - 0A, - 0N	0.20	≤ 0.35	0.50 - 1.30	0.035	0.030	≤ 0.010	0.009 ¹⁾	6)	Semikilled or killed
NV 410 - 1 FN	0.20	≤ 0.35	0.50 - 1.30	0.035	0.030	0.015 - ⁵⁾ 0.080	0.015	6)	Killed fine grained
NV 460 - 0A, - 0N	0.20	≤ 0.40	0.60 - ³⁾ 1.40	0.035	0.030	≤ 0.010	0.009 ¹⁾	6)	Semikilled or killed
NV 460 - 1 FN	0.20 ⁴⁾	≤ 0.40	0.60 - ³⁾ 1.40	0.035	0.030	0.015 - ⁵⁾ 0.080	0.015	6)	Killed fine grained
NV 490 - 0N	0.20 ⁴⁾	0.10 - 0.50	0.90 - 1.60	0.035	0.030	≤ 0.010	0.009 ¹⁾	6)	Killed
NV 490 - 1 FN	0.20 ⁴⁾	0.10 - 0.50	0.90 - 1.60	0.035	0.030	0.015 - ⁵⁾ 0.080	0.015	6)	Killed fine grained
NV 510 - 1 FN	0.22	0.10 - 0.60	1.00 - 1.60	0.035	0.030	0.015 - 0.080	0.015	6)	Killed fine grained
1) For electric furnace steel, maximum 0.012.									
2) For thicknesses exceeding 40 mm, Mn = 0.40 - 1.20%.									
3) If high temperature properties of Table B7 are specified, Mn content shall be 0.80 - 1.40%.									
4) For thickness t > 30 mm and t ≤ 100 mm, C _{max} 0.22%.									
5) Aluminium may be replaced by other grain refining elements.									
6)									
Cr 0.20									
Cu 0.35									
Ni 0.40									
Mo 0.08									
Total 0.70									

Table B2 Alloy steels for boilers and pressure vessels. Chemical composition

Grade	Chemical composition, (%)								<i>Residual elements</i> , maximum
	<i>C</i>	<i>Si</i>	<i>Mn</i>	<i>P</i> maximum	<i>S</i> maximum	<i>Al</i> _{tot} maximum	<i>Cr</i>	<i>Mo</i>	
NV 0.3 Mo	0.12 - 0.20	0.15 - 0.35	0.50 - 0.80	0.035	0.030	0.012	< 0.30	0.25 - 0.35	Cu 0.25 Ni 0.30
NV 1 Cr 0.5 Mo	0.10 - 0.18	0.15 - 0.35	0.40 - 0.80	0.035	0.030	0.020	0.70 - 1.30	0.40 - 0.60	
NV 2.25 Cr 1 Mo	0.08 - 0.18	0.15 - 0.50	0.40 - 0.80	0.035	0.030	0.020	2.00 - 2.50	0.90 - 1.10	

Table B3 Carbon and carbon-manganese steels for boilers and pressure vessels, as rolled condition. Mechanical properties

Grade	<i>Tensile strength</i> <i>R_m</i> (N/mm ²)	<i>Yield stress, R_{eH} or R_{p0.2}</i> (N/mm ²) minimum for thickness, (mm)		<i>Elongation</i> <i>A₅</i> (%) minimum	<i>KV, average</i>		
		≤ 16	> 16 ≤ 25		<i>Test temperature</i> (°C)	<i>Transverse (J) minimum</i>	<i>Longitudinal (J) minimum</i>
NV 360 - 0A	360 - 480	205	195	26	20	20	27
NV 410 - 0A	410 - 530	235	225	24	20	20	27
NV 460 - 0A	460 - 580	285	255	22	20	20	27

Table B4 Carbon and carbon-manganese steels for boilers and pressure vessels, normalised or controlled rolled condition. Mechanical properties

Grade	Tensile strength R_m (N/mm ²)	Yield stress, R_{eH} or $R_{p0.2}$ (N/mm ²) minimum for thickness, (mm)				Elongation A_5 , (%) minimum	KV, average		
		≤ 16	$> 16 \leq 40$	$> 40 \leq 63$	$> 63 \leq 100$		Test temperature (°C)	Transverse (J) minimum	Longitudinal (J) minimum
NV 360 - 0N	360 - 480	205	195	185	175	26 ¹⁾	20	20	27
NV 360 - 1 FN	360 - 480	235	215	195	2)	26 ¹⁾	0	20	27
NV 410 - 0N	410 - 530	235	225	215	205	24 ¹⁾	20	20	27
NV 410 - 1 FN	410 - 530	265	245	235	2)	24 ¹⁾	0	20	27
NV 460 - 0N	460 - 580	285	255	245	235	22 ¹⁾	20	20	27
NV 460 - 1 FN	460 - 580	295	285	275	2)	22 ¹⁾	0	20	27
NV 490 - 0N	490 - 610	305	275	265	255	21 ¹⁾	20	22	31
NV 490 - 1 FN	490 - 610	315	315	305	2)	21	0	22	31
NV 510 - 1 FN	510 - 650 ³⁾	355	345	335	315	20	0	22	31

1) For thicknesses 40 - 63 mm, the minimum value is 1 unit lower and for thicknesses 63 - 100 mm 2 units lower.
2) For thickness $t > 63$ mm but $t \leq 100$ mm, the values specified for the thickness range $t > 40$ mm but $t \leq 63$ mm are lowered by 1% for each 5 mm of thickness over 63 mm.
3) For thicknesses 63 - 100 mm: R_m 490 - 630.

Table B5 Alloy steels for boilers and pressure vessels. Mechanical properties

Grade	Tensile strength R_m (N/mm ²)	Yield strength R_{eH} or $R_{p0.2}$ (N/mm ²) minimum for thickness, (mm) ²⁾			Elongation A_5 , (%) minimum	KV, average		
		≤ 16	$> 16 \leq 40$	$> 40 \leq 63$		Test temperature (°C)	Transverse (J) minimum	Longitudinal (J) minimum
NV 0.3 Mo	440 - 590	260	250	250	24 ¹⁾	20	20	27
NV 1 Cr 0.5 Mo	470 - 620	305	305	305	20 ¹⁾	20	22	31
NV 2.25 Cr 1 Mo	480 - 630	275	265	265	18 ¹⁾	20	20	27

1) For thicknesses 40 - 63 mm, the minimum value is 1 unit lower and for thicknesses 63 - 100 mm, 2 units lower.
2) For thickness $t > 63$ mm but $t \leq 100$ mm, the values specified for the thickness range $t > 40$ mm but $t \leq 63$ mm are lowered by 1% for each 5 mm of thickness over 63 mm.

Table B6 Steels for boilers and pressure vessels. Minimum lower yield stress (R_{eL}) or 0.2% proof stress ($R_{p0.2}$) values at high temperatures for design purposes

Grade		Thickness (mm) ¹⁾	Minimum R_{eL} or $R_{p0.2}$ (N/mm ²) Temperature, (°C)									
			100	150	200	250	300	350	400	450	500	
C- and C/Mn-steels, normalised	NV 360 - 0N	< 16 16 ≤ 40 > 40 ≤ 63	175 171 162	172 169 158	168 162 152	150 144 141	124 124 124	117 117 117	115 115 115	113 113 113		
	NV 360 - 1 FN	<16 >16 ≤ 40 > 40 ≤ 63	204 196 179	185 183 172	165 164 459	145 145 145	127 127 127	116 116 116	110 110 110	106 106 106		
	NV 410 - 0N	< 16 > 16 ≤ 40 > 40 ≤ 63	211 201 192	208 198 188	201 191 181	180 171 168	150 150 150	142 142 142	138 138 138	136 136 136		
	NV 410 - 1 FN	< 16 > 16 ≤ 40 > 40 ≤ 63	235 228 215	216 213 204	194 192 188	171 171 171	152 152 152	141 141 141	134 134 134	130 130 130		
	NV 460 - 0N	< 16 > 16 ≤ 40 > 40 ≤ 63	248 230 222	243 227 218	235 220 210	210 198 194	176 176 176	168 168 168	162 162 162	158 158 158		
	NV 460 - 1 FN	< 16 > 16 ≤ 40 > 40 ≤ 63	266 260 251	247 242 236	223 220 217	198 198 198	177 177 177	167 167 167	158 158 158	153 153 153		
	NV 490 - 0N	< 16 > 16 ≤ 40 > 40 ≤ 63	270 248 240	264 245 236	255 237 227	228 214 210	192 192 192	183 183 183	177 177 177	172 172 172		
	NV 490 - 1 FN	< 16 > 16 ≤ 40 > 40 ≤ 63	284 279 272	265 260 256	240 237 234	213 213 213	192 192 192	182 182 182	173 173 173	168 168 168		
	NV 510 - 1 FN	≤ 63	-	-	265	245	225	205	175	155		
	C- and C/ Mn-steels as rolled	NV 360 - 0A	≤ 25	150	150	145	125	110	105			
		NV 410 - 0A	≤ 25	180	180	170	150	130	125			
		NV 460 - 0A	≤ 25	210	210	200	180	160	150			
Alloy steels	NV 0.3 Mo	< 63	237	232	218	200	167	153	148	143	139	
	NV 1 Cr 0.5 Mo	< 63	270	259	248	237	216	203	199	194	188	
	NV 2.25 Cr 1 Mo	< 63	249	241	233	224	219	212	207	194	180	

1) For thickness $t > 63$ but $t < 100$ mm the values specified for thickness range $t > 40$ but $t \leq 63$ mm are lowered by 1% for each 5 mm of thickness over 63 mm.

Table B7 Estimated average stress to rupture values in 100 000 and 200 000 hours for design purposes										
Temperature (°C)	Stress to rupture, (N/mm ²) for steel grades									
	NV 360 - 0N NV 360 - 1FN NV 410 - 0N NV 410 - 1FN		NV 460 - 0N NV 460 - 1FN NV 490 - 0N NV 490 - 1FN NV 510 - 1FN		NV 0.3 Mo		NV 1 Cr 0.5 Mo		NV 2.25 Cr 1 Mo	
	100 000 h	200 000 h	100 000 h	200 000 h	100 000 h	200 000 h	100 000 h	200 000 h	100 000 h	200 000 h
380	165	145	227	206						
390	148	129	203	181						
400	132	115	179	157						
410	118	101	157	135						
420	103	89	136	115						
430	91	78	117	97						
440	79	67	100	82						
450	69	57	85	70	239	217	-	-	221	203
460	59	48	73	60	208	188	-	-	204	186
470	50	40	63	52	178	159	-	-	186	169
480	42	33	55	44	148	130	210	180	170	152
490			47	37	123	105	177	148	153	135
500			41	30	101	84	146	122	137	119
510					81	69	121	99	122	103
520					66	55	99	79	107	89
530					53	45	81	64	93	77
540							67	52	79	68
550							54	42	69	58
560							43	34	59	50
570							35	-	51	43
580									44	-

Table B8 Heat treatment of steel for boilers and pressure vessels	
Grade	Heat treatment or condition of supply
NV 360 0A NV 410 0A NV 460 0A	As rolled
NV 360 - 0N, - 1 FN NV 410 - 0N, - 1 FN NV 460 - 0N, - 1 FN NV 490 - 0N, - 1 FN NV 510 - 1 FN	Normalised/controlled rolled ¹⁾ Thermo-mechanically treated
NV 0.3 Mo	Normalised
NV 1 Cr 0.5 Mo NV 2.25 Cr 1 Mo	Normalised and tempered
1) See 402.	

C. Steel for Low Temperature Service

C 100 Steel grades

101 Requirements are specified for fine grained carbon-manganese steels and nickel alloy steels with toughness properties at low temperatures.

C 200 Chemical composition

201 The chemical composition shall satisfy the requirements specified in Table C1 for carbon manganese steels and in Table C2 for nickel alloy steels.

202 The content of all elements given in the specifications including grain refining elements shall be determined and entered on the certificate. The content of residual elements shall be checked by random tests as agreed upon with the surveyor.

203 Where Al is replaced by other grain refining elements, the minimum contents of such elements shall be:

- Nb, minimum 0.02%
- V, minimum 0.05%.

204 For carbon and carbon-manganese steels, the carbon equivalent shall be calculated from the ladle analysis using the

following formula when applicable:

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

C 300 Mechanical properties

301 The mechanical properties of the material shall comply with the requirements specified in the following tables:

Table C3: Carbon-manganese steels

Table C4: Nickel alloy steels

The values for tensile strength, yield stress and elongation specified in the tables refer to testing at room temperature.

302 Pellini's drop weight test shall be carried out for plates and sections of nickel alloy steels with thickness 13 mm and more in the following cases:

- NV 1.5 Ni when intended for design temperature below – 60°C
- NV 3.5 Ni when intended for design temperature below – 80°C
- NV 5 Ni when intended for design temperature below – 90°C

The test specimens shall display a “no break performance” when tested 5°C below the design temperature.

C 400 Heat treatment

401 The materials shall be supplied in the heat treatment conditions stated in Table C5.

402 The designation of quenched and tempered, controlled rolled and thermo-mechanically treated steel grades shall be given the suffix QT, CR, and TMCP respectively instead of N.

Guidance note:

Hot forming or normalising of thermo-mechanically treated steels may result in considerable reduction of tensile strength and yield stress. Thermo-mechanically treated steels shall not be used where hot forming or normalising will be carried out.

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

Table C1 Carbon-manganese steels for low temperature service. Chemical composition

Grade	Chemical composition, %							Residual elements
	<i>C</i> maxi- mum	<i>Si</i>	<i>Mn</i>	<i>S</i> maxi- mum	<i>P</i> maxi- mum	<i>Al</i> ⁴⁾ total	<i>N</i> maxi- mum	
NV 360 - 2FN	0.17	0.10 0.35	0.40 1.00 ²⁾	0.025	0.030	≥ 0.018	0.015	Cr 0.20 maximum Cu 0.35 maximum Ni 0.40 maximum ¹⁾ Mo 0.08 maximum Cr+Mo+Cu 0.45 maximum
NV 2 - 2	0.16	0.10 0.40	0.40 1.60	0.025	0.030	≥ 0.018	0.015	
NV 2 - 3	0.14	0.10 0.40	0.70 1.60	0.025	0.030	≥ 0.018	0.015	
NV 2 - 4	0.14	0.10 0.40	0.70 1.60 ³⁾	0.025	0.030	≥ 0.018	0.015	
NV 2 - 4L	0.14	0.10 0.40	0.70 1.60 ³⁾	0.025	0.030	≥ 0.018	0.015	
NV 4 - 2	0.16	0.10 0.40	< 1.60	0.025	0.030	≥ 0.018	0.015	
NV 4 - 3	0.16	0.10 0.40	0.70 1.60	0.025	0.030	≥ 0.018	0.015	
NV 4 - 4	0.16	0.10 0.40	0.70 1.60 ³⁾	0.025	0.030	≥ 0.018	0.015	
NV 4 - 4L	0.16	0.10 0.40	0.70 1.60 ³⁾	0.025	0.030	≥ 0.018	0.015	

- 1) For the steel grades NV 2 - 3, NV 2 - 4, NV 2 - 4L, NV 4 - 3, NV 4 - 4 and NV 4 - 4L a Ni-content up to 1.25% may be approved.
- 2) For thicknesses exceeding 40 mm, Mn = 0.40 - 1.20%.
- 3) A maximum Mn content of 1.65% is accepted provided the carbon-content does not exceed 0.13% for NV 2 - 4 or NV 2 - 4L and 0.14% for NV 4 - 4 or NV 4 - 4L.
- 4) Aluminium may be either partly or totally replaced by other grain refining elements.

