



RULES FOR
CLASSIFICATION OF

SHIPS / HIGH SPEED, LIGHT CRAFT AND NAVAL SURFACE CRAFT

NEWBUILDINGS

MATERIALS AND WELDING

PART 2 CHAPTER 2

METALLIC MATERIALS

JANUARY 2003

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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 December 2002, and supersedes the January 2001 edition of the same chapter.

The rule changes come into force 1 July 2003.

This chapter is valid until superseded by a revised chapter.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 1 – Rolled Steel for Structural Application

- A new item B102 has been added concerning requirements for Z grade steel.
- Item C402 has been deleted concerning Z ductility.
- Table C4 has been amended concerning tensile strength.
- A new item D103 has been added concerning requirements for Z grade steel.
- Item D402 has been deleted concerning Z ductility.
- A new sub-section, E100 to E900, concerning Z quality steel plates has been added.
- Previous sub-section E “Testing” has been renamed to F.
- Previous sub-section E400, “Testing of through thickness properties”, has been deleted.
- Previous Table E1 has been renamed to F1
- Renumbered table F1 has been amended concerning the extent of impact testing at delivery.
- Previous sub-section F, “Repairs”, has been renumbered to G.

• Section 2 – Rolled Steel for Boilers, Pressure Vessels and Special Applications

- Item E601 has been amended to include a reference to new sub-section E in Sec.1.

• Section 5 – Steel Forgings

- Item A103 has been amended to include a reference to Pt.4 Ch.3 Sec.3.

- Item A301 has been amended to include a requirement for special approval for the manufacture of clean steel forgings for machinery parts.
- Item A302 has been amended to include the requirement for the steel used for the manufacture of forgings to be made by a process approved by the Society.
- Item A307 has been amended to include specific requirements applicable to crankshafts.
- New item A309 has been added concerning the cleanliness of steel forgings according to ISO 4967.
- Item A506 has been amended to include approval of the Society for all straightening operations.
- Tables B1 and B2 have been amended concerning composition and yield stress, respectively.
- Item C501 has been amended concerning magnetic particle and liquid penetrate testing.
- Item C502 has been amended concerning ultrasonic testing.
- Table C2 has been amended concerning mechanical properties for steel forgings.
- Figures 1, 2, 3 and 4 have been amended.
- New item E102 has been added concerning heat and mechanical testing.
- In items E301 and E302 the tempered temperatures have been changed from 480°C to 540°C.
- Item E403 has been amended to include gear wheel tests when the finished diameter exceeds 2500 mm.
- Item E406 has been amended concerning hardness tests.
- Items E501 and E502 have been significantly reduced.
- Item E503 has been deleted.
- Items E601 has been amended concerning magnetic particle and liquid penetrate testing.
- Item E602 has been amended concerning ultrasonic testing.

• Section 9 - Aluminium Alloys

- Table A4 concerning extruded aluminium alloys has been amended.

• Section 10 - Copper Alloy Castings

- Table C1 concerning chemical compositions has been amended
- Table C4 concerning severity zones has been amended.

Corrections and Clarifications

In addition to the above stated rule requirements, a number of detected errors, 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 are to 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 is to 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 is to 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 is to be delivered in a condition complying with the requirements given in Table B2.

B 400 Mechanical properties

401 Normal strength steel is to 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 is not to 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 is not to 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 is to comply with the following minimum values:										
Thickness, mm		t ≤ 5	5 < t ≤ 10	10 < t ≤ 15	15 < t ≤ 20	20 < t ≤ 25	25 < t ≤ 30	30 < t ≤ 40	40 < t ≤ 150	
Elongation		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 is to be indicated.

202 Grades which according to Table C1 are to be fine grain treated, are 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.

203 The content of all elements specified is to be determined for each cast, by ladle analysis, and is to 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 is to 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 is to 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 is to be delivered in a condition complying with the requirements given in Table C3.

C 400 Mechanical properties

401 High strength steel is to 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 is to contain Al, Nb, V or other suitable grain refining elements, either singly or in any combination. When used singly the steel is to 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 is to 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 is to be indicated.

202 All extra high strength steel grades are to 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 is to be determined for each cast, by ladle analysis, and is to be stated on the certificate.

204 When the weldability is to be evaluated from the chemical composition, the following formula is to 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 is to be delivered in a condition complying with the requirements given in Table D2.

D 400 Mechanical properties

401 Extra high strength steel is to 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 is to comply with the approved specification of the steel grade in question.							
2) The steel is to contain Al, Nb, V or other suitable grain refining elements, either singly or in any combination. When used singly the steel is to 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 is to 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.

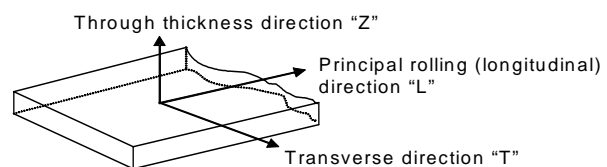


Fig. 1
Through thickness tensile testing

E 200 Manufacture

201 All the materials are to 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 is to 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 are to be as given below.

402 For plates and wide flats, one test sample is to 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 ≤ 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 are to be prepared while the rest of the sample remains for possible retest.

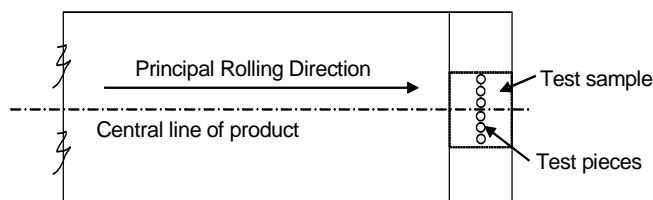


Fig. 2
Plate and wide flat sampling position.

E 500 Mechanical testing

501 Round test pieces are to 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 are to be taken from the remaining test sample. The average of all 6 tensile tests is to 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.

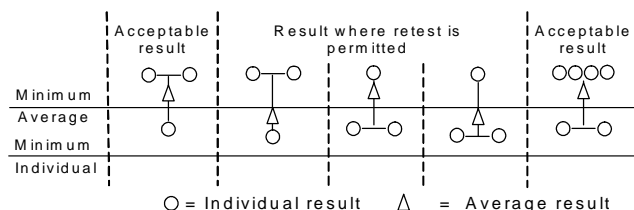


Fig. 3
Diagram showing acceptance and rejection and retest criteria

E 700 Non-destructive testing

701 Ultrasonic testing is required and is to 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 are to 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 is to 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 are to be fully representative of the material and, where appropriate, are not to be cut from the material until heat treatment has been completed.

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

102 Unless otherwise agreed, the test samples for tensile and impact test pieces are to be taken from the following positions:

- Plates and flats with a width ≥ 600 mm

The test samples are to 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 are to 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 are to 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 are to 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 are to be agreed upon by the Society.

F 200 Tensile testing

201 The dimensions of the tensile test pieces are to be in accordance with Ch.1 Sec.2. Generally for plates, wide flats and sections flat test pieces of full product thickness are to 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 is to be made from one sample product unless the weight of finished material is greater than 50 tonnes in which case one extra test is to be made from a different sample product from each 50 tonnes or fraction thereof. Additional tests are to 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 is to 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 are to be in accordance with the requirements of Ch.1.

F 300 Impact testing

301 The impact test pieces are to 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 are to 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 is to be cut in a face of the test pieces which was originally perpendicular to the rolled surface. The position of the notch is not to 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 is to be as specified in Table F1. One set of three test pieces is to be taken from one of the thickest products of each specified test unit or part thereof.

303 For thicknesses equal to or below 50 mm, the impact test pieces are to be cut with their edge within 2 mm from the as-rolled surface. For plate thicknesses exceeding 50 mm, impact test pieces are to 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 is to 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 are to 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 are to 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 is to 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 is to 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 is to 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 is to 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 are to 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 is to be in accordance with the requirements of a recognised international or national standard.

The under thickness tolerance acceptable for classification is to 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 is to be measured at random locations whose distance from a longitudinal edge is to 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 are to 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:

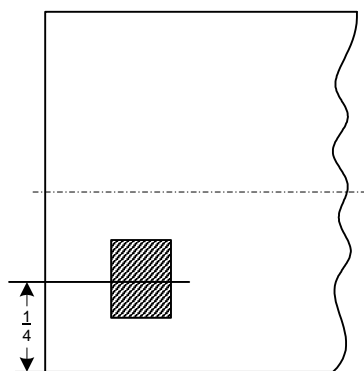
- the thickness is in no place reduced to less than 93% of the nominal thickness, but in no case by more than 3 mm
- each single ground area does not exceed 0.25 m² and
- all ground areas do not exceed 2% of the total surface in question.

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

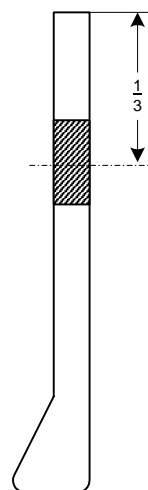
The repairs are to be agreed with the surveyor in each case, and are to be carried out under the surveyor's supervision unless otherwise agreed.

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.

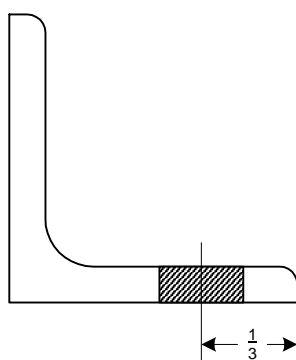
- after removal of the defect, and before welding, the thickness of the piece is in no place to be reduced by more than 20%. The welding is to be carried out according to an approved procedure with approved electrodes. The weld is to be ground smooth to the correct nominal thickness
- the weld repair is to 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 is to be the same as prescribed for the steel grade in question.



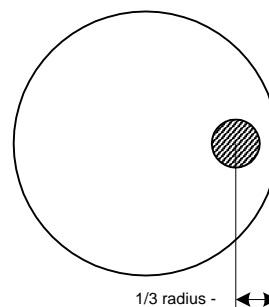
(a) Plates and flats



(e) Bulb flats



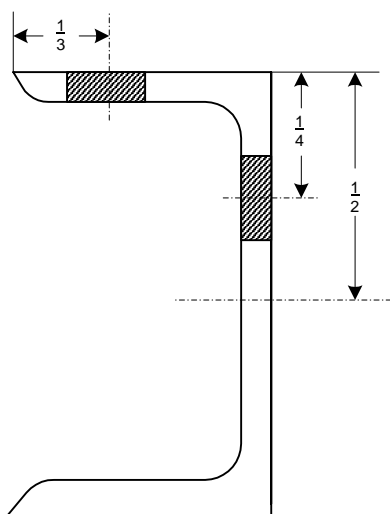
(b) Angles



(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 is to 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 is to 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 is to 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 is to 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 are to be determined and entered on the certificate. The content of residual elements is to 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 are to be:

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

204 For carbon and carbon-manganese steels, the carbon equivalent is to 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 are to 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 are to be supplied in the heat treatment conditions stated in Table B8, except that materials which are to 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 is to be carried out after forming.

402 The designation of controlled rolled- and thermo-mechanically treated steel grades are to 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>maximum</i>	<i>Residual</i> <i>elements,</i> <i>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 - ²⁾ 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 - ²⁾ 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 is to 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. 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, (%)								Residual elements, maximum
	<i>C</i>	<i>Si</i>	<i>Mn</i>	<i>P</i> <i>maximum</i>	<i>S</i> <i>maximum</i>	<i>Al</i> _{tot} <i>maximum</i>	<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	Tensile strength <i>R_m</i> (N/mm ²)	Yield stress, <i>R_{eH}</i> or <i>R_{p0.2}</i> (N/mm ²) minimum for thickness, (mm)		Elongation <i>A₅</i> (%) minimum	KV, average		
		≤ 16	> 16 ≤ 25		Test temperature (°C)	Transverse (J) minimum	Longitudinal (J) minimum
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	175	172	168	150	124	117	115	113	
		16 ≤ 40	171	169	162	144	124	117	115	113	
		> 40 ≤ 63	162	158	152	141	124	117	115	113	
	NV 360 - 1 FN	< 16	204	185	165	145	127	116	110	106	
		> 16 ≤ 40	196	183	164	145	127	116	110	106	
		> 40 ≤ 63	179	172	159	145	127	116	110	106	
	NV 410 - 0N	< 16	211	208	201	180	150	142	138	136	
		> 16 ≤ 40	201	198	191	171	150	142	138	136	
		> 40 ≤ 63	192	188	181	168	150	142	138	136	
	NV 410 - 1 FN	< 16	235	216	194	171	152	141	134	130	
		> 16 ≤ 40	228	213	192	171	152	141	134	130	
		> 40 ≤ 63	215	204	188	171	152	141	134	130	
C- and C/Mn-steels, normalised	NV 460 - 0N	< 16	248	243	235	210	176	168	162	158	
		> 16 ≤ 40	230	227	220	198	176	168	162	158	
		> 40 ≤ 63	222	218	210	194	176	168	162	158	
	NV 460 - 1 FN	< 16	266	247	223	198	177	167	158	153	
		> 16 ≤ 40	260	242	220	198	177	167	158	153	
		> 40 ≤ 63	251	236	217	198	177	167	158	153	
	NV 490 - 0N	< 16	270	264	255	228	192	183	177	172	
		> 16 ≤ 40	248	245	237	214	192	183	177	172	
		> 40 ≤ 63	240	236	227	210	192	183	177	172	
	NV 490 - 1 FN	< 16	284	265	240	213	192	182	173	168	
		> 16 ≤ 40	279	260	237	213	192	182	173	168	
		> 40 ≤ 63	272	256	234	213	192	182	173	168	
C- and C/Mn-steels as rolled	NV 510 - 1 FN	≤ 63	-	-	265	245	225	205	175	155	
	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 ≤ 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 is to 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 is to be determined and entered on the certificate. The content of residual elements is to 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 are to be:

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

204 For carbon and carbon-manganese steels, the carbon equivalent is to 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 are to 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 is to 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 are to display a “no break performance” when tested 5°C below the design temperature.

C 400 Heat treatment

401 The materials are to 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 is to 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 are not to 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> maximum	<i>Si</i>	<i>Mn</i>	<i>S</i> maximum	<i>P</i> maximum	<i>Al</i> ⁴⁾ total	<i>N</i> maximum	
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 are to 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 is to 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

- 1) These requirements are applicable to products up to maximum 40 mm thickness. For thicknesses exceeding 40 mm the requirements are to 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 liquefied gas carriers see Pt.5 Ch.5 Sec.2 Table D3 of the Rules for Classification of Ships.
4) For thickness 25 < t ≤ 40 mm the impact test temperature is to be stamped on the products and stated in the certificate.
5) In certain cases the materials are to be subjected to Pellini's drop weight test according to 302.

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⁾

- 1) Other heat treating processes, e.g. quenching and tempering or thermo-mechanical controlled processing may be approved. See 402.
2) See 402.
3) Quenching and tempering will normally be required for thicknesses above 30 mm.

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 is to comply with the requirements given in Table D1, or the approved specification.

D 300 Mechanical properties

301 The mechanical properties of the material are to comply with the requirements specified in Table D2. For austenitic steels both the 0.2 and 1.0% yield stress are to 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 are to 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 are to 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 is to be carried out for each tensile test. The testing is to be carried out according to ASTM A262, Practice E, Copper - Copper Sulphate - Sulphuric Acid Test or another recognised

standard.

The bent specimens are to 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, are to 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, are to 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 are to be in accordance with the appropriate requirements of Ch.1.

102 Test samples are to be taken from positions as required according to Sec.1 E100.

E 200 Tensile testing at ambient temperature

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

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

202 For plates, one tensile test piece is to 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 is to represent the top of the ingot.

When the weight exceeds 2500 kg, tensile test pieces are to 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 is not to exceed 60 N/mm².

204 For sections, one tensile test piece is to be taken from test units of not more than 10 tonnes. The material in each test unit is to 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 is to be carried out in compliance with ISO 783.

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

The intervals used for estimation of strain rate from measure-

ments of strain are not to exceed 6 seconds.

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

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

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

E 400 Impact testing

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

The average value from each set of three impact test pieces are to 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 is to 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 are to 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 are to 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 is to 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 is to be made for each tensile test. When the test temperature is –50°C or lower, one set of tests is to be taken from each end of the rolled plate regardless of the plate weight.

For sections at least one set of tests is to be made for each tensile test. When the test temperature is –50°C or lower, one set of tests is to 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) is to 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 are to be manufactured and tested in accordance with Sec.1 E.

E 700 Intercrystalline corrosion testing

701 When intercrystalline corrosion testing is required, the test is to 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 are to 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 are to 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 is to vary more than 0.30 mm or 6% under the thickness specified, whichever is the lesser.

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

F 300 Surface condition and rectification of defects

301 All products are to 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 is not to 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 is not to be carried out unless a detailed repair procedure is submitted and approved.

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

304 Depressions caused by grinding are to 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 are to be supplied in that condition of heat treatment which is most appropriate for both types of material. The material is not to 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 is to 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 is to at least to satisfy the requirements for materials for such components.

Work's certificate stating chemical composition is to 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 is to be delivered either with a low carbon content, i.e. maximum 0.03%, or it is to 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 is to be supplied by the manufacturer. The manufacturer is to guarantee that the analysis complies with the requirements of the specification. Check analysis is to be made if required by the Society.

D. Testing

D 100 General

101 Tensile and bend test pieces are to 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 are to 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 are to be tested. Impact test pieces, if any, are to 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 is to 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 is to satisfy the requirements for the base material.

202 From hull steel, one set of tensile tests is to 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 is to be taken from each plate.

D 300 Impact testing

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

D 400 Bend testing

401 The bend test pieces are to 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 is to 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 are to be taken from each plate. On single clad plates, one test piece is to be bent with the cladding in tension and the other with the cladding in compression. On double clad plates, the test pieces are to 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 is to be made from each plate in accordance with ASTM A 264. The shear strength is to be at least 140 N/mm².

D 600 Ultrasonic testing

601 To check the bonding, ultrasonic testing is to be made. If bonding defects are found, their extent is to 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 is to be checked 100% for a width of at least 50 mm. Further tests are to 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 is to 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 is to 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 is to be surveyed before delivery. The plates are to satisfy the requirements for minus tolerances on thickness as stipulated in Sec.2 F200. The thickness control is to 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 are to be repaired.

Before welding, the defects are to be reported to the surveyor for approval of the repair.

Approved filler metal and welding processes are to 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 are to 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 are to 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 is to 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 TUBES, PIPES AND FITTINGS

A. General

A 100 Scope

101 This Section specifies the requirements for seamless and welded steel pipes, tubes and fittings intended for pressure, boiler, heat exchanger, superheater, chemicals and low temperature services.

102 The products are to be in accordance with relevant ISO Standards or recognised regional or national standards provided that these standards give reasonable equivalence to the ISO requirements included in this section. The given standard must also comply with the additional requirements given in the following subsections.

A 200 Manufacture

201 Pipes, tubes and fittings are to be manufactured by works approved by the Society. Pipes, tubes and fittings may be manufactured by any of the following methods:

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

202 Welded tubes, pipes and fittings are normally not to be used for working pressure above 32 bar or design temperature above 300°C. Further, they are not accepted for liquefied gases with temperature below -10°C. These limits may be exceeded provided that an automatic non-destructive testing of the weld is carried out. The whole length of the weld is to be tested. Such tubes and pipes are considered equivalent to seamless types.

203 Tubes and pipes intended as strength members of structures are to satisfy the requirements for material for the structure in question, e.g. for hull and engine material.

A 300 Quality

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

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

Repair of defects by welding is not accepted.

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

A 400 Dimensional tolerances

The tolerances on the outside diameter and the wall thicknesses of tubes and pipes are to be in accordance with the relevant ISO-standard or an acceptable national standard.

A 500 Chemical composition

501 The requirements for the chemical composition of ladle samples are to be in accordance with the ISO-requirements detailed in subsequent subsections or an acceptable national or international standard.

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

A 600 Heat treatment

601 Tubes and pipes are to be supplied in the heat treatment conditions indicated in Table A1 if not otherwise specified in the following subsections.

A 700 Mechanical properties

The number of tests to be performed and the mechanical properties of the tubes and pipes covered by this section are to be in accordance with the tables contained in this section or, where applicable, in the relevant standard.

A 800 Test material

801 Pipes, tubes and fittings are to be presented for test in batches. A batch is formed by tubes of the same size, the same steel grade, the same manufacturing process and the same heat treatment conditions. The size of a batch is to be in accordance with Table A2 or the relevant standard if not otherwise stated in the following subsections.

802 The procedures used for all tests are to be in accordance with the appropriate requirements of Ch.1.

803 Ring tests may be carried out in conformity with the following ISO standards:

<i>Bend test</i>	8491
<i>Flattering test</i>	8492
<i>Drift expanding test</i>	8493
<i>Flanging test</i>	8494
<i>Ring expanding test</i>	8495
<i>Ring tensile test</i>	8495

or other equivalent standards.

Table A1 Heat treatment conditions						
Steel grade	Reference heat treatment ¹⁾	Austenitizing temperature (°C)	Tempering temperature (°C)	Subcritical Annealing temperature (°C)	Quenching and tempering	
					Hardening temperature (°C)	Tempering temperature (°C)
Unalloyed steel						

TW 320	N or SA ²⁾	870 to 940	-	640 to 700	-	-
TS 360/TW 360	N or SA ²⁾	870 to 940	-	640 to 700	-	-
TS 410/TW 410	N or SA ²⁾	870 to 940	-	640 to 700	-	-
TS 410-1	N	870 to 900	-	-	-	-
TS 430/TW 430	N or SA ²⁾	870 to 940	-	640 to 700	-	-
TS 460-1/TW 460	N	880 to 910	-	-	-	-
TS 500/TW 500	N or SA ²⁾	870 to 940	-	640 to 700	-	-
TS 510/TW 510	N	880 to 910	-	-	-	-
TS 6/TW6 (N)	N	900 to 940	-	-	-	-
TS 6/TW 6(QT)	QT	-	-	-	890 to 930	600 to 680
TS 10/TW 10	N	890 to 930	-	-	-	-
TS 15/TW 15	N	890 to 930	-	-	-	-
Alloy steel						

TS 380	N	910 to 960	-	-	-	-
	FA ³⁾	860 to 960	-	-	-	-
TS 410-3	N & T	920 to 960	660 to 750	-	-	-
	FA ³⁾	860 to 960	-	-	-	-
TS 410-4	N & T	920 to 960	660 to 750	-	-	-
	FA ³⁾	860 to 960	-	-	-	-
TS 430	FA ³⁾	850 to 950	-	-	-	-
TS 440	N & T	910 to 940	660 to 720	-	-	-
TS 450-1	N	910 to 940	-	-	-	-
TS 450-2 TC	FA ³⁾	860 to 960	-	-	-	-
TE	N & T	900 to 960	650 to 750	-	-	-
TS 460-2	N & T	930 to 980	650 to 720	-	-	-
TS 500 TC	FA ³⁾	850 to 950	-	-	-	-
TE	N & T	900 to 1000	700 to 800	-	-	-
TS 590 ⁷⁾	N & T	1050 to 1125	760 to 820	-	-	-
TS 610	N	880 to 980	580 to 680	-	-	-
TS 690	N & T	1020 to 1170	680 to 780	-	-	-
26 CrMo 4	QT	-	-	-	830 to 860	600 to 680
11 MnNi 5 3	N ⁴⁾	890 to 940	(580 to 640)	-	-	-
13 MnNi 6 3	N ⁴⁾	890 to 940	(580 to 640)	-	-	-
TS 43/TW 43	QT ⁵⁾	830 to 880	580 to 640	-	820 to 880	580 to 660
12 Ni 19	QT ⁵⁾	800 to 850	580 to 640	-	800 to 850	580 to 660
TS 45/TW 45	QT	880 to 930	-	-	770 to 820	540 to 600
¹⁾ N = Normalising; SA = Subcritical annealing; QT = Quenching and tempering; FA = Full annealing; N & T = Normalising and tempering ²⁾ Tubes and pipes for ordinary pressure systems may be delivered in the subcritical annealed condition. ³⁾ This heat treatment may be replaced by isothermal annealing at the discretion of the manufacturer. ⁴⁾ Tempering may be necessary after normalising. ⁵⁾ If the product dimensions so permit, normalising (with subsequent tempering if necessary) may be carried out.						