Table C2 Nickel alloy steels for low temperature service. Chemical composition

Grade	Chemical composition, (%)						
	<i>C</i> maximum	<i>Si</i>	<i>Mn</i>	<i>S</i> maximum	<i>P</i> maximum	<i>Ni</i>	<i>Al</i> _{tot}
NV 1.5 Ni	0.14	0.10 - 0.35	0.30 - 1.50	0.025	0.025	1.30 - 1.70	≥ 0.018
NV 3.5 Ni	0.12	0.10 - 0.35	0.30 - 0.70	0.025	0.025	3.25 - 3.75	≥ 0.018
NV 5 Ni	0.12	0.10 - 0.35	0.30 - 0.80	0.025	0.025	4.70 - 5.30	≥ 0.018
NV 9 Ni	0.10	0.10 - 0.35	0.30 - 0.90	0.025	0.025	8.50 - 10.0	≥ 0.018

Table C3 Carbon-manganese steels for low temperature service. Mechanical properties ¹⁾									
<i>Grade</i>	<i>Tensile strength (N/mm²)</i>	<i>Yield stress (N/mm²) minimum for thickness, (mm)</i>		<i>Elongation A₅ (%) minimum</i>	<i>Impact energy KV, average ²⁾</i>				<i>Min design temperature</i>
		<i>≤ 16</i>	<i>> 16 ≤ 40</i>		<i>Thickness (mm)</i>	<i>Test temperature (°C) ³⁾⁴⁾⁵⁾</i>	<i>Transverse (J) minimum</i>	<i>Longitudi- nal (J) minimum</i>	
NV 360 - 2FN	360 - 480	235	215	26	≤ 25 > 25 ≤ 30 > 30 ≤ 35 > 35 ≤ 40	- 20 - 25 - 30 - 35	27	41	-15°C
NV 2 - 2	400 - 490	265	255	24	≤ 25 > 25 ≤ 30 > 30 ≤ 35 > 35 ≤ 40	- 20 - 25 - 30 - 35	27	41	-15°C
NV 2 - 3	400 - 490	265	255	24	≤ 25 > 25 ≤ 30 > 30 ≤ 35 > 35 ≤ 40	- 40 - 45 - 50 - 55	27	41	-35°C
NV 2 - 4	400 - 490	265	255	24	≤ 25 > 25 ≤ 30 > 30 ≤ 35 > 35 ≤ 40	- 55 - 60 - 65 - 70	27	41	-50°C
NV 2 - 4L	400 - 490	265	255	24	≤ 25 > 25 ≤ 30 > 30 ≤ 35 > 35 ≤ 40	- 60 - 65 - 70 - 75	27	41	-55°C
NV 4 - 2	490 - 610	335	325	21	≤ 25 > 25 ≤ 30 > 30 ≤ 35 > 35 ≤ 40	- 20 - 25 - 30 - 35	27	41	-15°C
NV 4 - 3	490 - 610	335	325	21	≤ 25 > 25 ≤ 30 > 30 ≤ 35 > 35 ≤ 40	- 40 - 45 - 50 - 55	27	41	-35°C
NV 4 - 4	490 - 610	335	325	21	≤ 25 > 25 ≤ 30 > 30 ≤ 35 > 35 ≤ 40	- 55 - 60 - 65 - 70	27	41	-50°C
NV 4 - 4L	490 - 610	335	325	21	≤ 25 > 25 ≤ 30 > 30 ≤ 35 > 35 ≤ 40	- 60 - 65 - 70 - 75	27	41	-55°C
1) These requirements are applicable to products up to maximum 40 mm thickness. For thicknesses exceeding 40 mm the requirements shall be agreed. 2) The specified impact toughness requirements also apply in the heat affected zone of welded connections and it is recommended that the steel is ordered with sufficient margin. 3) Materials for tanks or parts of tanks completely thermally stress relieved after welding may for all thicknesses up to t ≤ 40 mm be tested at a temperature 5°C below the minimum design temperature. 4) Materials for liquefied gas carriers, see Pt.5 Ch.5 Sec.2 Table D2 of the Rules for Classification of Ships. 5) For thickness 25 < t ≤ 40 mm the impact test temperature shall be stamped on the products and stated in the certificate.									

Table C4 Nickel alloy steels for low temperature service. Mechanical properties ¹⁾

Grade	Tensile strength (N/mm ²)	Yield stress (N/mm ²) minimum for thickness, (mm)		Elongation A ₅ (%) minimum	Impact energy KV, average ²⁾				Min design temperature
		≤ 30	> 30 ≤ 40		Thickness (mm)	Test temperature (°C) ³⁾⁴⁾	Transverse (J) minimum	Longitudinal (J) minimum	
NV 1.5 Ni ⁵⁾	470 - 640	275	265	22	≤ 25 > 25 ≤ 30 > 30 ≤ 35 > 35 ≤ 40	- 65 - 70 - 75 - 80	27	41	-60°C
NV 3.5 Ni ⁵⁾	540 - 690	345	335	22	≤ 25 > 25 ≤ 30 > 30 ≤ 35 > 35 ≤ 40	- 95 - 100 - 105 - 110	27	41	-90°C
NV 5 Ni ⁵⁾	570 - 710	390	380	21	≤ 25 > 25 ≤ 30 > 30 ≤ 35 > 35 ≤ 40	- 110 - 115 - 120 - 125	27	41	-105°C
NV 9 Ni	640 - 840	490	480	19	≤ 40	- 196	27	41	-165°C
<p>1) These requirements are applicable to products up to maximum 40 mm thickness. For thicknesses exceeding 40 mm the requirements shall be agreed.</p> <p>2) The specified impact toughness requirements also apply in the heat affected zone of welded connections and it is recommended that the steel is ordered with sufficient margin.</p> <p>3) Materials for liquefied gas carriers see Pt.5 Ch.5 Sec.2 Table D3 of the Rules for Classification of Ships.</p> <p>4) For thickness 25 < t ≤ 40 mm the impact test temperature shall be stamped on the products and stated in the certificate.</p> <p>5) In certain cases the materials shall be subjected to Pellini's drop weight test according to 302.</p>									

Table C5 Heat treatment of steels for low temperature service

Grade	Heat treatment/condition of supply
NV 360 - 2FN NV 2 - 2 NV 2 - 3 NV 2 - 4 NV 2 - 4L NV 4 - 2 NV 4 - 3 NV 4 - 4 NV 4 - 4L	Plates: normalised ¹⁾ Sections: normalised, thermo-mechanically treated or controlled rolled ²⁾
NV 1.5 Ni NV 3.5 Ni NV 5 Ni	Normalised, normalised and tempered or quenched and tempered
NV 9 Ni	Double normalised and tempered or quenched and tempered ³⁾
<p>1) Other heat treating processes, e.g. quenching and tempering or thermo-mechanical controlled processing may be approved. See 402.</p> <p>2) See 402.</p> <p>3) Quenching and tempering will normally be required for thicknesses above 30 mm.</p>	

D. Stainless Steel

D 100 Steel grades

101 Requirements are specified for seven grades of austenitic and two grades of duplex (ferritic/austenitic) stainless steels. Steel grades with chemical composition and mechanical properties deviating from these specifications may be accepted for the purpose in question after consideration in each separate case.

The austenitic steels may be used for applications where the design temperature is not lower than -165°C.

D 200 Chemical composition

201 The chemical composition shall comply with the requirements given in Table D1, or the approved specification.

D 300 Mechanical properties

301 The mechanical properties of the material shall comply with the requirements specified in Table D2. For austenitic steels both the 0.2 and 1.0% yield stress shall be reported.

The values for tensile strength, yield stress and elongation refer to testing at room temperature.

For austenitic steels impact tests are only required for design temperatures below -105°C.

For duplex steels impact tests at design temperature or -20°C, whichever is the lower, are required.

D 400 Heat treatment

401 All materials shall be supplied in the solution treated condition.

D 500 Intercrystalline corrosion tests

501 Unless otherwise agreed by the Society for the order in question, the materials shall be subjected to intercrystalline corrosion test, in order to demonstrate that the material is not susceptible to intergranular corrosion resulting from grain boundary precipitation of chromium-rich carbides. One test shall be carried out for each tensile test. The testing shall be carried out according to ASTM A262, Practice E, Copper - Copper Sulphate - Sulphuric Acid Test or another recognised

standard.

The bent specimens shall be free from cracks indicating the presence of intergranular attack.

Table D1 Austenitic and duplex stainless steels. Chemical composition									
Grade	Chemical composition, (%)								
	C maximum	Si maximum	Mn maximum	P maximum	S maximum	Cr	Ni	Mo	Other
<i>Austenitic</i>									
NV 304 L	0.03	1.0	2.0	0.045	0.030	18.0 - 20.0	8.0 - 12.0	-	
NV 316 L	0.03	1.0	2.0	0.045	0.030	16.5 - 18.5	11.0 - 15.0	2.5 - 3.0	
NV 316 L N	0.03	1.0	2.0	0.045	0.030	16.5 - 18.5	11.0 - 14.5	2.5 - 3.0	N 0.14 - 0.22
NV 317 L	0.03	1.0	2.0	0.045	0.030	18.0 - 20.0	11.0 - 15.0	3.0 - 4.0	
NV 317 L N	0.03	1.0	2.0	0.045	0.030	18.0 - 20.0	12.5 - 15.0	3.0 - 4.0	N 0.14 - 0.22
NV 321	0.08	1.0	2.0	0.045	0.030	17.0 - 19.0	9.0 - 12.0	-	Ti 5xC ≤ Ti ≤ 0.70
NV 347	0.08	1.0	2.0	0.045	0.030	17.0 - 19.0	9.0 - 13.0	-	10xC ≤ Nb ≤ 1.0
<i>Duplex</i>									
UNS S31803	0.03	1.0	2.0	0.030	0.020	21.0 - 23.0	4.5 - 6.5	2.5-3.5	N 0.14 - 0.20
UNS S32750	0.03	0.80	1.2	0.035	0.020	24.0 - 26.0	6.0 - 8.0	3.0-5.0	N 0.24 - 0.32

Table D2 Austenitic and duplex stainless steel. Mechanical properties						
Grade	Tensile strength (N/mm ²) <i>R_m</i>	Yield stress ¹⁾ (N/mm ²), minimum		Elongation (%) <i>A₅</i>	Impact energy Charpy V-notch ²⁾	
		<i>R_{p0.2}</i>	<i>R_{p1.0}</i>		Test temperature (°C)	minimum average (J)
Austenitic						
NV 304 L	450 - 700	175	215	40	- 196	transverse: 27 longitudinal: 41
NV 316 L	450 - 700	195	235	40		
NV 316 L N	600 - 800	300	340	40		
NV 317 L	500 - 700	195	235	40		
NV 317 L N	600 - 800	300	340	40		
NV 321	500 - 750	205	245	40		
NV 347	500 - 750	205	245	40		
Duplex						
UNS S31803	minimum 620	450		25	-20	longitudinal: 41
UNS S32750	minimum 690	550		25	-20	transverse: 27
1) The specified yield stress at both 0.2% and 1.0%, <i>R_{p0.2}</i> and <i>R_{p1.0}</i> respectively, shall be documented for austenitic stainless steels.						
2) Verification of impact values for austenitic stainless steels is required only for materials intended for design temperatures below - 105°C.						

1) The specified yield stress at both 0.2% and 1.0%, R_{p0.2} and R_{p1.0} respectively, shall be documented for austenitic stainless steels.

2) Verification of impact values for austenitic stainless steels is required only for materials intended for design temperatures below - 105°C.

E. Testing

E 100 General

101 The procedures used for all tests shall be in accordance with the appropriate requirements of Ch.1.

102 Test samples shall be taken from positions as required according to Sec.1 F100.

E 200 Tensile testing at ambient temperature

201 Test pieces for tensile testing of plates at ambient temperature shall be cut with their principal axes transverse to the final direction of rolling.

For testing of sections the test pieces shall be taken transverse or parallel to the final direction of rolling at the option of the steelmaker.

202 For plates, one tensile test piece shall be taken from each rolled plate provided the weight of the piece does not exceed 2500 kg.

Where ingot casting is used, the test piece shall represent the top of the ingot.

When the weight exceeds 2500 kg, tensile test pieces shall be taken from both ends of the rolled plate.

203 When test pieces are required from each end of a rolled plate, the difference between the values obtained for the tensile strength shall not exceed 60 N/mm².

204 For sections, one tensile test piece shall be taken from test units of not more than 10 tonnes. The material in each test unit shall be from the same heat and of the same shape with a thickness variation of not more than 5 mm.

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

E 300 Tensile testing at high temperatures

301 When determination of lower yield stress or proof stress at high temperatures is required according to B302, the testing shall be carried out in compliance with ISO 783.

The straining rate when approaching the stress values shall be controlled to within 0.1 to 0.3% strain per minute.

The intervals used for estimation of strain rate from measurements of strain shall not exceed 6 seconds.

302 The test pieces shall be cut with their principal axes transverse to the final direction of rolling.

At least one tensile test shall be made on material from each cast. The pieces shall be taken from the thickest plate of the cast.

303 When no special test temperature is specified in the order, the tests shall be carried out at 300°C.

E 400 Impact testing

401 For material thickness 6 mm and above, impact testing shall be carried out at the prescribed temperatures.

The average value from each set of three impact test pieces shall comply with the appropriate requirements in tables B3, B4, B5, C3, C4, and D2. Further, only one individual value within each set may be below the specified minimum average value, but not lower than 70% of this value.

402 The required minimum values specified in B, C and D refer to standard test pieces 10 x 10 mm. Where it is impossible to use a standard test piece, the larger of the following pieces shall be used: 10 x 7.5 mm, 10 x 5 mm.

The impact values required are then reduced to respectively 5/6 and 2/3 of the required values for standard test pieces.

403 The 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, where practicable.

404 For plates and flats having a width of 600 mm or more the test pieces shall be cut with their longitudinal axes transverse to the final direction of rolling. For other products the test pieces may be taken transverse or parallel to the final direction of rolling.

Requirements for test pieces cut with their longitudinal axes transverse and parallel to the final direction of rolling are stated in the tables as "transverse" and "longitudinal" respectively.

405 The notch shall be cut in a face of the test pieces which was originally perpendicular to the rolled surface.

406 For plates at least one set (3 pieces) of tests shall be made for each tensile test. When the test temperature is -50°C or lower, one set of tests shall be taken from each end of the rolled plate regardless of the plate weight.

For sections at least one set of tests shall be made for each tensile test. When the test temperature is -50°C or lower, one set of tests shall be made for every 2 tonnes or part thereof of each type from the same heat and with thickness variation less than 5 mm.

E 500 Drop weight testing

501 When drop weight test is required according to C302, one set of tests (2 test pieces) shall be taken from the thickest plate alternatively section of each cast. The extent of testing may be reduced subject to a thorough statistical documentation.

E 600 Testing of through thickness properties

601 When steel with improved through thickness properties (Z-steel) is required or specified in the order, the materials shall be manufactured and tested in accordance with Sec.1 E.

E 700 Inter-crystalline corrosion testing

701 When inter-crystalline corrosion testing is required, the test shall be carried out according to ASTM, A 262, Practice E, Copper—Copper Sulfate—Sulfuric Acid Test or another recognised standard.

F. Inspection, Dimensional Tolerances and Surface Condition

F 100 Inspection

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

Acceptance by the surveyors of material which is later found to be defective does not absolve the steelmaker from this responsibility.

102 Plates and other products shall be subjected to a thorough, visual inspection on 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, dye penetrant and/or ultrasonic inspection may be required.

All plates shall be accessible to the surveyor for final inspection and checking.

F 200 Tolerances

201 No minus tolerance is permitted in the thickness of plates intended for boilers, pressure vessels and low temperature service. For stainless steels intended for chemical tankers without pressure rating no plate shall vary more than 0.30 mm or 6% under the thickness specified, whichever is the lesser.

For sections the minus tolerance shall be in accordance with a recognised national or international standard.

F 300 Surface condition and rectification of defects

301 All products shall display a workmanlike finish free from defects and imperfections which may impair their proper workability and use.

302 Surface defects may be removed by local grinding. Normally the thickness beneath the ground area shall not be less than the nominal thickness of the material. Repair of deeper defects by grinding or welding will be subject to special consideration in each separate case, and shall not be carried out unless a detailed repair procedure is submitted and approved.

303 When defects are removed by grinding, complete elimination of the defects shall be proven by suitable non-destructive examination of the affected area.

304 Depressions caused by grinding shall show a smooth transition to the surface.

SECTION 3 CLAD STEEL PLATES

A. General

A 100 Scope

101 This section specifies the requirements for clad steel plates consisting of a base material and a thinner layer (cladding metal) on one or both sides, continuously and integrally bonded.

A 200 Heat treatment

201 The plates shall be supplied in that condition of heat treatment which is most appropriate for both types of material. The material shall not be subjected to any kind of heat treatment by the user, beyond what is recommended by the manufacturer and approved by the Society. The heat treatment shall be checked by the surveyor.