Table A2 Number of tubes or fittings per batch	
Outside diameter range (mm)	Number of tubes or fittings per batch ¹⁾
D ≤ 114.3	400
114.3 < D ≤ 323.9	200
323.9 < D	100
¹⁾ Any residual fraction of the batch is considered as a batch.	

A 900 Visual and non-destructive testing

901 All pipes for Class I and II pressure systems (for which a NV- certificate is requested) are to be presented for visual examination and verification of dimensions. In particular, their conformity with the requirements of 300 is to be confirmed.

A 1000 Hydraulic test

1001 Each tube and pipe is to be subjected to a hydraulic test at the manufacturer's work.

1002 The hydraulic test pressure is to be determined by the following equation:

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

where

P = test pressure, in bars
D = nominal outside diameter, in mm
t = nominal wall thickness, in mm
S = 80% of the specified minimum yield stress (R_{eH} or $R_{p0.2}$) in N/mm² for ferritic steels and 70% of the specified minimum proof stress ($R_{p1.0}$) in N/mm² for austenitic steels.

The maximum test pressure need not exceed 80 bar, or the maximum test pressure specified in the national or international standard referred to.

1003 The test pressure is to be maintained for sufficient time to permit proof and inspection, and for at least 5 s.

The tube is to withstand the test without showing leaks or visible deformation.

Unless otherwise agreed, the manufacturer's certificate of satisfactory hydraulic test will be accepted.

1004 Other pressure tests, such as pneumatic testing under water, may in special cases subject to agreement, be substituted for the hydraulic pressure tests.

1005 Subject to special approval, either an automatic ultrasonic or eddy current test can be accepted in lieu of the hydraulic test.

A 1100 Re-testing

1101 If one or more of the sample method tests prove unsatisfactory, the tube or pipe in question is rejected, and twice as many new pipes or tubes of the batch in question are to be selected for testing. All these tests are to show satisfactory results. If not, the whole batch is rejected. A renewed heat treatment of the batch and subsequent retesting of the material will be accepted. The tests are to be executed in the same way as for the first time. All results are to be satisfactory, if not, the whole batch will be rejected.

A 1200 Identification

1201 Pipes and tubes are to be clearly marked by the manufacturer in accordance with the requirements of Ch.1 Sec.1.

A 1300 Certification

1301 For tubes and pipes which have been accepted, a material certificate is to be issued. The level of documentation, i.e. NV- certificate, works certificate, etc., is given under the relevant part of the rules.

B. Tubes and Pipes for Ordinary Pressure Systems

B 100 Scope

101 These rules are applicable to seamless and welded carbon and carbon-manganese steel tubes and pipes for ordinary pressure systems. Tubes and pipes conforming to this subsection are intended for use at ambient temperature.

B 200 Manufacture

201 Tubes and pipes are to be manufactured seamless or by

a welding process, and may be hot or cold finished. When welded, an automatic electric welding process, with or without filler metal is to be applied.

B 300 Chemical composition

301 The chemical composition of ladle samples is to comply with the requirements given in Table B1. Steels for the production of tubes and pipes covered by this subsection are to be killed, except for steel TW 320 which may be semikilled.

B 400 Heat treatment

401 Seamless tubes and pipes are to be supplied in the hot-finished condition or one of the following heat treatment conditions (see Table A1):

- annealed
- normalised
- normalised and tempered.

Welded tubes and pipes are to be supplied in the normalised condition.

B 500 Mechanical properties

501 Tubes and pipes are to be presented for testing in batches as defined in A800. The number of tubes or pipes per batch is to comply with the conditions given in Table A2.

502 Two pipes are selected from each of at least two batches. From the remaining batches one pipe from each batch is selected for testing.

503 For each tube or pipe selected for testing the following tests are to be carried out:

Seamless tubes and pipes:

- one tensile test
- one flattening test or bend test or ring tensile test.

Welded tubes and pipes:

- one tensile test on the base material
- one tensile test on the weld for pipes with D ≤ 508 mm
- two flattening tests or two drift expanding tests or two bend tests (ERW and IW)
- two bend tests (SAW).

504 The results of all mechanical tests are to comply with the appropriate requirements given in Table B2, or an equivalent national or international standard.

Table B1 Chemical composition (ladle analysis) ¹⁾ , (%)					
Steel grade	C maximum	Si maximum	Mn	P maximum	S maximum
TW 320	0.16	-	0.30 to 0.70	0.040	0.040
TS 360/TW 360	0.17	0.35	0.30 to 0.80	0.040	0.040
TS 410/TW 410	0.21	0.35	0.40 to 1.20	0.040	0.040
TS 430/TW 430					
TS 500/TW 500 ²⁾	0.22	0.55	≤ 1.60	0.040	0.040

1) Elements not included in this table are not to be intentionally added without the agreement of the purchaser, except for elements such as aluminium which may be added for finishing the cast. All reasonable precautions are to be taken to prevent the addition of elements from scrap or other materials used in the manufacture; however, residual elements may be tolerated, provided that the mechanical properties and applicability are not adversely affected. A maximum copper content of 0.25% may be requested by the purchaser in order to facilitate subsequent operations of forming.

2) Additions of niobium, titanium and vanadium are permitted at the discretion of the manufacturer, unless otherwise agreed between the purchaser and the manufacturer, up to the levels permitted for non-alloyed steels in ISO 4948-1. In this case, the test certificate is to state the level of these elements.

Table B2 Mechanical properties at room temperature

Steel grade ¹⁾	Tensile test				Flattening test		Bend test	Drift expanding test ⁶⁾ Percentage increase of D			
	Tensile strength (N/mm ²)	Upper yield stress or proof stress R _{eH} or R _{p0.2} ²⁾ minimum for thicknesses in mm		Elongation ³⁾ A, minimum		Constant C for t/D ratio					
		t ≤ 16 (N/mm ²)	16 < t ≤ 40 (N/mm ²)	40 < t ≤ 65 (N/mm ²)	l (%)				t (%)	t/D ≤ 0.15	t/D > 0.15
TS 320 TS 360/TW 360	320 to 460 360 to 500	195 235	- 215	25 25	23 23	0.09	0.08	3 t 3 t	10 10	12 12	
	410 to 550 430 to 570	255 275	245 265	22 21	30 19	0.07 0.07	0.06 0.06	4 t 4 t	8 8	10 10	
TS 500/TW 500	500 to 650	355	345	4)	21 ⁴⁾	19 ⁴⁾	0.07	0.06	4 t	6	8

1) TS = seamless steel tubes; TW = welded steel tubes

2) For thicknesses greater than 65 mm for seamless tubes and 40 mm for welded tubes, the value to be obtained is to be the subject of agreement between the manufacturer and the purchaser at the time of ordering.

3) l = longitudinal; t = transverse.

4) For thicknesses greater than 40 mm for seamless tubes, the values for R_{eH} and A are to be subject of agreement between the manufacturer and the purchaser at the time of ordering.

5) d = internal diameter; D = external diameter

6) Only applicable for welded tubes and pipes.

C. Stainless Steel Pressure Tubes and Pipes

C 100 Scope

101 These rules are applicable to seamless and welded stainless steel tubes and pipes for use in the construction of the piping systems for chemicals, liquefied gases and bulk chemical tankers.

C 200 Manufacture

201 The tubes and pipes are to be manufactured seamless or by a welding process. When welded, an automatic electric welding process, with or without filler metal is to be applied.

C 300 Chemical composition

The chemical composition of ladle samples is to comply with appropriate requirements of Table C1 or an equivalent national or international standard.

C 400 Heat treatment

The tubes and pipes are normally to be supplied in the solution treated condition. Welded pipes may be delivered in the welded condition without subsequent heat treatment provided that approval testing has demonstrated satisfactory characteristics of the material. Where the pipes are supplied in the welded condition, the strips or plates used must be in the solution treated condition.

C 500 Mechanical properties

501 The pipes are to be presented for testing in batches as defined in A800. Each batch is to comprise 100 pipes.

502 Two tubes or pipes are to be selected from each of at least two batches. From the remaining batches one pipe from each batch is selected for testing.

503 Each pipe selected for test is to be subjected to the following tests:

For seamless tubes and pipes

- one tensile test
- one flattening test or bend test or ring tensile test
- one drift or one ring expanding test where appropriate.

For welded tubes and pipes

- one tensile test on the base material
- one tensile test on the weld for tubes with outside diameter > 219.1 mm.
- two flattening tests or bend tests or one ring tensile test.

504 Impact testing of austenitic stainless steels is required only for design temperatures below -105°C. Test temperature is to be -196°C.

505 The result of all mechanical tests is to comply with appropriate requirements given in Table C2 or an equivalent national or international standard.

C 600 Corrosion testing

601 For austenitic stainless steel pipes intended used for piping systems for chemicals, intercrystalline corrosion tests are to be carried out. The test is to be carried out in accordance with ASTM A 262 Practice E "Copper-Copper Sulphate-Sulphuric Acid Test", or an equivalent standard.

Table C1 Chemical composition (ladle analysis), of austenitic steels for seamless and welded tubes

AISI designation	Steel type ISO designation	Chemical composition, (%) ¹⁾								
		C	Si maximum	Mn maximum	P maximum	S maximum	Cr	Mo	Ni	Others
304L	X 2 CrNi 18 10	≤ 0.030	1.00	2.00	0.045	0.030	17.00 to 19.00	-	9.00 to 12.00	
304	X 5 CrNi 18 9	≤ 0.07	1.00	2.00	0.045	0.030	17.00 to 19.00	-	8.00 to 11.00	
347	X 6 CrNiNb 18 10	≤ 0.08	1.00	2.00	0.045	0.030	17.00 to 19.00	-	9.00 to 12.00	10x%C ≤ Nb ≤ 1.00 ²⁾
321	X 6 CrNiTi 18 10	≤ 0.08	1.00	2.00	0.045	0.030	17.00 to 19.00	-	9.00 to 12.00	5x%C ≤ Ti ≤ 0.80
316L	X 2 CrNiMo 17 13	≤ 0.030	1.00	2.00	0.045	0.030	16.50 to 18.50	2.5 to 3.0	11.50 to 14.00	
316	X 5 CrNiMo 17 13	≤ 0.07	1.00	2.00	0.045	0.030	16.50 to 18.50	2.5 to 3.0	11.00 to 14.00	

1) Elements not quoted in this table are not to be intentionally added without the agreement of the purchaser, other than for the purpose of finishing the heat. If in special cases, the purchaser considers that the level of residual elements is important in relation to the mechanical and technological properties of the steel in the intended application, the cast (ladle) analysis limits for such elements are to be agreed at the time of enquiry or order. The agreed elements are then to be analysed and the values reported.

2) Niobium content includes tantalum analysed as niobium.

Table C2 Mechanical properties at room temperature of austenitic stainless steels¹⁾

AISI designation	Steel type ISO designation	Tensile test						Impact test		Flattening test	Drift expanding test			
		$R_{p0.2}$ minimum (N/mm ²)	$R_{p0.1}$ minimum (N/mm ²)	R_m (N/mm ²)	Elongation, A ²⁾ (%)		KV, minimum, (J) ²⁾	t^4	Constant	Percentage increase of D, for D_p/D				
					l	t				l^3	t^4	≤ 0.6	> 0.6 ≤ 0.8	> 0.8
304L	X 2 CrNi 18 10	180	215	480 to 680	40	35	41	27	0.09	9	15	17		
304	X 5 CrNi 18 9	195	230	500 to 700	40	35	41	27	0.09	9	15	17		
347	X 6 CrNiNb 18 10	205	240	510 to 740	35	30	41	27	0.09	9	15	17		
321	X 6 CrNiTi 18 10	200	235	510 to 710	35	30	41	27	0.09	9	15	17		
316L	X 2 CrNiMo 17 13	190	225	490 to 690	40	35	41	27	0.09	9	15	17		
316	X 5 CrNiMo 17 13	205	240	510 to 710	40	30	41	27	0.09	9	15	17		

1) For thicknesses greater than 50 mm, the value to be obtained is to be the subject of agreement between the manufacturer and the purchaser at the time of ordering.

2) l = longitudinal; t = transverse.

3) Applicable only in cases where transverse test pieces cannot be taken.

4) Applicable for wall thicknesses > 20 mm.

D. Tubes and Pipes for Low Temperature Services

D 100 Scope

101 These rules are applicable to seamless and welded carbon, carbon-manganese, low alloy and nickel steel tubes and pipes intended for use in piping systems for liquefied gases. These rules are also applicable to other types of pressure piping systems where guaranteed impact properties at low temperature are required.

D 200 Manufacture

201 The tubes and pipes are to be manufactured seamless or by a welding process, and may be hot or cold finished.

D 300 Chemical composition

301 The chemical composition of ladle samples is to comply with the requirements given in Table D1.

Steels for the production of tubes and pipes covered by this subsection are to be killed.

D 400 Heat treatment

401 Seamless and welded tubes and pipes are to be delivered in the following heat treated conditions (see Table A1):

Unalloyed steels are to be normalised, except for TS 6/TW 6 which may also be delivered in the quenched and tempered condition.

Alloy steels are to be quenched and tempered, except for 11 MnNi 5 3 and 13 MnNi 6 3 which are to be delivered in the normalised or normalised and tempered condition. TS 43/TW 43 and 12 Ni 19 may also be normalised or normalised and tempered if the dimensions of the product so permit.

D 500 Mechanical properties

501 Tubes and pipes are to be presented for testing in batches as defined in A800. Each batch is to comprise 100 tubes or pipes.

502 Each tube or pipe selected for test is to be subjected to the following tests:

Seamless tubes and pipes

- one tensile test
- one set of impact tests
- one flattening test or bend test or ring tensile test
- one drift or one ring expanding test where appropriate.

Welded tubes and pipes

- one tensile test on the base material
- one tensile test on the weld for pipes with $D \geq 508$ mm
- one set of impact tests
- two flattening tests or bend tests or one ring tensile test (ERW and IW)
- one drift or one ring expanding test (ERW and IW)
- two bend tests (SAW).

503 The impact tests are to be carried out as Charpy V-notch tests, and are to consist of a set of three test pieces. The pieces are to be cut in the longitudinal direction with the notch perpendicular to the original surface of the pipe. The dimensions of the test pieces are to be in accordance with the requirements of Ch.1 Sec.2. Standard pieces are to be used except where the wall thickness of the pipe or pipe does not permit this size.

The impact values are to be determined at the lowest test temperature specified for the steel grade and the wall thickness in question, given in Table D3. Impact testing is not required for wall thicknesses below 6 mm.

504 The results of all mechanical tests, except impact testing, are to comply with the appropriate values given in Table D2.

The results from impact testing are to comply with the values in Table D3. Subsize impact test pieces of dimension 10x7.5 mm and 10x5 mm are to meet a requirement of 5/6 and 2/3 respectively of the values specified for standard test pieces.

Table D1 Chemical composition (ladle analysis) ¹⁾ , %											
Steel grade	C	Si maximum	Mn	P maximum	S maximum	Al minimum	Cr	Mo	Ni	V maximum	Nb maximum
Unalloyed steel											
TS 6/TW 6	≤0.17	0.35	0.40 - 1.00	0.030	0.025	0.015 ²⁾	-	-	-	-	-
TS 10/TW 10	≤0.19	0.35	0.60 - 1.20	0.030	0.025	0.015 ²⁾	-	-	-	-	-
TS 15/TW 15	≤0.20	0.35	0.80 - 1.40	0.030	0.025	0.015 ²⁾	-	-	-	-	-
Alloy steel											
26 CrMo 4	0.22 - 0.29	0.35	0.50 - 0.80	0.030	0.025	-	0.90 - 1.20	0.15-0.30	-	-	-
11 MnNi 5 3	0.14	0.50	0.70 - 1.50	0.030	0.025	0.020 ³⁾	-	-	0.30 ⁴⁾ - 0.80	0.05	0.05
13 MnNi 6 3	0.18	0.50	0.85 - 1.65	0.030	0.025	0.020 ³⁾	-	-	0.305 ⁴⁾ - 0.85	0.05	0.05
TS 43/TW 43	0.15	0.15 - 0.35	0.30 - 0.80	0.025	0.020	-	-	-	3.25 - 3.75	0.05	-
12 Ni 19	0.15	0.35	0.30 - 0.80	0.025	0.020	-	-	-	4.50 - 5.30	0.05	-
TS 45/TW 45	0.13	0.15 - 0.35	0.30 - 0.80	0.025	0.020	-	-	max. 0.10	8.50 - 9.50	0.05	-
1) Elements not included in this table may not be intentionally added without the agreement of the purchaser except for elements which may be added for deoxidation and finishing of the heat. All reasonable precautions are to be taken to prevent the addition of elements from scrap or other materials used in the manufacture, but residual elements may be presented, provided that the mechanical properties and applicability are not adversely affected. If the amount of residual elements is likely to affect the weldability of the steel, the content of such elements (ladle analysis) is to be documented											
2) Metallic aluminium content. Where determination of the total aluminium content is performed, the result is to be deemed to meet this requirement, provided the total aluminium content is to be determined. Alternatively, an austenitic grain size of 6 or finer, determined in accordance with ISO 643, can be agreed. By agreement between the interested parties, aluminium may be replaced by other elements having a similar effect.											
3) Total aluminium content. By agreement between the interested parties, aluminium may be replaced by other elements having a similar effect.											
4) The lower limit value for the nickel content may be reduced to 0.15% by mass for tubes with wall thickness not exceeding 10 mm.											

Table D2 Mechanical properties at room temperature

Steel grade	Tensile test				Bend test	Flatten- ing test	Drift expanding test ⁴⁾			Ring expanding test ⁴⁾				
	Tensile strength (N/mm ²)	Upper yield stress or proof stress R _{eH} or R _{p0.2} I) minimum for thicknesses in mm					Elonga- tion I) A, mini- mum (%)	Diameter of mantrel (mm)	% increase of D for D _i /D			% increase of D for D _i /D		
		t ≤ 13 (N/mm ²)	13 < t ≤ 25 (N/mm ²)	25 < t ≤ 40 (N/mm ²)					≤ 0.6 (%)	> 0.6 ≤ 0.8	> 0.8	> 0.5 ≤ 0.6	> 0.6 ≤ 0.8	> 0.8 ≤ 0.9
Unalloyed steel	360 - 480	215	215	3)	4T	0.10	12	15	19	30	25	15	10	8
	360 - 490	255	255	235	-	-	-	-	-	-	-	-	-	8
	410 - 530	235	235	3)	4T	0.08	10	12	17	30	25	15	10	8
	460 - 580	265	275	3)	4T	0.07	8	10	15	30	25	15	10	8
Alloy steels	560 - 740	440	440	420	-	0.06	-	-	-					
	410 - 530	285	275	265	-	0.07	-	-	-					
	490 - 610	355	345	335	-	0.07	-	-	-					
	440 - 590	245	245	245	-	0.08	6	8	12					
	510 - 710	390	390	380	-	0.06	-	-	-					
	690 - 840	510	510	510	-	0.08	6	8	12					
1) For wall thicknesses greater than 40 mm, the value to be obtained is to be the subject of agreement between the manufacturer and the purchaser at the time of ordering.														
2) N = Normalising; QT = Quenching and tempering.														
3) To be agreed at the time of ordering.														
4) Not applicable for submerged arc welded (SAW) tubes.														

1) For wall thicknesses greater than 40 mm, the value to be obtained is to be the subject of agreement between the manufacturer and the purchaser at the time of ordering.

2) N = Normalising; QT = Quenching and tempering.

3) To be agreed at the time of ordering.

4) Not applicable for submerged arc welded (SAW) tubes.

Table D3 - Impact properties at low temperature																	
Steel grade		Wall thickness ¹⁾ T (mm)	Orientation of test pieces with respect to tube axis	Minimum impact value KV, 2) 3), in J, average of three test pieces													
				Temperature (°C)													
				-196	-120	-110	-100	-90	-60	-50	-40	-20	+20				
Unalloyed steel	TS 6/TW 6 (N)	≤ 10	Longitudinal														
	TS 6/TW 6 (QT)	≤ 25 25 < T ≤ 40	Longitudinal Transverse 4) Longitudinal Transverse 4)									40 27	45 30 40 45 27	50 35 40 45 30	60 40 55 35		
	TS 10/TW 10 TS 15/TW 15	≤ 25	Longitudinal Transverse 4)									27	40	45	50	35	
	26 CrMo 4	≤ 25	Longitudinal Transverse 4)							40 27	40	27	45	50	60	40	
Alloy steel	11 MnNi 5 3 13 MnNi 6 3	≤ 40	Longitudinal Transverse 4)									45 30	55 40	60 45	65 45	70	45
	TS 43/TW 43	≤ 25 25 < T ≤ 40	Longitudinal Transverse 4) Longitudinal Transverse 4)				40 27	45 40 27	50 35 45 30	55 40 50 30	60 45 55 40	65 45 55 40	70	45	45	45	
	12 Ni 19	≤ 25 25 < T ≤ 40	Longitudinal Transverse 4) Longitudinal Transverse 4)		40 27	45 30 40 27	50 30 45 30	55 35 60 30	65 45 60 40	70 45 65 45	75 50 70 45	80 55 75 45	85 60 80 45	90 65 85 45	95 70 90 45	100	
	TS 45/TW 45	≤ 40	Longitudinal Transverse 4)	40 27	50 35	55 35	60 40	65 45	70 50	75 55	80 60	85 65	90 70	95 75	100 80	105	
	The values for tubes with wall thickness exceeding 40 mm, with the exception of steels TS 6(N) and TS 6(QT), are to be agreed at the time of ordering.													50	50		
1) The values for tubes with wall thickness exceeding 40 mm, with the exception of steels TS 6(N) and TS 6(QT), are to be agreed at the time of ordering.																	
2) Single values not less than 70% of the average.																	
3) The values apply to standard 10x10 mm test pieces. For different sizes of test pieces, see 504.																	
4) Transverse test pieces are to be used only by agreement.																	