B. Base Material

B 100 General

101 Any steel which is suitable for joining with the cladding metal may be accepted as base material, provided that the process has no adverse effects on the finished plate. If the plate is intended for participation in the vessel's strength, the base material is at least to satisfy the requirements for corresponding hull materials. If the plates are intended for boilers or pressure vessels, the base material shall at least to satisfy the requirements for materials for such components.

Work's certificate stating chemical composition shall be supplied by the manufacturer.

C. Cladding Metal

C 100 General

101 The thickness of the cladding metal is subject to approval in each case.

C 200 Chemical composition

201 Cladding metal of austenitic stainless steel shall be delivered either with a low carbon content, i.e. maximum 0.03%, or it shall be stabilized as stated in Sec.2 Table D1 for steel NV 321 and NV 347. Other stainless steels, nickel and nickel-base alloys will be accepted, when they are suited for the intended service.

202 Works' certificate shall be supplied by the manufacturer. The manufacturer shall guarantee that the analysis complies with the requirements of the specification. Check analysis shall be made if required by the Society.

D. Testing

D 100 General

101 Tensile and bend test pieces shall be of the flat type. The test pieces are normally to have the full thickness of the plate. Where the thickness of the plate is more than 50 mm, or if necessary for the capacity of the testing machine, the thickness of the test piece may be reduced by machining. On single clad plates, both sides of the test piece shall be machined to maintain the same ratio of cladding metal to base steel as in the plate, but the cladding metal need not be reduced to less than 3

mm. Test pieces of double clad plates may be reduced by dividing. In this case, both halves shall be tested. Impact test pieces, if any, shall be taken from the base material.

D 200 Tensile testing

201 One set of tensile tests consists of two tests:

One test from the full clad plate which shall have a tensile strength R_m not less than derived from the following formula:

$$R_m = \frac{S_1 R_{m1} + S_2 R_{m2}}{S} \quad (\text{N/mm}^2)$$

R_{m1} = minimum tensile strength of base metal
 R_{m2} = minimum tensile strength of the cladding metal
 S = nominal thickness of the clad plate = $S_1 + S_2$
 S_1 = nominal thickness of the base metal
 S_2 = nominal thickness of the cladding metal

One test of the base metal after removal of the cladding metal. The test shall satisfy the requirements for the base material.

202 From hull steel, one set of tensile tests shall be taken from every fifth plate, and at least one set from each cast and each thickness interval (see Sec.1 E200). From steel for pressure vessels, one set of tensile tests shall be taken from each plate.

D 300 Impact testing

301 If impact tests are required, they shall comply with the requirements specified for the base material in each case.

D 400 Bend testing

401 The bend test pieces shall be bent 180°C around a former without showing signs of cracking or loosening of the cladding metal from the base material. The diameter of the former shall be twice the plate thickness when the tensile strength of the plate is less than 490 N/mm², and three times the thickness of the plate when the tensile strength is more than 490 N/mm². Two bend tests shall be taken from each plate. On single clad plates, one test piece shall be bent with the cladding in tension and the other with the cladding in compression. On double clad plates, the test pieces shall be bent, so that both cladding metals are tested both ways.

D 500 Shear testing

501 If a shear test is required to decide the shear strength between the base and the cladding metal, one shear test shall be made from each plate in accordance with ASTM A 264. The shear strength shall be at least 140 N/mm².

D 600 Ultrasonic testing

601 To check the bonding, ultrasonic testing shall be made. If bonding defects are found, their extent shall be clearly marked and reported to the surveyor. Rules for repairs are given in E100 and E203. The area adjacent to the edges of each plate shall be checked 100% for a width of at least 50 mm. Further tests shall be made at points equally distributed on the surface with maximum intervals of 150 mm.

D 700 Corrosion testing

701 If it is required to determine the resistance of the cladding metal against intergranular corrosion, testing shall be carried out according to ASTM A 262, Practice E (Copper — Copper Sulphate — Sulfuric Acid Test) or another recognised standard.

Guidance note:

By adding approximately 50 gram electrolytic copper to 1000 millilitres solution, the boiling time can be reduced to 15 hours. The base material shall be removed before the testing.

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

D 800 Inspection — tolerances

801 Each plate shall be surveyed before delivery. The plates shall satisfy the requirements for minus tolerances on thickness as stipulated in Sec.2 F200. The thickness control shall be carried out by the manufacturer and the results submitted to the surveyor.

E. Repair and Rejection

E 100 Surface defects

101 Minor surface defects and bonding defects which do not exceed the limits specified in 203, may be repaired by means of welding. Bonding defects along the edges shall be repaired. Before welding, the defects shall be reported to the surveyor for approval of the repair.

Approved filler metal and welding processes shall be used.

E 200 Rejection

201 If one of the mechanical tests does not satisfy the specified requirements, two new tests may be taken, both of which have to satisfy the requirements.

202 If the results of the chemical analysis deviate from the specifications, the results shall be submitted to the Society for a decision as to whether the plates will be accepted, or not.

203 The plate will be rejected if:

- a repair will cause a weakening of the plate.
- a bonding defect exceeds 4 dm² for plates up to 15 mm in thickness and 8 dm² for plates over 15 mm or several bonding defects amounting to more than 2% of the surface of the plate revealed.

F. Identification of Materials

F 100 Branding

101 The plates shall be marked according to the directions given in Ch.1 Sec.1. On single clad plates, the marking for both the base and cladding metal shall be stamped on the surface of the base plate. On double clad plates, all marking is done with a colour seal rather than by stamping.

SECTION 4 STEEL PIPES

A. General Requirements

A 100 Scope

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

102 Pipes shall be in accordance with recognised standards, as given in B to E, provided that supplementary requirements contained herein and in B to E are also met. Recognition of other standards is subject to submission to the Society for evaluation.

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

104 Where required by the relevant design and construction parts of the rules, pipes shall comply with the requirements of Ch. 1 and this section.

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

A 200 Manufacture

201 All pipes delivered with NV or works certificate shall be made by works approved by the Society. The steel used shall be made by works approved by the Society.

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

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

A 300 Chemical composition

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

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

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

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

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

A 400 Heat treatment

401 The pipes shall be supplied in a condition in accordance with the requirements of the relevant standard. Unless other-

wise required by the standard, hot finished or as-welded pipes need not be heat treated.

A 500 Mechanical testing

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

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

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

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

A 600 Leak tightness testing

601 Each pipe shall be subjected to a hydraulic test or an approved non-destructive test for leak tightness in accordance with the requirements of the relevant standard. Unless stricter requirements are specified in the standard, the testing shall be as given in 602.

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

A 700 Inspection

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

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

A 800 Repair

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

A 900 Identification

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

A 1000 Certification

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

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

ments specified.

B. Pressure Pipes

B 100 Scope

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

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

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

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

B 200 Manufacture

201 Pipes for class I and II pressure systems, as defined in Pt.4 Ch.6, shall be manufactured by any of the following methods:

- hot finished seamless
- cold finished seamless
- electric resistance or induction welded, see A203
- cold finished electric resistance or induction welded, see A203
- electric fusion welded, see A203.

C. Stainless Steel Pipes

C 100 Scope

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

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

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

C 200 Manufacture

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

- hot finished seamless
- cold finished seamless
- electric resistance or induction welded, see A203
- cold finished electric resistance or induction welded, see A203
- electric fusion welded, see A203.

C 300 Mechanical testing

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

C 400 Corrosion testing

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

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

D. Pipes for Low-temperature Service

D 100 Scope

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

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

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

D 200 Manufacture

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

- hot finished seamless
- cold finished seamless
- electric resistance or induction welded, see A203
- cold finished electric resistance or induction welded, see A203
- electric fusion welded, see A203.

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

D 300 Mechanical testing

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

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

E. Boiler and Superheater Tubes

E 100 Scope

101 These requirements are supplementary to A and apply to

carbon and carbon-manganese and alloy steel tubes for use in boilers, superheaters and heat exchangers.

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

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

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

E 200 Manufacture

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

- hot finished seamless
- cold finished seamless
- electric resistance or induction welded, see A203
- cold finished electric resistance or induction welded, see A203.

F. Piping Fittings

F 100 Scope

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

102 Fittings shall be in accordance with recognised standards, as given in 103. Recognition of other standards is subject to submission to the Society for evaluation.

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

EN 10253
ASTM A234, A403, A420, A744, A815, A960, A961

DIN 2605, DIN 2609, DIN 2615, DIN 2616, DIN 2617
JIS B2312, JIS B2313, JIS B2316.

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

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

F 200 Materials and manufacture

201 Materials for fittings shall consist of plates, seamless or welded pipes. The material used for fittings delivered with NV or works certificate shall be made by works approved by the Society.

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

F 300 Testing and inspection

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

F 400 Certification

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

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

SECTION 5 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 hulls, equipment, machinery, boilers, pressure vessels and piping systems. These requirements are also applicable to semi-finished rolled or forged products for forging stock and to rolled bars used for the manufacture (by machining operations only) of shafts, bolts, studs and other components of similar shape, as well as forgings from which blanks for various components may be cut out.

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

103 As an alternative to 102, materials which comply with national or proprietary specifications may be accepted provided such specifications give reasonable equivalence to the requirements of A or are especially approved. As a minimum the following particulars shall be specified: manufacturing process, chemical composition, heat treatment, mechanical properties and non-destructive testing. For machinery components, see also Pt.4 Ch.2 Sec.3.

104 Subsections A, C, D and E contain requirements applicable to general certification of materials. However, for components that shall be certified according to Pt.4 Ch.2, Ch.3, Ch.4 and Ch.5, the requirements in these chapters prevail.

A 200 Grading system

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

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

Guidance note:

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

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A 300 Manufacture

301 All forgings delivered with NV or works certificate shall be made at works approved by the Society. Forges without own steel making may only use starting material supplied by works approved by the Society. Special approval is required for the manufacture of clean steel forgings for machinery components, e.g. crankshafts and gearing, where higher stresses are allowed for design purposes. See also 309.

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

303 For forgings with specified minimum ultimate tensile strength 800 N/mm² or above, the molten steel shall be vacuum treated prior to or during pouring of the ingot in order to remove objectionable gases, particularly hydrogen and oxygen, and improve steel cleanliness. Other processes may be accepted provided adequate cleanliness is documented.

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

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

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

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

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

307 For crankshafts, 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 special approval by the Society. In such cases, tests will be required to demonstrate that satisfactory mechanical properties and grain flow are obtained.

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

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

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

A 400 Chemical composition

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

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

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

A 500 Heat treatment

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

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

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

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

505 All hot forming operations shall be conducted prior to the final heat treatment. If for any reasons a forging is subsequently heated for further hot forming, the forging shall be re-heat treated.

506 If a forging is locally reheated or any straightening operation is performed after the final heat treatment, consideration shall be given to a subsequent stress relieving heat treatment. For machinery parts all straightening operations are subject to approval by the Society.

A 600 Test material and test pieces for mechanical testing

601 Test material, from which test pieces are taken, shall be integral with the forging except as provided in 603. Test material shall be provided by prolongation or extensions with a cross-sectional area of not less than that part of the forging which it represents. For ring or disk-like forgings, test material shall be provided by increasing the diameter, thickness, or length of the forging.

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

603 Where batch testing is permitted according to 700, the test material may alternatively be a production part or separately forged. Separately forged test material shall have a cross-section and a reduction ratio similar to that used for the forgings represented.

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

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

Longitudinal test: longitudinal axis of test piece parallel to the

principal direction of fibre deformation.

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

Tangential test: longitudinal axis of test piece perpendicular to a plane containing the axis of the product and tangent to a circle drawn with a point on the axis of the product as a centre.

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

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

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

608 The preparation of test pieces and the procedures used for mechanical testing shall comply with the relevant requirements of Ch.1.

A 700 Test units and number of tests

701 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.

702 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.

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

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

- 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.

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

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

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

A 800 Mechanical properties

801 The material shall meet the mechanical properties specified in B to H.

802 If the results do not meet the specified requirements, the re-test procedures in Ch.1 may be adopted. Where the forgings and test material are submitted to re-heat treatment, they may

not be re-austenitised or solution treated more than twice. All the tests previously performed shall be repeated after re-heat treatment and the results must meet the specified requirements.

A 900 Inspection

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

902 Forgings for which certification by the Society is required shall be presented to the surveyor for visual inspection.

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

904 Forgings are subject to non-destructive testing where specified in B to H. For non-destructive testing of finished machined components, see the relevant construction rules. 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.:

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

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

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

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

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

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

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

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

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

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.

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

907 Where UT is specified, the tests shall be carried out after the final heat treatment when the forgings have been machined

to a condition suitable for UT, but prior to drilling of bores and prior to surface hardening. Both radial and axial scanning shall be carried out when appropriate for the shape and dimensions of the forging being tested.

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

909 The extent of non-destructive testing and acceptance criteria shall be agreed with the Society. For forgings, IACS Recommendation No. 68 is regarded as an example of an acceptable standard. For machinery forgings, the requirements stated in Pt. 4 Ch.2 apply.

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

A 1000 Repair

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

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

1003 Repair welding of forgings except crankshaft forgings may be permitted subject to prior approval of the Society. 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 approval.

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

A 1100 Identification

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

- a) Identification number, heat number or other marking which will enable the full history of the forging to be traced.
- b) DNV's certificate number, where applicable and as furnished by the surveyor.
- c) Test pressure, where applicable.

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

A 1200 Certification

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

- a) Purchaser's name, order number and vessel identification, where known.

- b) Manufacturer's name.
- c) Description of forgings and steel quality.
- d) Identification marking of forgings.
- e) Steel making process, heat number and chemical composition.
- f) Details of heat treatment, including temperatures and holding times.
- g) Results of mechanical tests.
- h) Results of non-destructive tests, where applicable.
- i) Test pressure, where applicable.
- j) Results of any supplementary and additional test requirements specified.

- 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 Society.

B 400 Mechanical testing

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

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

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

B 500 Inspection

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

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

B. Forgings for Hull Structures and Equipment

B 100 Scope

101 These requirements are supplementary to A and apply to steel forgings intended for hull structures and equipment such as rudder stocks, pintles, rudder coupling bolts and anchors. Provision is made for carbon and carbon-manganese and alloy steel grades suitable for assembly by welding or for clad welding.

B 200 Chemical composition

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

B 300 Heat treatment

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

Table B1 Chemical composition limits ¹⁾ for steel forgings for hull structures and equipment ²⁾

Steel type	C	Si	Mn	P	S	Cr ³⁾	Mo ³⁾	Ni ³⁾	Cu ³⁾	Total residuals
C and C-Mn	0.23	0.45	0.30 - 1.50	0.035	0.035	0.30	0.15	0.40	0.30	0.85
Alloy	0.25	0.45	0.30 - 1.00	0.035	0.030	Minimum 0.40 ⁴⁾	Minimum 0.15 ⁴⁾	Minimum 0.40 ⁴⁾	0.30	-

1) Composition in percentage mass by mass maximum unless shown as a range or as a minimum.
2) Forgings not intended for welding may be supplied to the composition limits given in Table C1.
3) Elements are considered as residual elements unless shown as a range or as a minimum.
4) One or more of the elements shall comply with the minimum content.

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

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

1) Testing at +20°C may be accepted subject to compliance with a specified minimum average energy of 45 J longitudinal or 30 J transverse for all grades.

l = longitudinal, t = transverse

C. Forgings for Shafting and Machinery

C 100 Scope

101 These requirements are supplementary to A and apply to steel forgings intended for shafting and machinery construction which are not within the scope of D and E. Provision is made for carbon and carbon-manganese steels and alloy steels.

C 200 Chemical composition

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

C 300 Heat treatment

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

- Fully annealed.
- Normalised
- Normalised and tempered at a temperature of not less than 550°C.
- Quenched and tempered at a temperature of not less than 550°C.

302 Alloy steel 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 Society.

C 400 Mechanical testing

401 Longitudinal tests shall be made but, at the discretion of the manufacturer, alternative tests as shown in Figs. 1 to 3 may be used. For shafts with keyways, splines, radial holes, slots etc., tangential tests shall be made provided the shape and dimensions make it possible.

402 The mechanical properties shall comply with the values given in Table C2 appropriate to the specified minimum tensile strength or, where applicable, the requirements of the approved specification.

403 Forgings may be supplied to any specified minimum tensile strength within the general limits given in Table C2 but subject to any restrictions of the relevant construction rules. Where it is proposed to use a steel with a specified minimum tensile strength intermediate to those given in Table C2, corresponding minimum values for the other properties may be obtained by interpolation.