E. Tubes and Pipes for Boilers, Heat Exchangers and Superheaters

E 100 Scope

101 These rules are applicable to seamless and welded carbon, carbon-manganese and low alloy steel tubes and pipes for boilers, superheaters and heat exchangers.

102 Austenitic stainless steels may also be used for high temperature service. Where such applications are proposed, details of the chemical composition, heat treatment and mechanical properties are to be submitted for approval.

E 200 Manufacture

201 The tubes and pipes are to be manufactured seamless or by a welding process, and may be hot or cold finished.

E 300 Chemical composition

301 The chemical composition of ladle samples is to comply with the requirements given in the Tables E1 and E3.

Steels for the production of tubes and pipes covered by this subsection are to be killed.

E 400 Heat treatment

401 Tubes and pipes are to be suitably heat treated over their full length. The following heat treatment is to be used depending of the type of steel (see Table A1):

- normalising
- normalising and tempering, or isothermal annealing
- full annealing or isothermal annealing.

E 500 Mechanical properties

501 Tubes and pipes are to be presented for testing in batches as defined in A800. Each batch is to comprise 100 tubes.

502 Two tubes or pipes are to be selected from each of at least two batches. From the remaining batches one pipe from each batch is selected for testing.

503 For each tube or pipe selected for test the following tests are to be carried out:

Seamless tubes and pipes

- one tensile test
- one flattening test or bend test or ring tensile test
- one drift or one ring expanding test where appropriate.

Welded tubes and pipes

- one tensile test on the base material
- one tensile test on the weld for pipes with DŠ 508 mm
- two flattening tests or bend tests or one ring tensile test (ERW and IW)
- one drift or ring expanding test (ERW and IW)
- two bend tests (SAW).

504 The results of all mechanical tests are to comply with the appropriate values given in the Tables E2 and E4.

Table E1 Chemical composition (ladle analysis)¹⁾ for seamless tubes and pipes, (%)

Steel grade	C	Si	Mn	P maximum	S maximum	Cr	Mo	Ni	V	Nb	Al maximum	Others
Unalloyed steel												
TS 360	≤ 0.17	0.10 - 0.35	0.30 - 0.80	0.035	0.035	-	-	-	-	-	-	2)
TS 410-1	≤ 0.21	0.10 - 0.35	0.40 - 1.20	0.035	0.035	-	-	-	-	-	-	2)
TS 460-1	≤ 0.22	0.10 - 0.40	0.65 - 1.40	0.035	0.035	-	-	-	-	-	-	2)
TS 510	≤ 0.22 ³⁾	0.15 - 0.55	1.00 - 1.50 ³⁾	0.035	0.035	-	-	-	5)	5)	-	2)4)
Alloy steel												
TS 380	0.10 - 0.20	0.10 - 0.50	0.30 - 0.80	0.035	0.035	-	0.45 - 0.65	-	-	-	0.020	2)
TS 410-3	≤ 0.15	≤ 0.50	0.30 - 0.60	0.035	0.035	0.80 - 1.25	0.45 - 0.65	-	-	-	0.020	2)
TS 410-4	≤ 0.15	0.50 - 1.00	0.30 - 0.60	0.030	0.030	1.00 - 1.50	0.45 - 0.65	-	-	-	0.020	2)
TS 430	0.08 - 0.15	0.15 - 0.50	0.30 - 0.60	0.030	0.030	4.00 - 6.00	0.45 - 0.65	-	-	-	0.020	2)
TS 440	0.10 - 0.17 ⁵⁾	0.15 - 0.35	0.40 - 0.70	0.035	0.035	0.70 - 1.10	0.45 - 0.65	-	-	-	0.020	2)
TS 450-1	0.12 - 0.20 ⁵⁾	0.15 - 0.35	0.40 - 0.80	0.035	0.035	-	0.25 - 0.35	-	-	-	0.020	2)
TS 450-2	0.08 - 0.15	0.15 - 0.40	0.30 - 0.80	0.035	0.035	2.00 - 2.50	0.90 - 1.20	-	-	-	0.020	2)
TS 460-2	0.10 - 0.15	0.15 - 0.35	0.40 - 0.70	0.035	0.035	0.30 - 0.60	0.50 - 0.70	-	0.22 - 0.28	-	0.020	2)
TS 500	0.08 - 0.15	0.25 - 1.00	0.30 - 0.60	0.030	0.030	8.00 - 10.00	0.90 - 1.10	-	-	-	0.020	2)
TS 590 ⁶⁾	≤ 0.15	0.20 - 0.65	0.80 - 1.30	0.030	0.030	8.50 - 10.50	1.70 - 2.30	≤ 0.30	0.20 - 0.40	0.30 - 0.55	0.020	2)
TS 610	≤ 0.17	0.25 - 0.50	0.80 - 1.20	0.030	0.030	≤ 0.30	0.25 - 0.40	1.00 - 1.30	-	0.015 - 0.045	0.020	Cu 0.50 - 0.80
TS 690	0.17 - 0.23	0.15 - 0.50	≤ 1.00	0.030	0.030	10.00 - 12.50	0.80 - 1.20	0.30 - 0.80	0.25 - 0.35	-	0.020	2)

1) Elements not included in this table may not be intentionally added without the agreement of the purchaser except for elements which may be added for deoxidation and finishing of the heat. All reasonable precautions are to be taken to prevent the addition of elements from scrap or other materials used in the manufacture, but residual elements may be presented, provided that the mechanical properties and applicability are not adversely affected. If the amount of residual elements is likely to affect the weldability of the steel, the content of such elements (ladle analysis) is to be documented.

2) A maximum copper content of 0.25% may be requested by the purchaser in order to facilitate subsequent operations of forming.

3) For tubes with wall thickness greater than 30 mm, the upper limit of the carbon content may be increased by 0.02% but the (C + Mn/6) value is never to exceed 0.47%.

4) Additions of niobium, titanium and vanadium are permitted at the discretion of the manufacturer, unless otherwise agreed between the purchaser and the manufacturer, up to the levels permitted for non-alloyed steels. In that case the test certificate is to state the level of these elements.

5) For tubes with wall thickness greater than 30 mm the upper limit of the carbon content may be increased by 0.02%.

6) Applicable for tubes with wall thickness not exceeding 15 mm.

Table E2 Mechanical properties at room temperature for seamless tubes and pipes

Steel grade	Tensile test				Bend test	Flatten- ing test	Drift expanding test			Ring expanding test ⁵⁾					Impact test ²⁾		
	Tensile strength (N/mm ²)	Upper yield stress or proof stress R _{eH} or R _{p0.2} ¹⁾ minimum for thicknesses in mm ¹⁾	Elongation ²⁾ A, minimum, (%)														
			Diameter of mantrel (mm)	Constant K	% increase of D for D _i /D										J	J	
					t ≤ 16 (N/mm ²)	16 < t ≤ 40 (N/mm ²)	40 < t ≤ 65 (N/mm ²)	l	t								≤ 0.6
Unalloyed steel																	
TS 360	360 - 480	235	225	215	25	23	0.09	12	15	19	30	25	15	10	8	27	35
TS 410-1	410 - 530	255	245	235	21	19	0.07	10	12	17	30	25	15	10	8	27	35
TS 460-1	460 - 580	270	270	260	23	21	0.07	8	10	15	30	25	15	10	8	27	35
TS 510	510 - 640	310	310	300	19	17	0.07	8	10	15	30	25	15	10	8	27	35
Alloy steels																	
TS 380	380 - 530	205	205	205	22	20	0.08	8	10	15	-	-	-	-	-	27	35
TS 410-3	410 - 560	205	205	205	22	20	0.08	8	10	15	30	20	10	8	6	27	35
TS 410-4	410 - 560	205	205	205	22	20	0.08	8	10	15	30	20	10	8	6	27	35
TS 430	430 - 580	205	205	205	20	18	0.07	8	10	15	30	20	10	8	6	27	35
TS 440	440 - 590	290 ⁵⁾	290	280	22	20	0.07	8	10	15	30	20	10	8	6	27	35
TS 450-1	450 - 600	270 ⁵⁾	270	260	22	20	0.07	8	10	15	30	20	10	8	6	27 ⁶⁾	35 ⁶⁾
TS 450-2, TC ⁷⁾	410 - 560	205	205	205	22	20	0.08	8	10	15	-	-	-	-	-	27	35
TS 450-2, TE ⁷⁾	450 - 600	280	280	270	20	18	0.07	8	10	15	30	20	10	8	6	27	35
TS 460-2	460 - 610	320	320	310	20	18	0.05	8	10	15	30	20	10	8	6	27 ⁸⁾	35 ⁸⁾
TS 500, TC ⁷⁾	440 - 620	205	205	205	20	18	0.07	8	10	15	30	20	10	8	6	27	35
TS 500, TE ⁷⁾	590 - 740	390	390	390	18	16	0.07	8	10	15	30	20	10	8	6	27	35
TS 590	590 - 740	390	390	390	18	16	0.07	8	10	15	30	20	10	8	6	27	35
TS 610	610 - 780	440	440	440	19	17	0.05	8	10	15	30	20	10	8	6	27	35
TS 690	690 - 840	490	490	490	17	14	0.05	6	8	12	30	20	10	8	6	27 ⁸⁾	35 ⁸⁾

1) For wall thicknesses greater than 65 mm, the value to be obtained is to be the subject of agreement between the manufacturer and the purchaser at the time of ordering.

2) l = longitudinal; t = transverse.

3) Applicable for wall thicknesses > 30 mm, unless otherwise indicated.

4) Applicable only in cases where transverse test pieces cannot be taken.

5) For wall thicknesses below or equal to 10 mm the minimum value of yield stress is increased by 10 N/mm².

6) Applicable for wall thicknesses > 20 mm.

7) TC = full or isothermal annealing; TE = normalising and tempering.

8) Applicable for wall thicknesses > 10 mm.

Table E3 Chemical composition (ladle analysis) 1) 6) for welded tubes and pipes, %									
Steel grade	C	Si	Mn	P maximum	S maximum	Cr	Mo	Al maximum	Others
Unalloyed steel									
----- TW 360	≤ 0.17	0.10 - 0.35 (≤ 0.35)	0.30 - 0.80 (0.40 - 1.20)	0.035	0.030	-	-	-	2)
TW 410	≤ 0.21 (≤ 0.20)	0.10 - 0.35 (≤ 0.35)	0.40 - 1.20 (0.50 - 1.40)	0.035	0.030	-	-	-	2)
TW 460	≤ 0.22 (≤ 0.20)	0.10 - 0.40 (≤ 0.35)	0.65 - 1.40 (0.90 - 1.50)	0.035	0.030	-	-	-	2)
TW 510	≤ 0.22 3)	0.15 - 0.55 (≤ 0.35)	1.00 - 1.50 3)(0.90 - 1.60)	0.035	0.030	-	-	-	2) 4)
Alloy steel									
----- TS 450-1	0.12 - 0.20 5)	0.15 - 0.35	0.40 - 0.80 (0.40 - 0.90)	0.035	0.030	(≤ 0.30)	0.25 - 0.35	0.020 (-)	2)
TS 440	0.10 - 0.17 5) (0.10 - 0.17)	0.15 - 0.35	0.40 - 0.70 (0.40 - 1.00)	0.035	0.030	0.70 - 1.15	0.40 - 0.60	0.020 (-)	2)
TS 450-2	0.08 - 0.15	0.15 - 0.40 (0.15 - 0.50)	0.30 - 0.70	0.035	0.030	2.00 - 2.50	0.90 - 1.10	0.020 (-)	2)
<p>1) Elements not included in this table may not be intentionally added without the agreement of the purchaser except for elements which may be added for deoxidation and finishing of the heat. All reasonable precautions are to be taken to prevent the addition of elements from scrap or other materials used in the manufacture, but residual elements may be presented, provided that the mechanical properties and applicability are not adversely affected. If the amount of residual elements is likely to affect the weldability of the steel, the content of such elements (ladle analysis) is to be documented.</p> <p>2) A maximum copper content of 0.25% may be requested by the purchaser in order to facilitate subsequent operations of forming.</p> <p>3) For tubes with wall thickness greater than 30 mm, the upper limit of the carbon content may be increased by 0.02% but the (C + Mn/6) value is never to exceed 0.47%.</p> <p>4) Additions of niobium, titanium and vanadium are permitted at the discretion of the manufacturer, unless otherwise agreed between the purchaser and the manufacturer, up to the levels permitted for non-alloyed steels. In that case the test certificate is to state the level of these elements.</p> <p>5) For tubes with wall thickness greater than 30 mm the upper limit of the carbon content may be increased by 0.02%.</p> <p>6) The values in brackets are valid for ERW and IW pipes.</p>									

Table E4 Mechanical properties at room temperature for welded tubes and pipes

Steel grade	Tensile test						Bend test	Drift expanding test ⁵⁾			Ring expanding test ⁵⁾					Impact test ²⁾		
	Tensile strength	Upper yield stress or proof stress				Elongation ²⁾ A. minimum. (%)												
		R_{eH} or $R_{p0.2}$ ¹⁾ minimum for thicknesses in mm																
		$t \leq 16$ (N/mm ²)	$16 < t \leq 40$ (N/mm ²)	$40 < t \leq 65$ (N/mm ²)	t													
	N/mm ²																	
Unalloyed steel																		
Alloy steels																		

1) For wall thicknesses greater than 65 mm, the value to be obtained is to be the subject of agreement between the manufacturer and the purchaser at the time of ordering.

2) 1 = longitudinal; t = transverse.

3) Applicable for wall thicknesses > 30 mm, unless otherwise indicated.

4) Applicable only in cases where transverse test pieces cannot be taken.

5) Drift- and ring expanding tests are only applicable for electric resistance and induction welded tubes and pipes.

6) Applicable for wall thicknesses > 20 mm.

7) The greatest diameter of mantrel is applicable for submerged arc welded (SAW) tubes and pipes.

8) For wall thicknesses below or equal to 10 mm the minimum value of yield stress is increased by 10 N/mm².

1) For wall thicknesses greater than 65 mm, the value to be obtained is to be the subject of agreement between the manufacturer and the purchaser at the time of ordering.

2) 1 = longitudinal; t = transverse.

3) Applicable for wall thicknesses > 30 mm, unless otherwise indicated.

4) Applicable only in cases where transverse test pieces cannot be taken.

5) Drift- and ring expanding tests are only applicable for electric resistance and induction welded tubes and pipes.

6) Applicable for wall thicknesses > 20 mm.

7) The greatest diameter of mantrel is applicable for submerged arc welded (SAW) tubes and pipes.

8) For wall thicknesses below or equal to 10 mm the minimum value of yield stress is increased by 10 N/mm².

F. Fittings

F 100 Scope

101 These rules are applicable to seamless and welded carbon, carbon-manganese, low alloy and alloy steel fittings for the applications covered by subsections B,C, D and E.

F 200 Materials

201 The materials to be used as basis for the manufacture of fittings are to meet the requirements of the relevant subsection, with respect to chemical composition, mechanical properties and manufacture.

202 The materials used for the manufacture of fittings are at least to be delivered with an inspection documentation corresponding to a works certificate.

F 300 Manufacture

301 Fittings may be hot or cold formed from tubes and pipes or may be welded from plate material. The Society is to be informed about the method of manufacture.

302 Where fittings are made by a welding process, details of the process are to be forwarded to the Society for approval. A procedure test may be requested by the surveyor.

F 400 Heat treatment

401 After the forming process all fittings are to be supplied in the heat treated condition specified for the material in question (see Table A1).

402 For fittings in carbon and carbon-manganese steels manufactured by hot forming where normalising is specified, subsequent heat treatment may be dispensed with if the manufacturer can give evidence of satisfactory properties and structure after hot forming.

403 Fittings manufactured by cold forming are generally to undergo renewed heat treatment. If fittings are to be delivered in the cold formed condition the manufacturer must prove that the materials possess the required properties.

F 500 Mechanical testing

501 The fittings are to be presented for testing in batches as defined in A800. Two fittings from each batch are to be selected for testing.

The test samples are to be from the same heat and are to undergo the same forming process and heat treatment as the fitting itself.

502 For each fitting the following tests are to be carried out:

Seamless fittings

- one tensile test
- one flattening test or bend test or ring tensile test
- one drift or one ring expanding test where appropriate.

Welded fittings

- one tensile test on the base material
- one tensile test on the weld for pipes with D ≤ 508 mm
- two flattening tests or bend tests or one ring tensile test (ERW and IW)
- one drift or ring expanding test (ERW and IW)
- two bend tests (SAW).

503 If fittings are to be used in low temperature systems where impact testing is required, impact testing is to be carried out in accordance with the appropriate requirements of subsection C500 and D500.

504 The results of all mechanical tests are to comply with the requirements of the relevant part of this section, or satisfy the required characteristics specified for the starting material used (e.g. plates).

505 For fittings where tensile testing is not possible, this test is to be carried out on material from the tube before forming.

F 600 Hardness testing

601 Hardness testing is to be carried out on 10% of the test unit, and on at least 3 fittings where the numbers are less than 30. The difference in hardness value within the unit tested may not be greater than 30 Brinell units.

F 700 Corrosion testing

701 Where fittings of austenitic stainless steels are to be used in systems where corrosion testing of the pipes are required, testing is to be carried out in accordance with C600.

F 800 Surface finish and dimensions

801 The quality and dimensions of the fittings are subject to the same requirements as pipes of the same dimensions, see A300 and A400.

F 900 Marking and certification

901 The fitting is to be marked in accordance with A1200 and the level of documentation is to be in accordance with A1300.

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 are to 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 are to 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 are to 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 are to 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 are to 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 is to be made by a process approved by the Society. All forgings are to be made from killed steel.

303 For forgings with specified minimum ultimate tensile strength 800 N/mm² or above, the molten steel is to 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 are to be cast in chill moulds with the larger cross-section up, and with efficient feeder heads. Adequate top and bottom discards are to 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, are to be removed.

305 The material is to be progressively hot worked by hammer or press, and is to 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 is to be undertaken in accordance with recognised good practice and, unless otherwise approved, is to be carried out before the final heat treatment.

306 The reduction ratio is to 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 is to 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 is to 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 is to 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 type	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	Fine	0
	Thick	0

A 400 Chemical composition

401 The chemical composition of each heat is to be determined by the manufacturer on a sample taken preferably during the pouring of the heat and is to 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 is to be reported.

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

A 500 Heat treatment

501 All forgings are to be heat treated for mechanical properties as specified in B to H. Heat treatment is to 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 are to be such as to allow the whole furnace charge to be uniformly heated to the necessary temperature.

502 Sufficient thermocouples are to 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 is to maintain records of heat treatment identifying the furnace used, furnace charge, date, temperature and time at temperature. The records are to be presented to the surveyor on request.

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

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

506 If a forging is locally reheated or any straightening operation is performed after the final heat treatment, consideration is to 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, is to be integral with the forging except as provided in 603. Test material is to 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 is to be provided by increasing the diameter, thickness, or length of the forging.

602 Except for closed die forgings or for components which are to be carburised or for hollow forgings where the ends are to be subsequently closed or for forgings submitted to re-heat treatment, the test material is not to 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 is to have a cross-section and a reduction ratio similar to that used for the forgings represented.

604 All test material is to 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 is to be positioned as follows:

- a) For thickness or diameter up to maximum 50 mm, the axis is to be at the mid-thickness or the centre of the cross section.
- b) For thickness or diameter greater than 50 mm, the axis is to 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 are to 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 are to 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 is to 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 is to 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 is to 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 is to 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 are to 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 is to be related to the total length and mass of the original multiple forging.

A 800 Mechanical properties

801 The material is to 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 are to be repeated after re-heat treatment and the results must meet the specified requirements.

A 900 Inspection

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

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

903 When visually inspected, forgings are to 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 are to be carried out by personnel qualified and certified in accordance with recognised standards or schemes, e.g. ISO 9712, EN 473 or ASNT. Non-destructive testing is to be performed in accordance with the general practice of recognised standards, e.g.:

- 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 are to be carried out after the final heat treatment when the surface is in the final condition, but before any peening. Machined forgings are to 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 are to be carried out after the final heat treatment when the forgings have been ma-

chined to a condition suitable for UT, but prior to drilling of bores and prior to surface hardening. Both radial and axial scanning is to 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 is to ensure that a suitable ultrasonic test is carried out to verify the internal quality.

909 The extent of non-destructive testing and acceptance criteria are to 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 is to maintain records of own inspections including dimensional measurements traceable to each forging. The records are to be presented to the surveyor on request. The forging manufacturer is 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 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 are to have a bottom radius of approximately three times the groove depth and are to be blended into the surrounding surface so as to avoid any sharp contours. Complete elimination of the defective material is to be verified by magnetic particle testing or liquid penetrant testing.

1002 Unless otherwise approved for hull forgings, the permissible depth of grinding is to 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 are to be submitted for the approval.

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

A 1100 Identification

1101 Each forging which has been tested and inspected with satisfactory results is to 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 is to 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 are to 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 are to be agreed with the Society.

B 400 Mechanical testing

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

402 The mechanical properties are to 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 is to be carried out on forgings intended for rudder stocks and pintles with diameter larger than 100 mm, see A906.

502 Ultrasonic testing is to 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 is to 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 are to 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 is to 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 is to 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 are to 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 are to 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 are to be agreed with the Society.

C 400 Mechanical testing

401 Longitudinal tests are to 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 are to be made provided the shape and dimensions make it possible.

402 The mechanical properties are to 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 is to be carried out as specified in the relevant construction rules.

vant construction rules.