C 500 Inspection

501 Magnetic particle or liquid penetrant testing of finished machined forgings shall be carried out as specified in the relevant construction rules.

vant construction rules.

502 Ultrasonic testing of forgings shall be carried out as specified in the relevant construction rules.

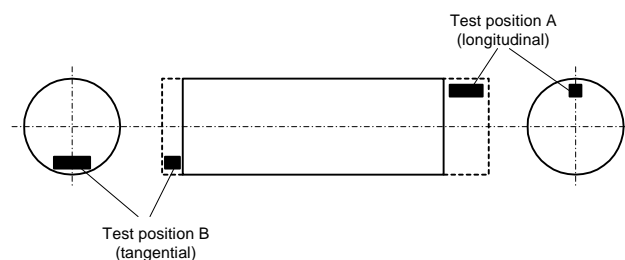


Fig. 1
Plain shaft

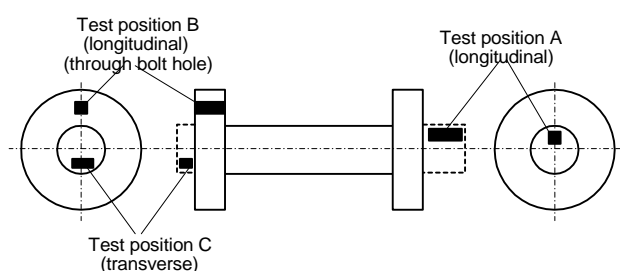


Fig. 2
Flanged shaft

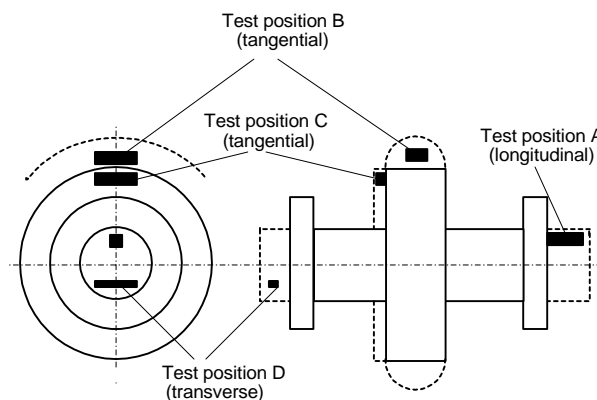


Fig. 3
Flanged shaft with collar

Table C1 Chemical composition limits ¹⁾ for steel forgings for shafting and machinery ²⁾

Steel type	C	Si	Mn	P	S	Cr ³⁾	Mo ³⁾	Ni ³⁾	Cu ³⁾	Total residuals
C and C-Mn	0.65	0.45	0.30 - 1.50	0.035	0.035	0.30	0.15	0.40	0.30	0.85
Alloy	0.45	0.45	0.30 - 1.00	0.035	0.035	Minimum 0.40 ⁴⁾	Minimum 0.15 ⁴⁾	Minimum 0.40 ⁴⁾	0.30	-

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

2) Other specifications may also be approved, see A103. Forgings intended for welding shall comply with the composition limits given in Table B1.

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

4) One or more of the elements shall comply with the minimum content.

Table C2 Mechanical properties for steel forgings for shafting and machinery											
Steel type	Tensile strength R_m minimum (N/mm ²)	Yield stress R_e minimum (N/mm ²)	Elongation A_5 minimum (%)			Reduction of area Z minimum (%)			Charpy V-notch ^{1) 2)} Energy (J)		
			l	ta	t	l	ta	t	l	ta	t
C and C-Mn	400	200	26	22	19	50	43	35	-	-	-
	440	220	24	20	18	50	43	35	-	-	-
	480	240	22	19	16	45	38	30	-	-	-
	520	260	21	18	15	45	38	30	-	-	-
	560	280	20	17	14	40	34	27	-	-	-
	600	300	18	15	13	40	34	27	-	-	-
	640	320	17	14	12	40	34	27	-	-	-
	680	340	16	14	12	35	30	24	-	-	-
	720	360	15	13	11	35	30	24	-	-	-
	760	380	14	12	10	35	30	24	-	-	-
Alloy	600	360	18	16	14	50	43	35	41	31	24
	700	420	16	14	12	45	38	30	32	24	22
	800	480	14	12	10	40	34	27	32	24	22
	900	630	13	11	9	40	34	27	27	22	18
	1000	700	12	10	8	35	30	24	25	19	16
	1100	770	11	9	7	35	30	24	21	15	13

1) Testing shall be carried out at +20°C.
2) For propeller shafts intended for ships with class notations covered under "Arctic or Icebreaking Service", in accordance with Pt.5 Ch.1 Sec.4, Charpy V-notch impact testing shall be carried out in the longitudinal direction for all steel types at minus 10°C and the average energy value shall be minimum 27 J.
 l = longitudinal, t = transverse, ta = tangentially

D. Forgings for Crankshafts

D 100 Scope

101 These requirements are supplementary to A and apply to steel forgings intended for crankshafts. Provision is made for carbon and carbon-manganese steels and alloy steels. Special requirements for clean steel forgings are given in A300.

D 200 Chemical composition

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

D 300 Heat treatment

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

- Normalised and tempered at a temperature of not less than 550°C.
- Quenched and tempered at a temperature of not less than 550°C.

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

D 400 Mechanical testing

401 For solid forged crankshafts, one set of longitudinal tests shall be taken from the driving shaft end of each forging (test position A in Fig. 4). Where the mass, as heat treated but excluding test material, exceeds 3 tonnes, a second set of tests shall be taken from the opposite end (test position B in Fig. 4).

402 For crankthrow forgings and other forgings where the method of manufacture has been especially approved in accordance with A300, the number and position of the tests shall be agreed.

403 Forgings with mass up to 500 kg each may be batch tested in accordance with A700. For quenched and tempered forgings, two sets of mechanical tests are required for each test unit.

404 The mechanical properties shall comply with the values given in Table C2 appropriate to the specified minimum tensile strength or, where applicable, the requirements of the approved specification.

405 For forgings which have been batch tested, hardness tests shall be made on at least 10% of the forgings.

D 500 Inspection

501 Magnetic particle or liquid penetrant testing of finished machined crankshafts shall be carried out as specified in Pt.4 Ch.3 Sec.1.

502 Ultrasonic testing of crankshafts shall be carried out as specified in Pt.4 Ch.3 Sec.1.

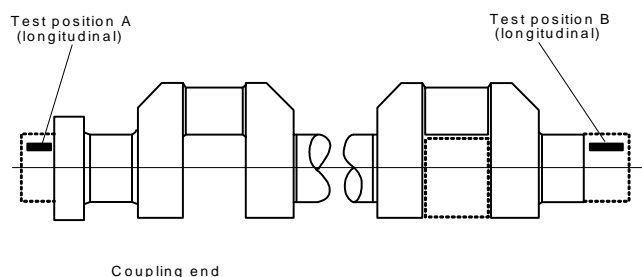


Fig. 4
Solid forged crankshaft

E. Forgings for Gearing

E 100 Scope

101 These requirements are supplementary to A and apply to steel forgings intended for use in the construction of gearing.

Provision is made for carbon and carbon-manganese steels and alloy steels. Special requirements for clean steel forgings are given in A300.

102 Heat treatment and/or mechanical testing may be performed by the forge or the gear manufacturer.

E 200 Chemical composition

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

E 300 Heat treatment

301 Carbon and carbon-manganese steel forgings not intended for carburising shall be supplied in one of the following conditions:

- Normalised and tempered at a temperature of not less than 540°C.
- Quenched and tempered at a temperature of not less than 540°C.

302 Alloy steel forgings not intended for carburising shall be quenched and tempered at a temperature of not less than 540°C.

303 Forgings for gears which shall be carburised shall be supplied in either the fully annealed or the normalised and tempered condition. Forgings for gears which shall be induction hardened or nitrided shall be heat treated at an appropriate stage (generally by quenching and tempering). Requirements for surface hardening are given in the relevant construction rules.

E 400 Mechanical testing of forgings not intended for carburising

401 Pinions

Where the finished machined diameter of the toothed portion exceeds 200 mm, tangential tests shall be taken adjacent to the toothed portion (test position B in Fig. 5). Where the dimensions preclude the preparation of tests from this position, transverse tests shall be taken from the end of the journal (test position C in Fig. 5). If, however, the journal diameter is 200 mm or less, longitudinal tests shall be taken (test position A in Fig. 5). Where the finished length of the toothed portion exceeds 1250 mm, tests shall be taken from each end.

402 Small pinions

Where the finished diameter of the toothed portion is 200 mm or less, longitudinal tests shall be taken from the end of the journal (test position A in Fig. 5).

403 Gear wheels

Tangential tests shall be taken (test position A in Fig. 6). Where the finished diameter exceeds 2 500 mm tests shall be taken from two diametrically opposite positions.

404 Gear wheel rims (made by expanding)

Tangential tests shall be taken (from one of the test positions A in Fig. 7). Where the finished diameter exceeds 2500 mm or the mass (as heat treated but excluding test material) exceeds 3 tonnes, tests shall be taken from two diametrically opposite positions.

405 Hollow pinions

Tangential tests shall be taken (test position A in Fig. 8). Where the finished length of the toothed portion exceeds 1250 mm, tests shall be taken from each end.

406 Batch testing of small forgings

For forgings which have been batch tested in accordance with A700, at least one hardness test shall be made on each forging. The variation in hardness in each batch shall not exceed 30 Brinell Hardness numbers.

407 The mechanical properties shall comply with the values given in Table C2 appropriate to the specified minimum tensile strength or, where applicable, the requirements of the approved specification.

E 500 Testing of forgings for carburising applications

501 When forgings shall be carburised after machining, sufficient test material shall be provided for final tests after completion of carburising and hardening, as agreed with the purchaser.

502 Requirements for measurement of case depth and other characteristics are given in the relevant construction rules.

E 600 Inspection

601 Magnetic particle or liquid penetrant testing of finished machined forgings shall be carried out as specified in Pt.4 Ch.4 Sec2.

602 Ultrasonic testing of forgings shall be carried out as specified in Pt.4 Ch.4 Sec2.

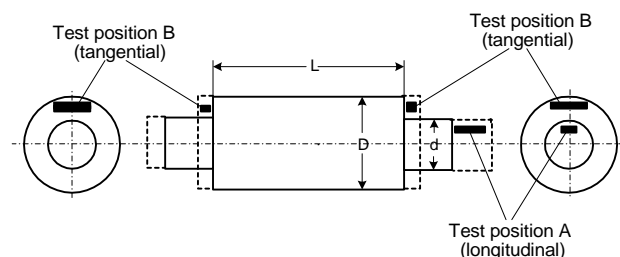


Fig. 5
Pinion

- L = length of toothed portion
 D = diameter of toothed portion
 d = journal diameter

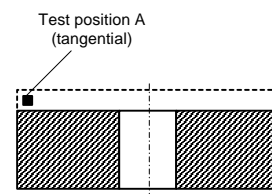


Fig. 6
Gear wheel

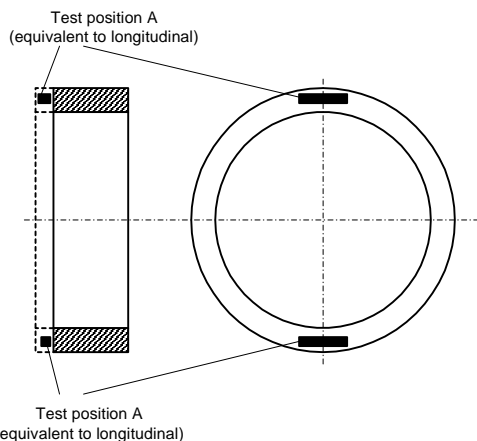


Fig. 7
Gear rim (made by expanding)

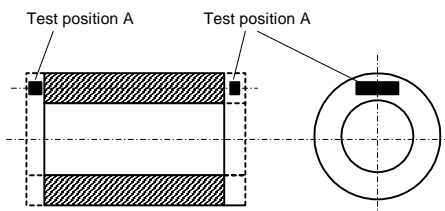


Fig. 8
Hollow pinion

F. Forgings for Boilers, Pressure Vessels and Piping Systems

F 100 Scope

101 These requirements are supplementary to A and apply to steel forgings intended for boilers, pressure vessels and piping systems where the design temperature is not lower than 0°C. Provision is made for carbon and carbon-manganese steels and

alloy steels.

F 200 Chemical composition

201 The chemical composition shall comply with the overall limits given in Table F1 or, where applicable, the requirements of the approved specification.

F 300 Heat treatment

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

- Normalised.
- Normalised and tempered at a temperature of not less than 550°C.
- Quenched and tempered at a temperature of not less than 550°C.

302 Alloy steel forgings shall be normalised and tempered or 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 Society.

F 400 Mechanical properties

401 The mechanical properties shall comply with the values given in Table F2 or, where applicable, the requirements of the approved specification.

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

F 500 Inspection

501 Quenched and tempered forgings are subject to magnetic particle testing, see A906 and Pt.4.

502 Normalised forgings with mass 1000 kg or more and quenched and tempered forgings with mass 500 kg or more are subject to ultrasonic testing.

F 600 Pressure testing

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

Table F1 Chemical composition limits ¹⁾ for steel forgings for boilers, pressure vessels and piping systems

Steel type	C	Si	Mn	P	S	Cr ²⁾	Mo ²⁾	Ni ²⁾	Cu ²⁾	Al ³⁾	Total residuals
C and C-Mn	0.23	0.15-0.40	0.50-1.60	0.030	0.030	0.30	0.15	0.40	0.30	0.02-0.05	0.85
½Mo	0.23		0.50-0.90	0.030	0.030	0.30	0.45-0.65	0.40	0.30	0.02	-
1Cr ½Mo	0.20		0.30-0.80	0.030	0.030	0.80-1.25	0.45-0.65	0.40	0.30		-
2¼Cr 1Mo	0.15	0.50	0.30-0.80	0.030	0.030	2.00-2.50	0.90-1.20	0.40	0.30		-
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) Aluminium total content.											

Table F2 Mechanical properties for steel forgings for boilers, pressure vessels and piping systems

Steel type	Grade	Yield stress <i>R_e</i> minimum (N/mm ²)	Tensile strength <i>R_m</i> (N/mm ²)	Elongation <i>A₅</i> minimum (%)	Reduction of area <i>Z</i> minimum (%)
C and C-Mn	450H	240	450 - 600	22	35
	490H	275	490 - 640	18	30
½Mo	-	275	480 - 630	18	35
1Cr ½Mo	-	275	480 - 630	18	35
2 ¼Cr 1Mo, Normalised	-	315	520 - 670	18	35
2 ¼Cr 1Mo, QT	-	380	580 - 730	16	35

G. Ferritic Steel Forgings for Low Temperature Service

G 100 Scope

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

G 200 Chemical composition

201 The chemical composition shall comply with the overall limits given in Table G1 or, where applicable, the requirements of the approved specification.

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

G 300 Heat treatment

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

- Normalised.
- Normalised and tempered at a temperature of not less than

550°C.

- Quenched and tempered at a temperature of not less than 550°C.

302 Alloy steel forgings shall be normalised and tempered, double normalised and tempered, or quenched and tempered at a temperature of not less than 550°C.

G 400 Mechanical properties

401 The mechanical properties shall comply with the values given in Table G2 or, where applicable, the requirements of the approved specification.

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

G 500 Inspection

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

502 Normalised forgings with mass 1000 kg or more and quenched and tempered forgings with mass 500 kg or more are subject to ultrasonic testing.

G 600 Pressure testing

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

Table G1 Chemical composition limits ¹⁾ for ferritic steel forgings for low temperature service

Table G1 Chemical composition limits for ferritic steel forgings for low temperature service											
Steel type	C	Si	Mn	P	S	Cr ²⁾	Mo ²⁾	Ni	Cu ²⁾	Al ³⁾	Total residuals
C and C-Mn	0.23	0.15 - 0.35	0.60 - 1.50	0.030	0.030	0.40	0.10	0.80	0.30	0.02 - 0.05	0.60
3 ½ Ni	0.20		0.30 - 0.90			0.025	0.025	0.25			0.08
5 Ni	0.12			4.70 - 5.30							
9 Ni	0.10			8.50 - 10.0							
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) Aluminium total content. Other grain refining elements may be used for carbon and carbon-manganese steel, see 200.											

Table G2 Mechanical properties for ferritic steel forgings for low temperature service

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

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

H. Stainless Steel Forgings

H 100 Scope

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

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

H 200 Manufacture

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

H 300 Mechanical properties

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

H 400 Inspection

401 Forgings with mass 1000 kg or more are subject to ultrasonic testing.

SECTION 6 BARS FOR CHAIN CABLES

A. General

A 100 Scopes

101 This Section specifies the requirements for steel intended for chain cable links and accessories (shackles, swivels etc.).

A 200 Steel grades

201 Three steel grades are specified:
NV K1, NV K2, NV K3.

A 300 Chemical composition

301 The chemical composition of ladle samples shall comply

with the approved specification. For the steel grades NV K1, NV K2 and NV K3 the overall limits given in Table A1 apply.

A 400 Mechanical properties

401 The mechanical properties shall comply with the requirements given in Table A1.

A 500 Heat treatment

501 The requirements for heat treatment given in Table A1 apply to finished chain cable and accessories. Material intended for such application may be delivered without the heat treatment stipulated.

Table A1 Material requirements for bars for chain cables

Grade			NV K1	NV K2	NV K3
Deoxidation and fine-grain treatment			Killed	Killed, fine-grain treated with Al	Killed, fine-grain treated
Heat treatment			Normalised ³⁾	Normalised	Quenched and tempered, normalised or normalised and tempered ²⁾
Chemical composition	Silicon	%	0.15 - 0.35	0.15 - 0.55	0.15 - 0.55
	Phosphorus	%	Maximum 0.040	Maximum 0.035	Maximum 0.035
	Sulphur	%	Maximum 0.040	Maximum 0.035	Maximum 0.035
	Nitrogen	% ¹⁾	Maximum 0.009	Maximum 0.015	Maximum 0.009
Mechanical properties	Yield stress R_{eH} or proof stress $R_{p0.2}$ (N/mm ²)			Minimum 295	Minimum 410
	Tensile strength, R_m (N/mm ²)		370 - 490	490 - 690	Minimum 690
	Elongation ($L_0 = 5d$) A_5 (%)		Minimum 25	Minimum 22	Minimum 17
	Reduction of area, Z (%)				Minimum 40
	Impact values (KV), as an average of 3 tests, (J)		Minimum 27; 20°C	Minimum 27; 0°C	Minimum 60; 0°C

- 1) If Al or another strong nitride former is present in sufficient quantity, a N-content of maximum 0.015% is accepted.
- 2) When chain cables are delivered as normalised, or normalised and tempered, the steel shall be fine-grain treated with Al. For such material a maximum content of 0.015% N is accepted.
- 3) Chain cables with diameters up to 50 mm may be supplied without heat treatment after welding, provided that the links are produced by hot forming and that a breaking test is carried out on one piece from each 27.5 m length.

B. Testing

B 100 Number of tests

101 One set of tests (1 tensile and 3 impact test pieces) shall be taken for every 50 ton or fraction thereof of bar material from the same cast. The tests shall be taken from the bar of the largest diameter.

Test material from bars shall be heat-treated in full diameter and in a manner simulating the treatment applied to the finished cable.

B 200 Impact testing

201 The impact test pieces shall be cut as shown in Fig. 1. The tests shall satisfy the requirements stated in Table A1.

C. Identification of Materials

C 100 Marking

101 The minimum markings required for the bars are the manufacturer's brand mark, the steel grade and an abbreviated symbol of the cast.

Bars having diameter of up to and including 40 mm combined into bundles, may be marked on permanently affixed labels.

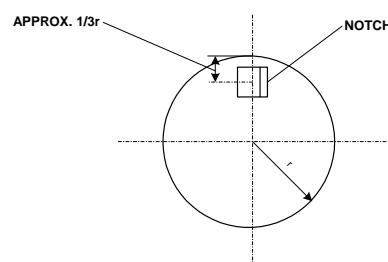


Fig. 1
Position of impact test piece.

SECTION 7 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 hulls, equipment, machinery, boilers, pressure vessels and piping systems.

102 Where required by the relevant design and construction parts of the rules, steel castings shall comply with the requirements of Ch.1, the general requirements of A and the appropriate specific requirements of B to G. If the specific requirements differ from the general requirements, the specific requirements shall prevail.

103 As an alternative to 102, materials which comply with national or proprietary specifications may be accepted provided such specifications give reasonable equivalence to the requirements of Sec.7 or are approved for each specific application. As a minimum the following particulars shall be specified: manufacturing process, chemical composition, heat treatment, mechanical properties and non-destructive testing. For machinery components, see also Pt.4 Ch.2 Sec.3.

A 200 Grading system

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

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

Guidance note:

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

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A 300 Manufacture

301 All castings delivered with NV or works certificate shall be made at foundries approved by the Society.

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

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

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

A 400 Chemical composition

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

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

403 Elements designated as residual elements in the individual specifications shall not be intentionally added to the steel.

The content of such elements shall be reported.

A 500 Heat treatment

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

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

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

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

A 600 Test blocks and test pieces for mechanical testing

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

602 In the case of castings of the same type under 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.

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

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

605 The preparation of test pieces and the procedures used for mechanical testing shall comply with the relevant requirements of Ch.1.

A 700 Test units and number of tests

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

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

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

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

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

A 800 Mechanical properties

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

802 If the results do not meet the specified requirements, the re-test procedures of Ch.1 may be adopted. Where the castings and test blocks are submitted to re-heat treatment, they may not be solution treated or re-austenitised more than twice. All the tests previously performed shall be repeated after re-heat treatment and the results must meet the specified requirements.

A 900 Inspection

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

902 Castings for which certification by the Society is required shall be presented to the surveyor for visual inspection. The surveyor may require areas to be etched for the purpose of investigating weld repairs.

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

904 Castings are subject to non-destructive testing where specified in B to G. 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.:

- a) Magnetic particle testing (MT): ASTM E709, using wet continuous method.
- b) Liquid penetrant testing (PT): ISO 3452, ASTM E165.
- c) Ultrasonic testing (UT): ASTM A609.
- d) Radiographic testing (RT): ISO 5579, ASTM E94.

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

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

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

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

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

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

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

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

Guidance note:

Where a casting is delivered in the as-cast or rough condition for subsequent processing and final MT or PT by the purchaser, the foundry should perform suitable intermediate inspections taking into consideration the quality level required in finished condition.

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

- 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.

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

909 Unless otherwise required 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.

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

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

A 1000 Repair

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

1002 Where the repair entails removal of more than 10% of the thickness or 15 mm, whichever is smaller, the defective area shall be repaired by welding. Shallow defective areas (see 1001) may also be repaired by welding. The excavations shall be suitably shaped to allow good access for welding. The resulting grooves shall be subsequently ground smooth and complete elimination of the defective material shall be verified by MT or PT.

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

- the depth of the groove prepared for welding exceeds 25%

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

All other weld repairs are considered minor.

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

1005 Minor weld repairs do not require the approval of the Society 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 surveyor on request.

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

1007 The welding consumables used shall be of a suitable composition giving a weld deposit with mechanical properties at least similar to those of the parent castings. Only approved low hydrogen consumables shall be used. Welding consumables shall be stored and handled so as to maintain the hydrogen classification and in accordance with the manufacturers recommendations.

1008 When repair welding is done after the casting has been heat treated for mechanical properties, the repaired casting shall be given a furnace stress relieving heat treatment. Subject to prior approval, however, local stress relieving heat treatment may be accepted for minor repairs. Special consideration may be given to the omission of stress relieving heat treatment for minor repairs in areas of low operating stress and provided that the combination of material and welding procedure is such that tensile residual stresses and hardness are minimised.

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

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

A 1100 Identification

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

- a) Heat number or other marking which will enable the full history of the casting to be traced.
- b) DNV's certificate number, where applicable and as furnished by the surveyor.
- c) Test pressure, where applicable.

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

A 1200 Certification

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

- a) Purchaser's name, order number and vessel identification, where known.

- b) Manufacturer's name.
- c) Description of castings and steel quality.
- d) Identification marking of castings.
- e) Steel making process, heat number and chemical composition.
- f) Details of heat treatment, including temperatures and holding times.
- g) Results of mechanical tests.
- h) Results of non-destructive tests, where applicable.
- i) Test pressure, where applicable.
- j) Results of any supplementary and additional test requirements specified.

B. Castings for Hull Structures and Equipment

B 100 Scope

101 The requirements in B are supplementary to A and apply to steel castings for hull structures and equipment such as stem, stern frames, rudder members, propeller shaft supports and anchors. 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 approval of the design for which the material is proposed.

B 200 Chemical composition

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

B 400 Mechanical properties

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

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

B 500 Inspection

501 The castings are subject to magnetic particle (see A906)

and ultrasonic testing.

Table B1 Chemical composition limits ¹⁾ for steel castings for hull structures and equipment ²⁾											
<i>Steel type</i>	<i>C</i>	<i>Si</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Cr ³⁾</i>	<i>Mo ³⁾</i>	<i>Ni ³⁾</i>	<i>Cu ³⁾</i>	<i>V ³⁾</i>	<i>Total residuals</i>
C and C-Mn	0.23 ⁴⁾	0.60	0.50 - 1.60	0.040	0.035	0.30	0.15	0.40	0.30	0.12	0.95
Alloy	0.25	0.60	0.50 - 1.70	0.035	0.030	Minimum 0.40 ⁵⁾	Minimum 0.15 ⁵⁾	Minimum 0.40 ⁵⁾	0.30	0.12	-
¹⁾ Composition in percentage mass by mass maximum unless shown as a range or as a minimum. ²⁾ Castings not intended for welding may be supplied to the composition limits given in Table C1. ³⁾ Elements are considered as residual elements unless shown as a range or as a minimum. ⁴⁾ An increase is permitted up to maximum 0.30% provided that the Manganese content is reduced to maximum 1.20%. ⁵⁾ One or more of the elements shall comply with the minimum content.											

Table B2 Mechanical properties for steel castings for hull structures and equipment							
<i>Steel type</i>	<i>Steel grade</i>	<i>Yield stress R_e minimum (N/mm²)</i>	<i>Tensile strength R_m minimum (N/mm²)</i>	<i>Elongation A₅ minimum (%)</i>	<i>Reduction of area Z minimum (%)</i>	<i>Charpy V-notch ¹⁾</i>	
						<i>Temperature (°C)</i>	<i>Energy (J)</i>
C and C-Mn	410 W	235	410	24	40	0	27
	450 W	255	450	22	35	0	27
	480 W	275	480	20	30	0	27
Alloy	550 W	355	550	18	30	0	32
	620 W	430	620	16	30	0	32
¹⁾ Testing at +20°C may be accepted subject to compliance with a specified minimum average energy of 45 J for all grades.							

C. Castings for Machinery

C 100 Scope

101 The requirements in C are supplementary to the requirements in A and apply to steel castings for machinery construction such as diesel engine components, gears, couplings and windlass components. Provision is made for carbon and carbon-manganese steels and alloy steels.

102 Where steel castings are intended for crankshafts or connecting rods, particulars of chemical composition, mechanical properties, heat treatment, non-destructive testing and repair shall be submitted in connection with the approval of the design for which the material is proposed.

C 200 Chemical composition

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

C 300 Heat treatment

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

- Fully annealed.
- Normalised.
- Normalised and tempered at a temperature of not less than 550°C.

- Quenched and tempered at a temperature of not less than 550°C.

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

303 Castings for components as specified in Pt.4 Ch.3 Sec.1 and any other castings where dimensional stability and freedom from internal stresses are important, shall be given a stress relief heat treatment. This shall be at a temperature not lower than 550°C, followed by furnace cooling to 300°C or lower. Alternatively, full annealing may be used provided that the castings are furnace cooled to 300°C or lower.

C 400 Mechanical properties

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

402 Where it is proposed to use a steel with a specified minimum tensile strength intermediate to those given in Table C2, corresponding minimum values for the other properties may be obtained by interpolation.

C 500 Inspection

501 The castings are subject to magnetic particle (see A906) and ultrasonic testing as specified in the relevant construction rules.

Table C1 Chemical composition limits ¹⁾ for steel castings for machinery ²⁾										
<i>Steel type</i>	<i>C</i>	<i>Si</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Cr</i> ³⁾	<i>Mo</i> ³⁾	<i>Ni</i> ³⁾	<i>Cu</i> ³⁾	<i>Total residuals</i>
C and C-Mn	0.40	0.60	0.50-1.60	0.040	0.040	0.30	0.15	0.40	0.30	0.85
Alloy	0.45	0.60	0.50-1.60	0.035	0.030	Minimum 0.40 ⁴⁾	Minimum 0.15 ⁴⁾	Minimum 0.40 ⁴⁾	0.30	-

1) Composition in percentage mass by mass maximum unless shown as a range or as a minimum.
2) Castings intended for welding shall comply with the composition limits given in Table B1.
3) Elements are considered as residual elements unless shown as a range or as a minimum.
4) One or more of the elements shall comply with the minimum content.

Table C2 Mechanical properties for steel castings for machinery							
<i>Steel type</i>	<i>Steel grade</i>	<i>Yield stress R_e minimum (N/mm²)</i>	<i>Tensile strength, R_m minimum (N/mm²)</i>	<i>Elongation A₅ minimum (%)</i>	<i>Reduction of area Z minimum (%)</i>	<i>Charpy V-notch</i>	
						<i>Temperature (°C)</i>	<i>Energy (J)</i>
C and C-Mn	410	205	410	24	38	-	-
	450	225	450	22	30	-	-
	480	240	480	20	27	-	-
	520	260	520	18	25	-	-
Alloy	550	340	550	16	35	20	32
	600	400	600	16	35	20	32
	690	490	690	13	30	20	32

D. Castings for Propellers

D 100 Scope

101 The requirements are supplementary to the requirements in A and apply to stainless steel castings for propellers, blades and bosses. These requirements may also be used for the repair of propellers damaged in service, subject to prior agreement with the Society.

D 200 Chemical composition

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

D 300 Heat treatment

301 Martensitic steel castings shall be austenitised and tempered. Austenitic steel castings shall be solution heat treated.

D 400 Mechanical testing

401 Test blocks shall be cast integral with the hub of propeller castings, or with the flange of propeller blade castings. Removal of test blocks shall be by non-thermal procedures.

402 One set of tests shall be made on material representing each casting. The mechanical properties shall comply with the values given in Table D2 or, where applicable, the requirements of the approved specification.

403 As an alternative to 401 and 402, where a number of small propellers of about the same size and less than 1 m diameter is cast from one heat and heat treated in the same furnace charge, a batch testing procedure may be adopted using separately cast test blocks. One set of tests shall be made for each multiple of five castings in the batch.

D 500 Inspection

501 The castings are subject to inspection in accordance with A900 and as given in 502 to 511.

502 In order to relate the degree of inspection to the criticality of imperfections, propeller blades are divided into three severity zones designated A, B and C. Further, a distinction is made between low skew and high skew propellers.

503 The maximum skew angle of a propeller blade is defined as the angle, in projected view of the blade, between a line drawn through the blade tip and the shaft centreline and a second line through the shaft centreline which acts as a tangent to the locus of the mid-points of the helical blade section, see Fig 1. High skew propellers have a skew angle greater than 25°, low skew propellers a skew angle of up to 25°.

504 Zone A in low skew propellers is in the area on the pressure side of the blade, from and including the fillet to 0.4 R and bounded on either side by lines at a distance 0.15 times the chord length C_R from the leading edge and 0.2 times C_R from the trailing edge respectively, see Fig. 2. Where the hub radius (R_B) exceeds 0.27 R, the other boundary of zone A shall be increased to 1.5 R_B . Zone A also includes the parts of the separate cast propeller hub that are located in the area of the windows as described in Fig.4 and the flange and fillet area of controllable pitch and built-up propeller blades as described in Fig. 5.

505 Zone B in low skew propellers is on the pressure side the remaining area up to 0.7 R and on the suction side the area from the fillet to 0.7 R, see Fig. 2.

506 Zone C in low skew propellers is the area outside 0.7 R on both sides of the blade. It also includes the surface of the hub of a monobloc propeller and all the surfaces of the hub of a controllable pitch propeller other than those designated Zone A above.