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

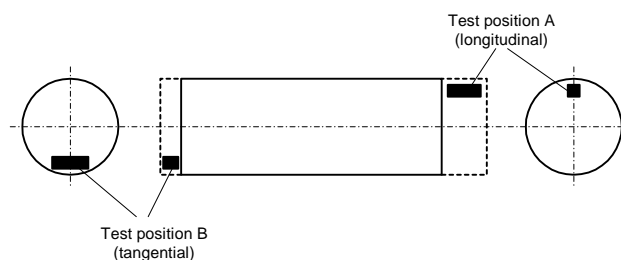


Fig. 1
Plain shaft

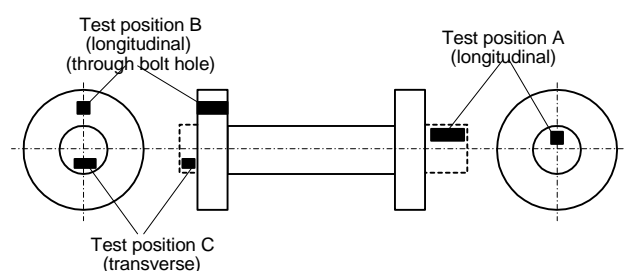


Fig. 2
Flanged shaft

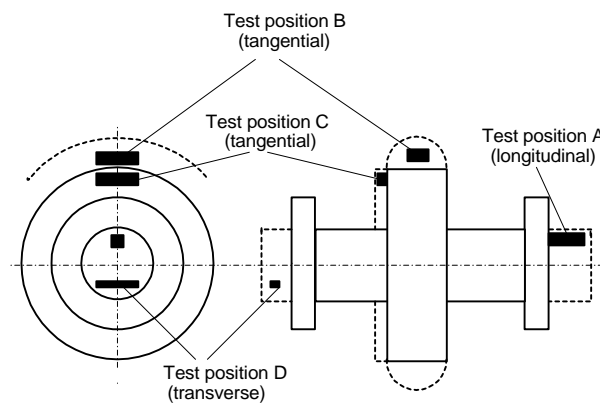


Fig. 3
Flanged shaft with collar

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 are to 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 is to 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 is to be carried out at +20°C.
2) For propeller shafts intended for ships with class notation **Icebreaker** or **POLAR**, Charpy V-notch impact testing is to be carried out for all steel types at minus 10°C and the average energy value is to 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 is to 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 are to 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 are to 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 are to be agreed with the Society.

D 400 Mechanical testing

401 For solid forged crankshafts, one set of longitudinal tests is to 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 is to 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 are to 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 are to 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 are to be made on at least 10% of the forgings.

D 500 Inspection

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

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

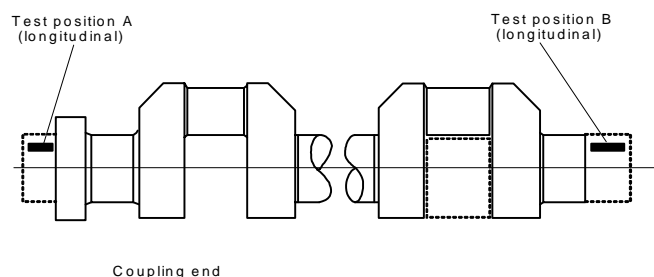


Fig. 4
Solid forged crankshaft

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 is to 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 are to 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 are to be quenched and tempered at a temperature of not less than 540°C.

303 Forgings for gears which are to be carburised are to be supplied in either the fully annealed or the normalised and tempered condition. Forgings for gears which are to be induction hardened or nitrided are to 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 are to 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 are to 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 are to be taken (test position A in Fig. 5). Where the finished length of the toothed portion exceeds 1250 mm, tests are to be taken from each end.

402 Small pinions

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

403 Gear wheels

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

404 Gear wheel rims (made by expanding)

Tangential tests are to 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 are to be taken from two diametrically opposite positions.

405 Hollow pinions

Tangential tests are to be taken (test position A in Fig. 8). Where the finished length of the toothed portion exceeds 1250 mm, tests are to 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 is to be made on each forging. The variation in hardness in each batch shall not exceed 30 Brinell Hardness numbers.

407 The mechanical properties are to 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 are to be carburised after machining, sufficient test material is to 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 is to be carried out as specified in Pt.4 Ch.4 Sec2.

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

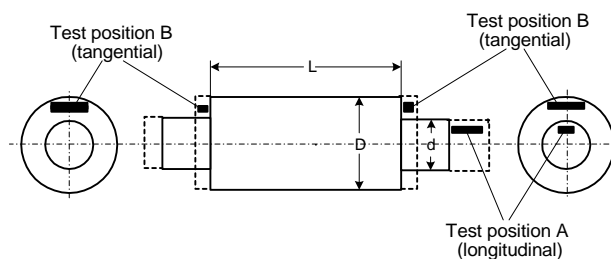


Fig. 5
Pinion

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

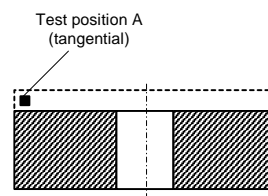


Fig. 6
Gear wheel

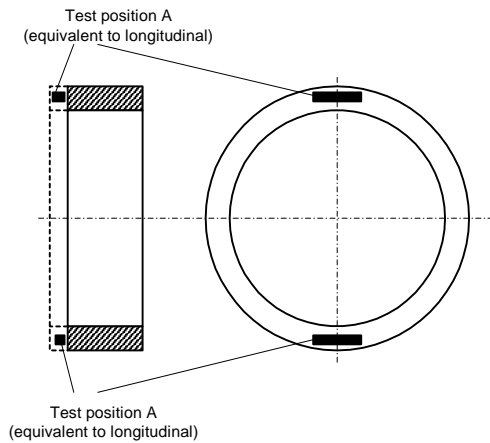


Fig. 7
Gear rim (made by expanding)

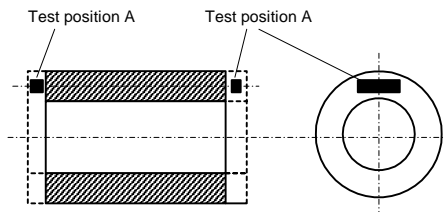


Fig. 8
Hollow pinion

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 is to 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 are to 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 are to 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 are to be agreed with the Society.

F 400 Mechanical properties

401 The mechanical properties are to 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 are to 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 are to 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					
<i>Steel type</i>	<i>Grade</i>	<i>Yield stress R_e minimum (N/mm²)</i>	<i>Tensile strength R_m(N/mm²)</i>	<i>Elongation A₅ minimum (%)</i>	<i>Reduction of area Z minimum (%)</i>
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 is to 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 is to be within 0.01 to 0.05%, V is to be 0.05% maximum and Ti is to be 0.02% maximum.

G 300 Heat treatment

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

a) Normalised.

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

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

302 Alloy steel forgings are to 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 are to 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 are to 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 are to 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											
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			0.25	0.08	3.25 - 3.75			-
5 Ni	0.12		0.025	0.025			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 are to 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 is to 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 is to be carried out at –196°C and the average energy value is to 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 is to 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 are to 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 is to 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) is to be taken for every 50 ton or fraction thereof of bar material from the same cast. The tests are to be taken from the bar of the largest diameter.

Test material from bars is to 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 are to be cut as shown in Fig. 1.

The tests are to 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.

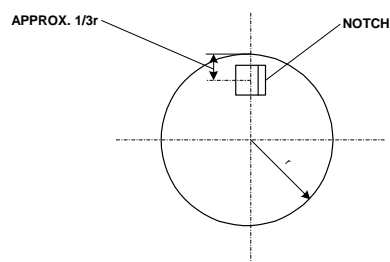


Fig. 1
Position of impact test piece.

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 are to 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 are to 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 are to 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.

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

A 300 Manufacture

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

302 Steel is to 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 are to be made from killed steel.

303 Where flame cutting, scarfing or arc-air gouging to remove surplus metal is undertaken, the affected areas are to 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 is to be submitted for approval. Welding procedure qualification tests may be required.

A 400 Chemical composition

401 The chemical composition of each heat is to be determined by the manufacturer on a sample taken preferably during the pouring of the heat and is to 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 is to be reported.

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

The content of such elements is to be reported.

A 500 Heat treatment

501 All castings are to be heat treated as specified in B to G. Heat treatment is to 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 are to be such as to allow the whole furnace charge to be uniformly heated to the necessary temperature.

502 Sufficient thermocouples are to 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 is to maintain records of heat treatment identifying the furnace used, furnace charge, date, temperature and time at temperature. The records are to 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, are to 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 are not to 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 are to receive substantially the same casting practices as the castings represented.

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

604 The dimensions of test blocks are to be in accordance with recognised standards but in all cases are to have a thickness of not less than 28 mm. The test pieces are to 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 are to 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 is to 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 is to 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 are to 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 are to 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 are to be repeated after re-heat treatment and the results must meet the specified requirements.

A 900 Inspection

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

902 Castings for which certification by the Society is required are to 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 are to 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 are to be carried out by personnel qualified and certified in accordance with recognised standards or schemes, e.g. ISO 9712, EN 473 or ASNT. Non-destructive testing is to be performed in accordance with the general practice of recognised standards, e.g.:

- 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 are to be carried out after the final heat treatment when the surface is in the final condition, but before any cold working. Machined castings are to 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.

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

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 are to 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 are to be agreed with the Society. For hull castings, IACS Recommendation No. 69 is regarded as an example of an acceptable standard.

911 The foundry is to maintain records of own inspections including dimensional measurements traceable to each casting. The records are to 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 are to have a bottom radius of approximately three times the groove depth and are to 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 is to 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 is to be repaired by welding. Shallow defective areas (see 1001) may also be repaired by welding. The excavations are to be suitably shaped to allow good access for welding. The resulting grooves are to be subsequently ground smooth and complete elimination of the defective material is to 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 are to be accompanied by sketches or photographs showing the extent and positions of the repairs. A grain refining heat treatment is to 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 are to be presented to the surveyor on request.

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

1007 The welding consumables used are to 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 are to be used. Welding consumables are to 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 is to 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 are to be ground smooth. All weld repairs are subject to non-destructive testing as required by 900.

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

A 1100 Identification

1101 Each casting which has been tested and inspected with satisfactory results is to 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 is to 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 are to be submitted in connection with the approval of the design for which the material is proposed.

B 200 Chemical composition

201 The chemical composition is to 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 are to 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 are to 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 are to be agreed with the Society.

B 400 Mechanical properties

401 The mechanical properties are to 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</i> ³⁾	<i>Mo</i> ³⁾	<i>Ni</i> ³⁾	<i>Cu</i> ³⁾	<i>V</i> ³⁾	<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 is to 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 are to be submitted in connection with the approval of the design for which the material is proposed.

C 200 Chemical composition

201 The chemical composition is to 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 are to be supplied in one of the following conditions:

- Fully annealed.
- Normalised.
- 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 are to 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 are to 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, are to be given a stress relief heat treatment. This is to 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 are to 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 are to 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 is to 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 is to 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 are to be austenitised and tempered. Austenitic steel castings are to be solution heat treated.

D 400 Mechanical testing

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

402 One set of tests is to be made on material representing each casting. The mechanical properties are to 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 is to 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 is to 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 is to 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 is to 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 are to be repaired in accordance with A1000 and as given in 602 to 610.

602 In general the repairs are to be carried out by mechanical means, e.g. by grinding or milling. Weld repairs are to 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 are to be accompanied by sketches or photographs showing the extent and positions of the repairs. Welds having an area less than 5 cm² are to 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 is to 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 is to be used. The welding consumables are to be stored and handled in accordance with the manufacturer's recommendations.