507 Zone A in high skew propellers is the area on the pressure face contained within the blade root-fillet and a line running from the junction of the leading edge with the root fillet to the trailing edge at 0.9 R and at passing through the mid-point of the blade chord at 0.7 R and a point situated at 0.3 of the chord length from the leading edge at 0.4 R. It also includes an area along the trailing edge on the suction side of the blade from the root to 0.9 R and with its inner boundary at 0.15 of the chord lengths from the trailing edge. See Fig. 3.

508 Zone B in high skew propellers constitutes the whole of the remaining blade surfaces. See Fig. 3.

509 For all propellers, separately cast blades and hubs, the surfaces covered by severity zones A, B and C are subject to PT. Testing of zone A shall be undertaken in the presence of

the surveyor whilst testing of zones B and C may be witnessed by the surveyor upon his request.

510 For the purpose of evaluating PT indications, the surface shall be divided into reference areas of 100 cm², which may be square or rectangular with the major dimension not exceeding 250 mm.

511 The indications detected may, with respect to their size and number, not exceed the values given in Table D3. Weld repairs are, independent of their location, always to be assessed according to zone A.

D 600 Repair

601 Defective castings shall be repaired in accordance with A1000 and as given in 602 to 610.

602 In general the repairs shall be carried out by mechanical means, e.g. by grinding or milling. Weld repairs shall be undertaken only when they are considered to be necessary.

603 Weld repairs require the approval of the Society before the repair is commenced. Proposals for weld repairs shall be accompanied by sketches or photographs showing the extent and positions of the repairs. Welds having an area less than 5 cm² shall be avoided.

604 Grinding in severity zone A may be carried out to an extent that maintains the blade thickness. Repair welding is generally not permitted in severity zone A and will only be allowed after special consideration.

605 Defects in severity zone B may be removed by grinding to a depth of $t/40$ mm (t is the minimum local thickness according to the rules) or 2 mm, whichever is greatest. Those defects that are deeper may be repaired by welding.

606 Repair welding is generally permitted in severity zone C.

607 Before welding is started, a detailed welding procedure specification shall be submitted covering the weld preparation, welding parameters, filler metals, preheating, post weld heat treatment and inspection procedures.

608 The scope of the welding procedure qualification test is given in 700.

609 Metal arc welding with electrodes or filler wire used in the procedure tests shall be used. The welding consumables shall be stored and handled in accordance with the manufacturer's recommendations.

610 The martensitic steels shall be furnace re-tempered after weld repair. Subject to prior approval, however, local stress relieving may be considered for minor repairs.

D 700 Welding procedure qualification test

701 For qualification of procedures, a test assembly of minimum 30 mm thickness shall be welded. See Fig.6.

702 Prior to sectioning, the test assembly shall be visually inspected and liquid penetrant tested. Imperfections shall be as-

sessed in accordance with 500.

703 Two macro-sections shall be prepared and etched on one side to clearly reveal the weld metal, the fusion line, and the heat affected zone. The sections shall be examined by eye (aided by low power hand lens if desired) for any imperfections present in the weld metal and HAZ. Cracks or lack of fusion are not permitted. Inclusions or pores greater than 3 mm are not permitted.

704 Two flat transverse tensile test pieces shall be prepared. The tensile strength shall meet the specified minimum value of the base material. The location of fracture shall be reported, i.e. weld metal, HAZ or base material.

705 Two transverse side bend test pieces shall be prepared. The former diameter shall be 4 times the thickness except for austenitic steels, in which case the former diameter shall be 3 times the thickness. The test piece, when visually inspected after bending, shall show no surface imperfections greater than 2 mm in length.

706 Where the base material is impact tested, two sets of Charpy V-notch test pieces shall be prepared; one set with the notch positioned in the centre of the weld and one set with the notch positioned in the fusion line, respectively. The test temperature and absorbed energies shall comply with the requirements for the base material.

707 One of the macro-sections shall be used for HV5 hardness testing. Indentations shall traverse 2 mm below the surface. At least three individual indentations shall be made in the weld metal, the HAZ (both sides) and in the base material (both sides). The values shall be reported for information.

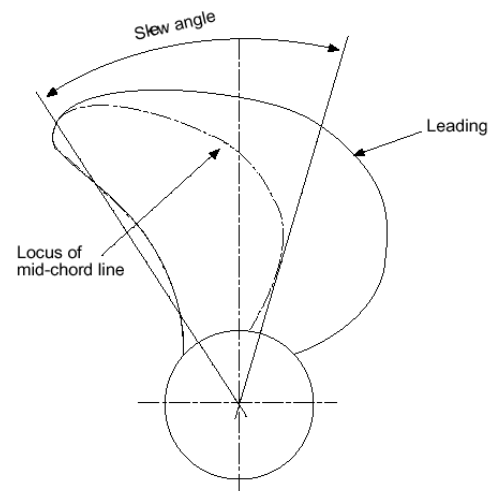


Fig. 1
Definition of skew angle

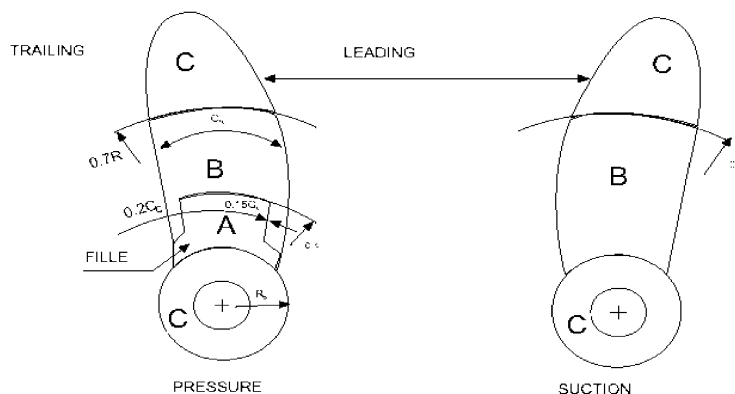


Fig. 2
Severity zones for low skew propellers and separately cast blades

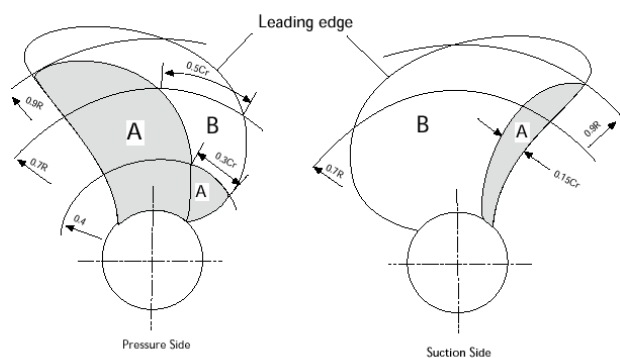


Fig. 3
Severity zones for high skew propellers and separately cast blades

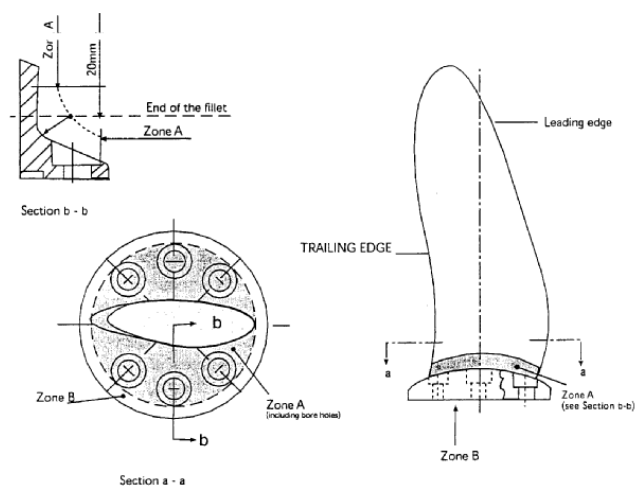


Fig. 5
Severity zones for controllable pitch propellers

Note: The remaining surface of the blades shall be divided into the zones shown in Fig. 2 and Fig.3

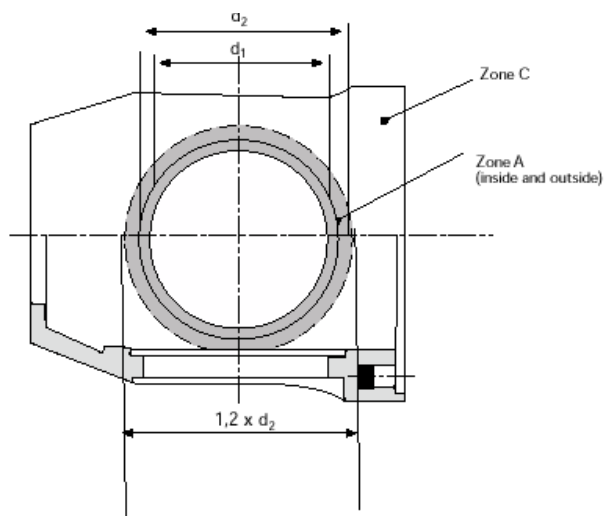


Fig. 4
Severity zones for separately cast propeller hubs

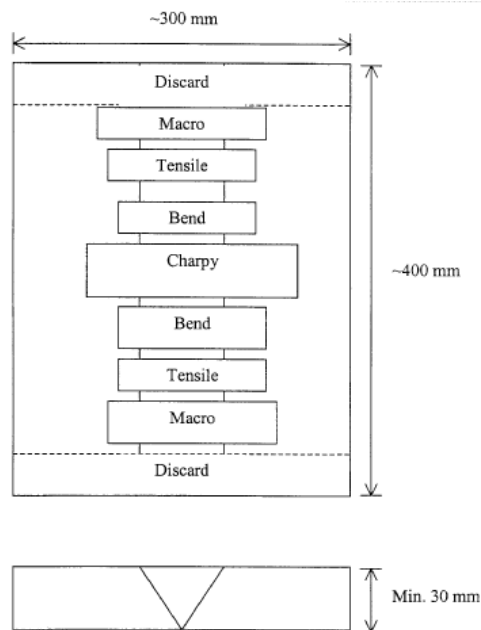


Fig. 6
Welding procedure qualification test assembly

Table D1 Chemical composition limits ¹⁾ for steel propeller castings								
<i>Alloy type</i>	<i>C</i>	<i>Si</i>	<i>Mn</i>	<i>P</i>	<i>S</i>	<i>Cr</i>	<i>Mo</i>	<i>Ni</i>
Martensitic 12Cr 1Ni	0.15	1.5	1.0	0.035	0.025	11.5-14.0	1.0	0.4-2.0
Martensitic 13Cr 4Ni	0.06	1.0	1.5	0.035	0.025	11.5-14.0	1.0	3.5-5.0
Martensitic 16Cr 5Ni	0.06	1.0	1.0	0.035	0.025	15.0-17.5	1.5	3.5-6.0
Austenitic 19Cr 11Ni	0.12	1.5	1.5	0.040	0.030	17.0-21.0	2.0-4.0	9.0-13.0

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

Table D2 Mechanical properties for steel propeller castings						
<i>Alloy type</i>	<i>Proof stress R_{p0.2} minimum (N/mm²)</i>	<i>Tensile strength R_m minimum (N/mm²)</i>	<i>Elongation A₅ minimum (%)</i>	<i>Reduction of area Z minimum (%)</i>	<i>Charpy V-notch ¹⁾</i>	
					<i>Temperature (°C)</i>	<i>Energy mini- mum (J)</i>
12Cr 1Ni	440	590	15	30	-10	20
13Cr 4Ni	550	750	15	35	-10	30
16Cr 5Ni	540	760	15	35	-10	30
19Cr 10Ni	180 ²⁾	440	30	40	-	-

1) Testing is required only for class notations covered under "Arctic or Icebreaking Service", in accordance with Pt.5 Ch.1 Sec.4.
2) R_{p1.0} value is 205 N/mm².

Table D3 Allowable number and size of indications depending on severity zones				
<i>Severity zone</i>	<i>Maximum number of indi- cations</i>	<i>Indication type</i>	<i>Maximum number for each type ^{1) 2)}</i>	<i>Maximum length of indica- tion (mm)</i>
A	7	Non-linear	5	4
		Linear or aligned	2	3
B	14	Non-linear	10	6
		Linear or aligned	4	6
C	20	Non-linear	14	8
		Linear or aligned	6	6

1) Single non-linear indications less than 2 mm in zone A and less than 3 mm in other zones may be disregarded.
2) The total number of non-linear indications may be increased to the maximum total number, or part thereof, represented by the absence of linear or aligned indications.

E. Castings for Boilers, Pressure Vessels and Piping Systems

E 100 Scope

101 These requirements are supplementary to the requirements in A and apply to steel castings for boilers, pressure vessels and piping systems where the design temperature is not lower than 0°C. Provision is made for carbon and carbon-manganese steels and alloy steels.

E 200 Chemical composition

201 The chemical composition shall comply with the overall limits given in Table E1 or, where applicable, the requirements of the approved specification.

E 300 Heat treatment

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

- Normalised.
- Normalised and tempered at a temperature of not less than 550°C.
- Quenched and tempered at a temperature of not less than 550°C.

302 Alloy steel castings shall be normalised and tempered or

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 Society.

E 400 Mechanical properties

401 The mechanical properties shall comply with the values given in Table E2 or, where applicable, the requirements of the approved specification.

E 500 Inspection

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

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

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

E 600 Pressure testing

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

Table E1 Chemical composition limits ¹⁾ for steel castings for boilers, pressure vessels and piping systems											
Steel type	C	Si	Mn	P	S	Cr ²⁾	Mo ²⁾	Ni ²⁾	Cu ²⁾	V ²⁾	Total residuals
C and C-Mn	0.25	0.60	0.50 - 1.20	0.035	0.035	0.40	0.15	0.40	0.40	0.03	1.00
½Mo	0.23	0.60	0.50 - 1.00	0.035	0.035	0.30	0.40 - 0.65	0.40	0.40	0.05	-
1Cr ½Mo	0.20	0.60	0.50 - 1.00	0.035	0.035	1.00 - 1.50	0.45 - 0.65	0.40	0.40	0.05	-
2¼Cr 1Mo	0.20	0.60	0.40 - 0.90	0.035	0.035	2.00 - 2.75	0.90 - 1.20	0.40	0.40	0.05	-
1) Composition in percentage mass by mass maximum unless shown as a range or as a minimum.											
2) Elements are considered as residual elements unless shown as a range or as a minimum.											

Table E2 Mechanical properties for steel castings for boilers, pressure vessels and piping systems					
Steel type	Grade	Yield stress <i>R_e</i> minimum (N/mm ²)	Tensile strength <i>R_m</i> (N/mm ²)	Elongation <i>A₅</i> minimum (%)	Reduction of area <i>Z</i> minimum (%)
C and C-Mn	450H	240	450 - 600	22	35
	490H	275	490 - 640	18	30
½Mo	-	250	450 - 600	21	35
1Cr ½Mo	-	275	480 - 630	17	35
2 ¼Cr 1Mo, Normalised	-	275	480 - 630	17	35
2 ¼Cr 1Mo, QT	-	380	580 - 730	16	35

F. Ferritic Steel Castings for Low Temperature Service

F 100 Scope

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

F 200 Chemical composition

201 The chemical composition shall comply with the limits given in Table F1 or, where applicable, the requirements of the approved specification.

F 300 Heat treatment

301 Castings shall be supplied in one of the following conditions:

tions:

- Normalised.
- Normalised and tempered at a temperature of not less than 550°C.
- Quenched and tempered at a temperature of not less than 550°C.

F 400 Mechanical properties

401 The mechanical properties shall comply with the values given in Table F2 or, where applicable, the requirements of the approved specification.

F 500 Inspection

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

may be substituted for the testing of each test unit.

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

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

F 600 Pressure testing

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

Table F1 Chemical composition limits ¹⁾ for ferritic steel castings for low temperature service

Steel type	C	Si	Mn	P	S	Cr ²⁾	Mo ²⁾	Ni	Cu ²⁾	V ²⁾	Total residuals
C and C-Mn	0.25	0.60	1.60	0.035	0.035	0.40	0.15	0.80	0.30	0.03	0.60
2 ½ Ni	0.25	0.60	0.50 - 0.80	0.035	0.035	0.40	0.15	2.00 - 3.00	0.30	0.03	0.60
3 ½ Ni	0.15	0.60	0.50 - 0.80	0.035	0.035	0.40	0.15	3.00 - 4.00	0.30	0.03	0.60

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

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

Table F2 Mechanical properties for ferritic steel castings for low temperature service

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

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

G. Stainless Steel Castings

G 100 Scope

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

G 200 Chemical composition

201 The chemical composition shall comply with the overall limits given in Table G1 or, where applicable, the requirements of the approved specification.

G 300 Heat treatment

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

G 400 Mechanical properties

401 The mechanical properties shall comply with the values given in Table G2 or, where applicable, the requirements of the approved specification.

G 500 Inspection

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

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

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

Table G1 Chemical composition limits ¹⁾ for stainless steel castings

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

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

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

Table G2 Mechanical properties for stainless steel castings					
Steel type	Proof stress $R_{p0.2}$ minimum (N/mm ²)	Tensile strength R_m minimum (N/mm ²)	Elongation A_5 minimum (%)	Charpy V-notch	
				Temperature (°C)	Energy (J)
GX 2 CrNi 18 10 (304L)	180	440	30	-196 ²⁾	41
GX 5 CrNi 19 9 (304)	180	440	30		
GX 6 CrNiNb 19 10 (347)	180	440	25		
GX 2 CrNiMo 19 11 2 (316L)	180	440	30		
GX 5 CrNiMo19 11 2 (316)	180	440	30		
GX 5 CrNiMo19 11 3 (317)	180	440	30		
1) The minimum $R_{p1.0}$ value is 25 N/mm ² higher.					
2) Impact tests may be omitted if the design temperature is above –105°C.					

SECTION 8 IRON CASTINGS

A. General

A 100 Scope

101 This Section gives the requirements for both ferritic and pearlitic nodular cast iron and for grey cast iron. This section covers IACS UR W9 and W10.

The use of bainitic or other type of cast iron may be accepted after special consideration.

102 Castings which comply with national or proprietary specifications may be accepted provided such specifications give reasonable equivalence to these requirements or otherwise are approved for a specific application.

103 Where small castings are produced in large quantities, the manufacturer may adopt alternative procedures for testing and inspection subject to approval by the Society.

104 Requirements with respect to retesting, identification and certification are outlined in Ch.1.

A 200 Quality of castings

201 Castings shall be free from surface or internal defects which would be prejudicial to their proper application in service. The surface finish shall be in accordance with good practice and any specific requirements of the approved plan.

A 300 Manufacture

301 Materials shall be manufactured at works which have been approved by the Society.

302 Suitable mechanical methods shall be employed for the removal of surplus material from castings. Thermal cutting processes are not acceptable, except as a preliminary operation to mechanical methods.

303 Where castings of the same type are regularly produced in quantity, the manufacturer shall make any tests necessary to prove the quality of the prototype castings and is also to make periodical examinations to verify the continued efficiency of the manufacturing technique. The surveyor shall be given the opportunity to witness tests.

A 400 Chemical composition

401 Unless especially required, the chemical composition is left to the discretion of the manufacturer, who shall ensure that it is suitable to obtain the mechanical properties specified for the casting

A 500 Heat treatment

501 Except as given in 502, the castings may be supplied in either the as cast or heat treated condition.

502 For some applications, such as high temperature service or where dimensional stability is important, castings may require to be given a suitable tempering or stress relieving heat treatment.

A 600 Testing

601 Test material sufficient for the required tests and for possible re-tests shall be provided for each casting or batch of castings. Separately cast test samples are normally to be used.

602 Separately cast test samples shall be cast in moulds made from the same type of material as used for the castings. The test samples shall not be stripped from the moulds until the temperature is below 500°C.

603 Where castings are supplied in the heat treated condition, the test samples shall be heat treated together with the

castings which they represent. For cast-on samples the sample shall not be cut off from the casting until after the heat treatment.

604 A batch testing procedure may be adopted for castings with a fettled mass of 1 tonne or less. All castings in a batch shall be of similar type and dimensions, and cast from the same ladle of treated metal. One test sample shall be provided for each multiple of 2.0 tonnes of fettled castings in each batch.

605 For large castings where more than one ladle of treated metal is used, additional test samples shall be provided so as to be representative of each ladle used.

A 700 Visual and non-destructive examination

701 All castings shall be cleaned and adequately prepared for examination. The surfaces shall not be hammered, peened or treated in any way which may obscure defects.

702 Before acceptance, all castings shall be visually examined including, where applicable, the examination of internal surfaces. Unless otherwise agreed, the verification of dimensions is the responsibility of the manufacturer.

703 Supplementary examination of castings by suitable non-destructive testing procedures is generally not required except in circumstances where there is reason to suspect the soundness of the casting.

704 When required by the relevant construction rules, castings shall be pressure tested before final acceptance.

705 In the event of any casting proving defective during subsequent machining or testing it shall be rejected notwithstanding any previous certification.

A 800 Repair of defects

801 At the discretion of the surveyor, small surface blemishes may be removed by local grinding.

802 Subject to the prior approval of the surveyor, castings containing local porosity may be rectified by impregnation with a suitable plastic filler, provided that the extent of the porosity is such that it does not adversely affect the strength of the casting.

803 Repairs by welding are generally not permitted, unless especially considered and accepted.

B. Nodular Cast Iron

B 100 Scope

This subsection gives the specific requirements to nodular cast iron

B 200 Test material

201 The test samples are generally to be one of the standard types detailed in recognised standards with a thickness of 25 mm.

202 Separately cast test samples are, where possible, to be taken towards the end of pouring of the casting.

B 300 Mechanical properties

301 Ferritic nodular cast iron with special requirements shall meet the values for grade NV1 and NV2, given in Table B1.

302 Nodular cast iron for ordinary use shall be in accordance with the requirements for grade 370 to 800, given in Table B1. Hardness values are given for information only. Values for

elongation which correspond to the tensile strengths between the values specified, shall be calculated by linear interpolation.

in spheroidal form

Guidance note:

Graphite types I II according to Plate I of ASTM A247 are considered to have a spheroidal form.

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

B 400 Metallographic examination

401 For nodular cast iron samples for metallographic examination shall be prepared for every ladle of metal, treated to produce nodular graphite. At least 90% of the graphite shall be

Table B1 Nodular cast iron - mechanical properties of separately cast test samples							
<i>Grade</i>	<i>Tensile strength¹⁾ R_m minimum (N/mm²)</i>	<i>Proof stress²⁾ R_{p0.2} minimum (N/mm²)</i>	<i>Elongation A₅ (%)</i>	<i>Average impact energy, KV</i>		<i>Hardness (HB)</i>	<i>Predominant structure</i>
				<i>minimum³⁾ (J)</i>	<i>test temperatur (°C)</i>		
NV 1	350	220	22	12(9)	- 40	110 - 170	Ferrite
NV 2	400	250	18	12(9)	- 20	140 - 200	Ferrite
370	370	230	17			120 - 180	Ferrite
400	400	250	12			140 - 200	Ferrite
500	500	320	7			170 - 240	Ferrite/ pearlite
600	600	370	3			190 - 270	Pearlite/ ferrite
700	700	420	2			230 - 300	Pearlite
800	800	480	2			250 - 350	Pearlite or tempered structure

1) For intermediate values of specified minimum tensile strength, the minimum values for 0.2% proof and elongation may be obtained by interpolation.
2) The 0.2% proof stress values are given for information purposes and unless otherwise agreed do not require to be verified by test.
3) The average value measured on 3 Charpy V-notch specimens one result may be below the average value but not less than the minimum shown in brackets. If the impact testing is carried out at +20°C the impact energy shall not be less than 17 (14) and 14 (11) J, respectively, for NV 1 and NV 2.

C. Grey Cast Iron

in diameter and of suitable length.

C 100 Scope

101 This subsection gives the specific requirements to grey cast iron.

C 200 Test material

201 Separately cast test samples shall be used unless otherwise agreed and generally shall be in the form of bars 30 mm

C 300 Mechanical properties

301 Only the tensile strength shall be determined and the results obtained from tests shall comply with the minimum value specified for the casting being supplied. The specified minimum tensile strength shall not be less than 200 N/mm².

302 The fractured surfaces of all tensile test specimens shall be granular and grey in appearance.

SECTION 9 ALUMINIUM ALLOYS

A. Wrought Aluminium Alloys

A 100 Scope

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

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

103 As an alternative to 102, materials which comply with national or proprietary specifications may be accepted provided such specifications give reasonable equivalence to the requirements of this section or are approved for each specific application. Generally, such materials shall comply with the appropriate requirements of Ch.1.

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

204 Aluminium for cryogenic applications shall be of the 5000 series alloys and supplied in the annealed condition.

A 300 Manufacture

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

302 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.

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

A 400 Chemical composition

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

402 Other alloys or alloys which do not fully comply with Table A1, may be accepted after consideration in each particular case. Special tests and/or other relevant information, e.g. which confirm satisfactory corrosion resistance and weldability, may be required.

A 500 Test material and test pieces for mechanical testing

501 For rolled products, the test material shall be taken at one third of the width from a longitudinal edge. The test pieces are normally to be cut with their longitudinal axis transverse to the final rolling direction. If the width is insufficient to obtain transverse tests, longitudinal tests will be permitted.

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

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

A 600 Test units and number of tests

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

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

A 700 Mechanical properties

701 The mechanical properties shall comply with the values given in Tables A3 and A4, as applicable. Other temper conditions with related mechanical properties may be accepted by the Society after consideration in each particular 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 least 60°. The test is considered to be unacceptable if it fails with a clean split along the weld

line.

A 900 Inspection and tolerances

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

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

A 1100 Identification

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

- a) Manufacturer's name or trade mark.
- b) Alloy grade and temper condition.

- c) Identification number, heat number or other marking which will enable the full history of the product to be traced.
- d) DNV's certificate number, where applicable and as furnished by the surveyor.

1102 Where a number of items are securely fastened together in bundles, only the top item of each bundle need to be branded. Alternatively, a durable label may be attached to each bundle.

A 1200 Certification

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

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

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	0.25	0.20	0.10	0.05	0.15

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

2) Includes Ni, Ga, V and listed elements for which no specific limit is shown. Regular analysis need not be made.

3) Mn + Cr: 0.10-0.60.

4) Zr: maximum 0.20. The total for other elements does not include Zirconium.

5) Zr: 0.05-0.25. The total for other elements does not include Zirconium.

6) Mn + Cr: 0.12-0.50.

Table A2 Temper descriptions and designations			
Temper description			Temper
Temper 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
Heat treated tempers	Special tempers - Less strain hardened than H11, e.g. by straightening or stretching - No controlled strain hardening, but there are mechanical property limits - Treatment against exfoliation corrosion - Strain hardened less than required for a controlled H32 temper		H111 H112 H116 H321
	Unstable condition after solution heat treatment		W
	Solution heat treated, naturally aged		T4
	Cooled from an high 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/mm ²)	Tensile strength R_m minimum or range (N/mm ²)	Elongation ¹⁾	
				$A_{50\text{ mm}}$ 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) Elongation in 50 mm apply for thickness up to and including 12.5 mm and in 5d for thickness over 12.5 mm.

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

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

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

5) Yield strength minimum 105 N/mm² and tensile strength minimum 240 N/mm² for thickness over 12.5 mm.

6) Yield strength minimum 260 N/mm² and tensile strength minimum 360 N/mm² for thickness over 20 mm.

Table A4 Mechanical properties for extruded aluminium alloys

Grade	Temper	Yield strength $R_{p0.2}$ minimum (N/mm ²)	Tensile strength R_m minimum or range (N/mm ²)	Elongation ¹⁾	
				$A_{50\text{ mm}}$ minimum (%)	A_{5d} minimum (%)
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

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

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

3) Property limits apply for thickness over 5.0 mm.

Table A5 Underthickness tolerances for rolled products (mm)

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

Table A6 Underthickness tolerances for extrusions (mm)

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

SECTION 10 COPPER ALLOY CASTINGS

A. General Requirements

A 100 General

101 This subsection specifies the general requirements for copper alloy castings to be used for equipment, machinery and piping systems.

102 Where required by the relevant design and construction parts of the rules, copper alloy castings shall comply with the requirements in Ch.1, the general requirements of this subsection and the appropriate specific requirements of subsections B and C. If the specific requirements differ from the general requirements, the specific requirements shall prevail.

103 As an alternative to 102, materials which comply with national or proprietary specifications may be accepted provided such specifications give reasonable equivalence to the requirements of this section or are approved for each specific application. Generally, such materials shall comply with the appropriate requirements of Ch.1.

A 200 Grading system

201 The castings concerned are classified by chemical composition into different alloy types e.g. bronzes, brasses etc.

A 300 Manufacture

301 All castings shall be made at foundries approved by the Society.

302 The melting shall be by induction melting or by gas or oil fired furnaces with a crucible or any other process approved by the Society.

303 The mould cavity shall be filled with a laminar flow of metal. The gating, risering and molding shall be in accordance with good foundry practice.

A 400 Chemical composition

401 The chemical composition of each ladle shall be determined and shall be within the specified limits.

402 When castings are made from alloyed ingots and no additions are made during melting, the chemical composition from the ingot maker's certificates can be adopted. If any foundry returns are added to the melt, the ingot maker's chemical analyses shall be supplemented by frequent checks as required by the surveyor.

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

A 500 Heat treatment

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

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

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

504 If a casting is locally reheated or any straightening operation is performed, a subsequent stress relieving heat treatment is required unless otherwise approved.

A 600 Test blocks and test pieces for mechanical testing

601 Test blocks, from which test pieces are taken, shall be cast separately into moulds with gating systems that ensure laminar flow into the mould cavity and comply with the relevant requirements in Ch.1. The test blocks shall receive substantially the same casting practices as the castings represented.

602 For centrifugal cast liners and bushes, the test material may be taken from the ends of the casting.

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

604 The preparation of test pieces and the procedures used for mechanical testing shall comply with the relevant requirements in Ch.1.

A 700 Test units and number of tests

701 Each ladle shall be regarded as a test unit. At least one set of mechanical test is required for each test unit.

702 In the case of multiple castings being poured from the same ladle, at least one set of mechanical test is required from the ladle representing all castings from that ladle.

703 Where castings are made from two or more ladles one set of mechanical test shall be made from each ladle unless the metal in the ladle originate from the same heat.

A 800 Mechanical properties

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

802 If the results of the mechanical tests do not conform to the specified requirements, the re-test procedures of Ch.1 may be adopted.

A 900 Inspection

901 All finished castings shall be visually inspected on accessible surfaces. Where applicable, this shall include the inspection of internal surfaces and bores. The surfaces shall be adequately prepared for inspection. The surfaces shall not be hammered, peened or treated in any way which may obscure discontinuities.

902 Castings for which certification by the Society is required shall be presented to the surveyor for visual inspection. The surveyor may require areas to be etched for the purpose of investigating weld repairs.

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

904 Unless otherwise agreed between the purchaser and the manufacturer, the verification of dimensions is the responsibility of the manufacturer.

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

— Liquid penetrant testing (PT): ISO 3452, ASTM E165.

906 For definitions relevant to PT indications the relevant parts of Sec.7 apply.

907 Where PT is specified, the tests shall be carried out when the surface is in the final condition. Machined castings shall be tested after final machining. Where certification by DNV is required, the surveyor may request to be present during PT.

908 The foundry shall maintain records of the foundry's inspections traceable to each casting. The records shall be presented to the surveyor upon request where applicable. The foundry is also to provide the surveyor with a statement confirming that non-destructive tests have been carried out with satisfactory results.

A 1000 Repair

1001 Defects may be removed by chipping, milling or grinding. Chipping or milling shall always be followed by 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 PT.

1002 Where repair by welding is permitted, 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 PT.

1003 All weld repairs shall be done by qualified welders using qualified procedures.

1004 The welding consumables used shall be of a suitable composition. Welding consumables shall be stored and handled in accordance with the manufacturer's recommendations.

1005 Weld repairs and adjacent material shall be ground smooth. All weld repairs are subject to non-destructive testing.

1006 The foundry shall maintain records of welding, subsequent heat treatment and inspections traceable to each casting repaired. The records shall be presented to the surveyor on request.

A 1100 Identification

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

- a) Heat number or other marking which will enable the full history of the casting to be traced.
- b) DNV's certificate No., where applicable and as furnished by the surveyor.
- c) Rest pressure, where applicable.

A 1200 Certification

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

- a) Manufacturer's and purchaser's name, order number and vessel identification, where known.
- b) Description of castings and alloy type.
- c) Identification marking of castings.
- d) Heat number and chemical composition.
- e) Details of heat treatment, including temperatures and holding times.
- f) Results of mechanical tests.
- g) Results of non-destructive tests, where applicable.

h) Test pressure, where applicable.

i) Results of any supplementary and additional test requirements specified.

B. Castings for Valves, Fittings and General Application

B 100 Scope

101 These requirements are supplementary to subsection A and apply to copper alloy castings for valves, fittings and other castings for use in vessel construction and machinery or piping systems.

B 200 Chemical composition

201 The chemical composition shall comply with the limits given in a recognised standard approved by the Society for the application in question. The copper alloys shall have a satisfactory resistance to sea water corrosion, where applicable.

B 300 Heat treatment

301 The castings shall be heat treated as specified in the recognised standard.

B 400 Mechanical properties

401 The test blocks and test pieces for mechanical testing shall be as described in the recognised standard. In addition subsections A600 to A800 shall apply.

402 The mechanical properties shall comply with the recognised standard.

B 500 Inspection

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

B 600 Repair

601 Defective castings shall be repaired in accordance with A1000 and as given in 602 to 605.

602 Defects may be removed to a depth of 10% of the section thickness. Where the repair entails removal of more than 10% of the thickness, the defective area shall be repaired by welding.

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

- the depth of the groove prepared for welding exceeds 20% of the section thickness, or
- the total weld area exceeds 4% of the casting surface, or
- castings have leaked on hydraulic testing.

All other weld repairs are considered minor

604 Major weld repairs require the approval of the Society 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.

605 Minor weld repairs do not require the approval of the Society 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 surveyor on request.

C. Castings for Propellers

C 100 Scope

101 These requirements are supplementary to subsection A and apply to copper alloy castings for propellers and separately

cast blades and hubs.

102 These requirements may also be used for the repair of propellers damaged in service, subject to prior agreement with the Society.

C 200 Chemical composition

201 The chemical composition shall comply with the limits given in Table C1.

C 300 Heat treatment

301 Propeller castings need generally not to be heat treated except as specified in 600.

C 400 Mechanical testing

401 The mechanical properties shall meet the requirements in Table C2.

C 500 Inspection

501 The castings are subject to inspection in accordance with A900 and as given in 502 to 504.

502 For all propellers, separately cast blades and hubs, the surfaces covered by severity zones A, B and C are subject to PT. For definition of skew and description of severity zones, see the relevant parts of Sec.7. Testing of zone A shall be undertaken in the presence of the surveyor whilst testing of zones B and C may be witnessed by the surveyor upon his request.

503 For the purpose of evaluating PT indications, the surface shall be divided into reference areas of 100 cm², which may be square or rectangular with the major dimension not exceeding 250 mm.

504 The indications detected may, with respect to their size and number, not exceed the values given in Table C4. Weld repairs are, independent of their location, always to be assessed according to zone A.

C 600 Repair

601 Defective castings shall be repaired in accordance with A1000 and as given in 602 to 610.

602 In general the repairs shall be carried out by mechanical means, e.g. by grinding or milling. Weld repairs shall be undertaken only when they are considered to be necessary.

603 Weld repairs require the approval of the Society before the repair is commenced. Proposals for weld repairs shall be accompanied by sketches or photographs showing the extent and positions of the repairs.

604 Grinding in severity zone A may be carried out to an extent that maintains the blade thickness. Repair welding is generally not permitted in severity zone A and will only be allowed after special consideration by the Society.

605 Defects in severity zone B that are not deeper than t/40 mm (t is the minimum local thickness according to the rules) or 2 mm, whichever is greatest, may be removed by grinding. Those defects that are deeper may be repaired by welding.

606 Repair welding is generally permitted in severity zone C.

607 Repair welding of propellers with skew angle equal to 0° is generally permitted on the blade faces, and may also be repaired at the root area if so agreed with the Surveyor.

608 Before welding is started, a detailed welding procedure specification shall be submitted covering the weld preparation, welding parameters, filler metals, preheating, post weld heat treatment and inspection procedures. Recommendations for welding are given in Table C3.

609 The scope of the welding procedure qualification test is given in 900.

610 With the exception of NiAl-Bronze all weld repairs shall be stress relief heat treated, in order to avoid stress corrosion cracking. The temperatures for the heat treatment is given in Table C3. The cooling rate shall not exceed 50°C/h until a temperature of 200°C is reached.

C 700 Identification

701 Castings shall be identified in accordance with A1100 and with the following additional particulars:

- Ice class symbol, where applicable.
- Skew angle for high skew propellers.
- Date of final inspection.

C 800 Certification

801 Castings shall be certified in accordance with A1200 and giving the following additional particulars:

- Description of the casting with drawing number.
- Diameter, number of blades, pitch, direction of turning.
- Skew angle for high skew propellers.
- Final mass.

802 The manufacturer shall provide records of weld repairs as detailed in A1000.

C 900 Welding procedure qualification

901 For qualification of procedures, a test assembly of minimum 30 mm thickness shall be welded. See Fig.1.

902 Prior to sectioning, the test assembly shall be visually inspected and liquid penetrant tested. Imperfections shall be assessed in accordance with 500.

903 Three macro-sections shall be prepared and etched on one side to clearly reveal the weld metal, the fusion line, and the heat affected zone. The sections shall be visually inspected for any imperfections present in the weld metal and HAZ. Inclusions or pores greater than 3 mm and cracks or lack of fusion are not permitted.

904 Two tensile test pieces shall be prepared as shown in Fig.2. The tensile strength shall meet the specified minimum values given in Table C5. The location of fracture shall be reported, i.e. weld metal, HAZ or base material.

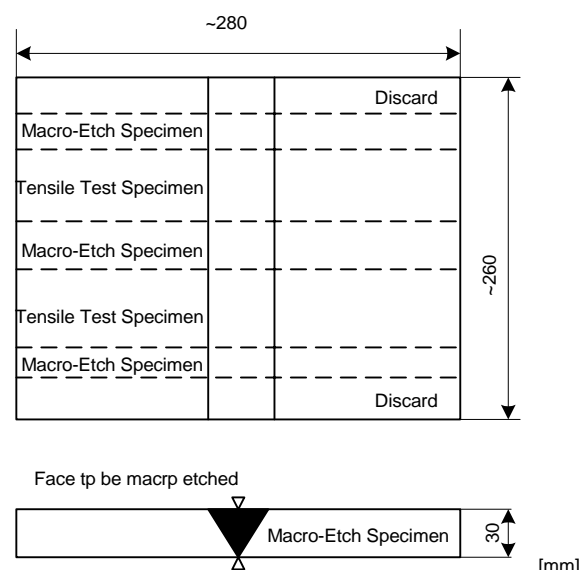


Fig. 1
Weld test assembly

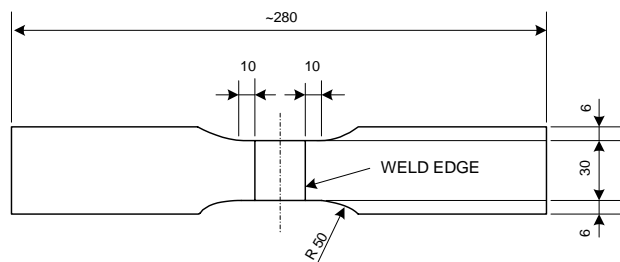


Fig. 2
Tensile test specimen for weld test assembly

Table C1 Chemical composition limits ¹⁾ for copper alloy propeller castings											
<i>Alloy type</i>	<i>Cu</i>	<i>Al</i>	<i>Mn</i>	<i>Fe</i>	<i>Ni</i>	<i>Zn</i>	<i>Sn</i>	<i>Pb</i>	<i>Cr</i>	<i>Mg</i>	<i>Si</i>
Mn-bronze ²⁾ , Cu1	52 - 62	0.5 - 3.0	0.5 - 4.0	0.5 - 2.5	1.0	35 - 40	0.1 - 1.5	0.5	-	-	-
Mn-Ni-bronze ²⁾ , Cu2	50 - 57	0.5 - 2.0	1.0 - 4.0	0.5 - 2.5	3.0 - 8.0	33 - 38	0.15	0.5	-	-	-
Ni-Al-bronze, Cu3	77 - 82	7.0 - 11.0	0.5 - 4.0	2.0 - 6.0	3.0 - 6.0	1.0	0.1	0.03	-	-	-
Mn-Al-Bronze, Cu4	70 - 80	6.5 - 9	8.0 - 20.0	2.0 - 5.0	1.5 - 3.0	6.0	1.0	0.05	-	-	-

1) Composition in percentage mass by mass maximum unless shown as a range or as a minimum.
2) Zinc equivalent not to exceed 45% when calculated using the following formula:
Zinc equivalent (%) = 100 - (100 Cu/100 + A) where A = Sn + 5 Al - 0.5 Mn - 0.1 Fe - 2.3 Ni

Table C2 Mechanical properties for copper alloy propeller castings			
<i>Alloy type</i>	<i>Yield strength R_{p0.2} minimum (N/mm²)</i>	<i>Tensile strength R_m minimum (N/mm²)</i>	<i>Elongation A₅ minimum (%)</i>
Mn-bronze, Cu1	175	440	20
Mn-Ni-bronze, Cu2	175	520	18
Ni-Al-bronze, Cu3	245	590	16
Mn-Al-Bronze, Cu4	275	630	18

Table C3 Recommendations for welding of copper alloy propeller castings	
<i>Alloy type</i>	<i>Description</i>
Mn-bronze, Cu1	Use Al-bronze ¹⁾ or Mn-bronze filler metal. Pre-heat to 150°C and interpass temperature not to exceed 300°C. Stress relief at 350°C to 500°C.
Mn-Ni-bronze, Cu2	Use Al-bronze or Mn-Ni-bronze filler metal. Pre-heat to 150°C and interpass temperature not to exceed 300°C. Stress relief at 350°C to 550°C.
Ni-Al-bronze, Cu3	Use Al-bronze, Ni-Al-bronze ²⁾ or Mn-Al-bronze filler metal. Preheat to 100°C and interpass temperature not to exceed 250°C. Stress relief at 450°C to 500°C.
Mn-Al-Bronze, Cu4	Use Mn-Al-bronze filler metal. Preheat to 100°C and interpass temperature not to exceed 300°C. Stress relief at 450°C to 600°C.

1) Ni-Al-Bronze and Mn-Al-Bronze acceptable
2) If Ni-Al-Bronze is used, stress relief is not required

Table C4 Allowable number and size of indications depending on severity zones				
<i>Severity zone</i>	<i>Maximum total number of indications</i>	<i>Indication type</i>	<i>Maximum number for each type ^{1) 2)}</i>	<i>Maximum dimension of indication (mm)</i>
A	7	Non-linear	5	4
		Linear or aligned	2	3
B	14	Non-linear	10	6
		Linear or aligned	4	6
C	20	Non-linear	14	8
		Linear or aligned	6	6

1) Single non-linear indications less than 2 mm in zone A and less than 3 mm in other zones may be disregarded.
2) The total number of non-linear indications may be increased to the maximum total number, or part thereof, represented by the absence of linear or aligned indications.

Table C5 Tensile strength requirements for weld qualification test	
<i>Alloy type</i>	<i>Tensile strength (N/mm²)</i>
Mn-Bronze (brass)	370
MnNi-Bronze (brass)	410
NiAl-Bronze (bronze)	500
MnAl-Bronze (bronze)	550

SECTION 11 NON-FERROUS TUBES

A. Copper and Copper Alloy Tubes

A 100 Scope

101 This subsection specifies requirements for copper and copper alloy tubes to be used in shipboard systems. Provision is made for phosphorus-deoxidised copper, aluminium brass and copper-nickel alloys.

102 Tubes shall be in accordance with recognised standards, e.g. ASTM B 111, ASTM B 543, DIN 17671, DIN 1785, JIS H 3300 and JIS H 3320 provided that supplementary requirements contained herein are also met. Recognition of other standards is subject to submission to the Society for evaluation.

103 Where required by the relevant design and construction parts of the rules, tubes shall comply with the requirements of Ch.1 and the requirements of this subsection.

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

A 200 Manufacture

201 Tubes for class I and II pressure systems shall be made at works approved by DNV.

202 Tubes for class I and II pressure systems shall be seamless drawn. Tubes for class III pressure systems may be seamless drawn or welded.

A 300 Chemical composition

301 The chemical composition shall comply with the requirements of a recognised standard and with the limits for principal elements given in Table A1.

A 400 Heat treatment

401 Copper tubes shall be supplied in the annealed or half-hard condition.

402 Copper alloy tubes shall be supplied in the annealed condition.

A 500 Mechanical testing

501 Tubes shall be sampled and subjected to testing in accordance with the requirements of a recognised standard.

502 The mechanical properties shall comply with the requirements of a recognised standard and with the minimum values given in Table A2.

A 600 Inspection

601 Each tube shall be subjected to eddy current testing or pressure testing in accordance with the requirements of a recognised standard.

A 700 Repair

701 Defects may be removed by grinding providing the dimensional tolerances are not exceeded. Repair by welding is not permitted.

A 800 Identification

801 Tubes shall be suitably marked for identification by the manufacturer. Hard stamping of tubes is not permitted.

A 900 Certification

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

- a) Purchaser's name, order number and vessel identification, where known.
- b) Manufacturer's name.
- c) Description of tubes and material quality.
- d) Identification marking of tubes.
- e) Heat number and chemical composition.
- f) Results of mechanical tests and, where applicable, technological tests.
- g) Test pressure or results of eddy current tests.
- h) Results of any supplementary and additional test requirements specified.

Table A1 Chemical composition limits ¹⁾ for principal elements in copper and copper alloy tubes									
Designation	Cu	As	P	Pb	Fe	Zn	Ni	Al	Mn
Phosphorus-deoxidised copper	Minimum 99.9 ²⁾	-	0.015 - 0.040	-	-	-	-	-	-
Aluminium brass	76.0 - 79.0	0.02 - 0.06	-	0.07	0.06	Remainder	-	1.8 - 2.5	-
Copper-Nickel 90-10 ³⁾	Remainder	-	-	-	1.0 - 2.0	-	9.0 - 11.0	-	0.5 - 1.0
Copper-Nickel 70-30 ³⁾	Remainder	-	-	-	0.40 - 1.0	-	29.0 - 33.0	-	0.5 - 1.5
1) Composition in percentage mass by mass maximum unless shown as a range or as a minimum.									
2) Including silver.									
3) When the product is for subsequent welding applications and so specified by the purchaser, the following maximum limits apply: Zinc 0.50%, Lead 0.02%, Phosphorus 0.02%, Sulphur 0.02% and Carbon 0.05%.									

Table A2 Mechanical properties for copper and copper alloy tubes				
<i>Designation</i>	<i>Condition</i>	<i>Yield strength R_{p0.2} minimum (N/mm²)</i>	<i>Tensile strength R_m minimum (N/mm²)</i>	<i>Elongation A₅ minimum (%)</i>
Phosphorus-deoxidised copper	Annealed	100	220	40
	Half-hard	150	250	20
Aluminium brass	Annealed	120	330	35
Copper-Nickel 90-10	Annealed	100	290	30
Copper-Nickel 70-30	Annealed	120	360	30

B. Titanium and Titanium Alloy Tubes

B 100 Scope

101 This subsection specifies requirements for titanium and titanium alloy tubes to be used in shipboard systems. Provision is made for grade 1 and grade 2 unalloyed titanium and grade 9 titanium alloy.

102 Tubes shall be in accordance with recognised standards, e.g. ASTM B 338, ASTM B 861 and ASTM B 862 provided that supplementary requirements contained herein are also met. Recognition of other standards is subject to submission to the Society for evaluation.

103 Where required by the relevant design and construction parts of the rules, tubes shall comply with the requirements of Ch.1 and the requirements of this subsection.

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

B 200 Manufacture

201 All tubes shall be made at works approved by DNV.

202 Tubes for class I and II pressure systems shall be seamless. Tubes for class III pressure systems may be seamless or welded.

B 300 Certification

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

- Purchaser's name, order number and vessel identification, where known.
- Manufacturer's name.
- Description of tubes and material quality.
- Identification marking of tubes.
- Heat number and chemical composition.
- Results of mechanical tests.
- Test pressure.
- Results of any supplementary and additional test requirements specified.