610 The martensitic steels are to 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 is to be welded. See Fig.6.

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

sessed in accordance with 500.

703 Two macro-sections are to be prepared and etched on one side to clearly reveal the weld metal, the fusion line, and the heat affected zone. The sections are to 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 are to be prepared. The tensile strength is to meet the specified minimum value of the base material. The location of fracture is to be reported, i.e. weld metal, HAZ or base material.

705 Two transverse side bend test pieces are to be prepared. The former diameter is to be 4 times the thickness except for austenitic steels, in which case the former diameter is to be 3 times the thickness. The test piece, when visually inspected after bending, is to 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 are to 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 are to comply with the requirements for the base material.

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

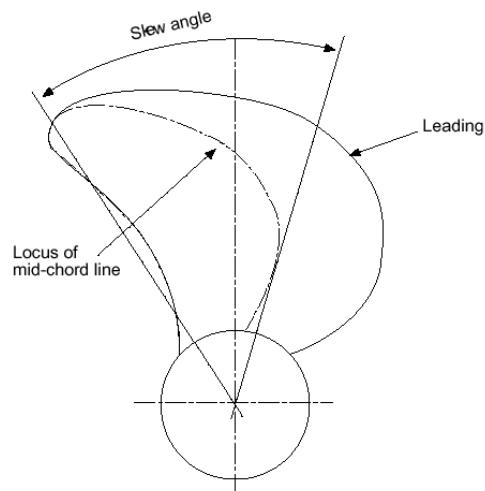


Fig. 1
Definition of skew angle

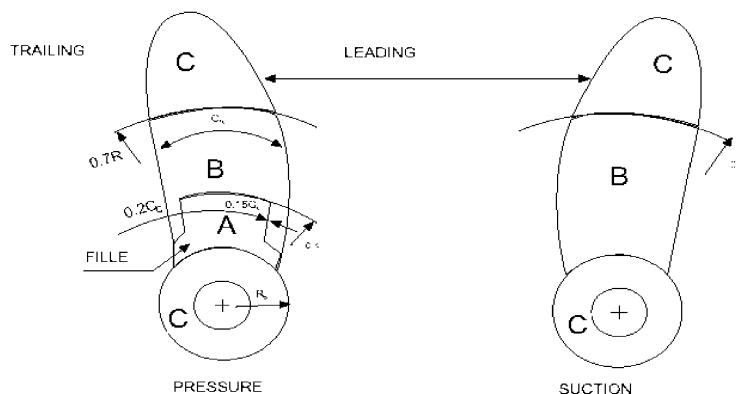


Fig. 2
Severity zones for low skew propellers and separately cast blades

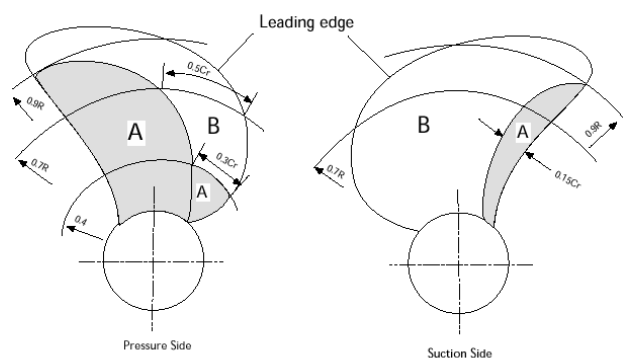


Fig. 3
Severity zones for high skew propellers and separately cast blades

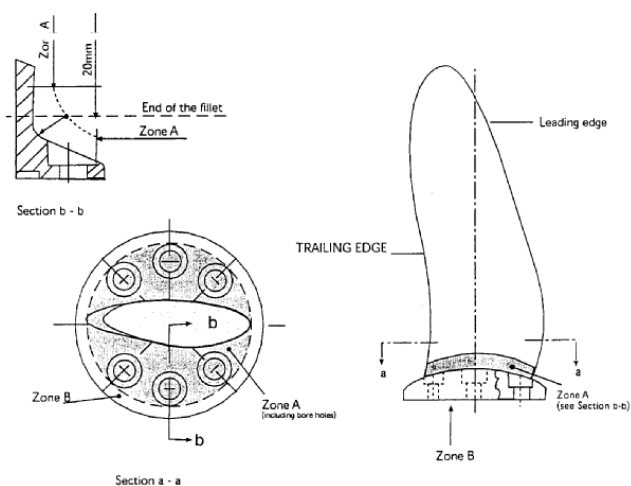


Fig. 5
Severity zones for controllable pitch propellers

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

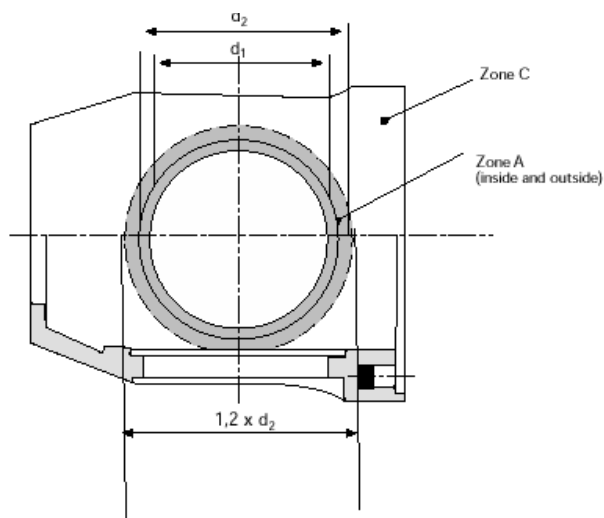


Fig. 4
Severity zones for separately cast propeller hubs

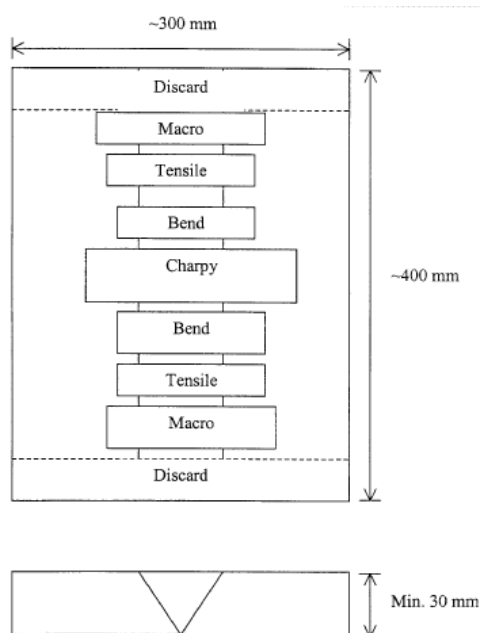


Fig. 6
Welding procedure qualification test assembly

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 minimum (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 notation Icebreaker or POLAR.

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 indications</i>	<i>Indication type</i>	<i>Maximum number for each type ^{1) 2)}</i>	<i>Maximum length 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.

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 is to 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 are to 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 are to 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 are to be agreed with the Society.

E 400 Mechanical properties

401 The mechanical properties are to 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 are to be non-destructive tested.

E 600 Pressure testing

601 Pressure retaining castings are to 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 R_e minimum (N/mm ²)	Tensile strength R_m (N/mm ²)	Elongation A_5 minimum (%)	Reduction of area Z 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 is to comply with the limits given in Table F1 or, where applicable, the requirements of the approved specification.

F 300 Heat treatment

301 Castings are to 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.

F 400 Mechanical properties

401 The mechanical properties are to 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 mag-

netic 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 are to be non-destructive tested.

F 600 Pressure testing

601 Pressure retaining castings are to 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 is to 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 are to be supplied in the solution treated condition.

G 400 Mechanical properties

401 The mechanical properties are to 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 are to 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 is to 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 are to be free from surface or internal defects which would be prejudicial to their proper application in service. The surface finish is to be in accordance with good practice and any specific requirements of the approved plan.

A 300 Manufacture

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

302 Suitable mechanical methods are to 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 is to 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 is to 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 is to 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 is to be provided for each casting or batch of castings. Separately cast test samples are normally to be used.

602 Separately cast test samples are to be cast in moulds made from the same type of material as used for the castings. The test samples are not to 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 are to 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 are to be of similar type and dimensions, and cast from the same ladle of treated metal. One test sample is to 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 are to be provided so as to be representative of each ladle used.

A 700 Visual and non-destructive examination

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

702 Before acceptance, all castings are to 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 are to be pressure tested before final acceptance.

705 In the event of any casting proving defective during subsequent machining or testing it is to 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 is to meet the values for grade NV1 and NV2, given in Table B1.

302 Nodular cast iron for ordinary use is to 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, are to be calculated by linear interpolation.

B 400 Metallographic examination

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

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---

Table B1 Nodular cast iron - mechanical properties of separately cast test samples							
Grade	Tensile strength ¹⁾ R_m minimum (N/mm ²)	Proof stress ²⁾ $R_{p0.2}$ minimum (N/mm ²)	Elongation A_5 (%)	Average impact energy, KV		Hardness (HB)	Predominant structure
				minimum ³⁾ (J)	test temperatur (°C)		
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 is not to be less than 17 (14) and 14 (11) J, respectively, for NV 1 and NV 2.

C. Grey Cast Iron

C 100 Scope

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

C 200 Test material

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

in diameter and of suitable length.

C 300 Mechanical properties

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

302 The fractured surfaces of all tensile test specimens are to 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 are to 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 are to 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, are to 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, are to 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 is to be agreed with DNV.

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

A 300 Manufacture

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

302 The alloys may be cast either in ingot moulds or by a continuous casting process. Plates are to 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 are to have a finish consistent with the method of manufacture and are to 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 is to be determined by the manufacturer on a sample taken preferably during the pouring of the heat. The chemical composition is to 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 is to 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 is to 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 is to be used for thicknesses up to and including 12.5 mm. The test piece is to be prepared so that both rolled surfaces are maintained. Round tensile test piece is to 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 is to be positioned at the mid-thickness. For thicknesses over 40 mm, the longitudinal axis is to 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) are to 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 are to 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 is to be verified by macrosection tests or drift expansion tests. Other tests may be accepted after consideration. Every profile is to be sampled, except where the profile is 6.0 m long or shorter, in which case every fifth profile is to be sampled. Every sample profile is to 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 are to 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 is to be twice the external diameter of the profile or 50 mm, whichever is greater. Testing is to be carried out at ambient temperature and is to 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 are to comply with a recognised standard.

903 The underthickness tolerance acceptable for classification is to 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 is to 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 is to 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
	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
Heat treated tempers	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 are to 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 are to 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 are to 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 are to be made at foundries approved by the Society.

302 The melting is to 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 is to be filled with a laminar flow of metal. The gating, risering and molding is to be in accordance with good foundry practice.

A 400 Chemical composition

401 The chemical composition of each ladle is to be determined and is to 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 are to be supplemented by frequent checks as required by the surveyor.

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

A 500 Heat treatment

501 Where castings are supplied in a heat treated condition, the heat treatment is to 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 are to be such as to allow the whole furnace charge to be uniformly heated to the necessary temperature.

502 Sufficient thermocouples are to 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 is to maintain records of heat treatment identifying the furnace used, furnace charge, date, temperature and time at temperature. The records are to 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, are to 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 are to 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 are to be suitably marked to identify them with the castings represented.

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

A 700 Test units and number of tests

701 Each ladle is to 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 is to 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 are to be visually inspected on accessible surfaces. Where applicable, this is to include the inspection of internal surfaces and bores. The surfaces are to be adequately prepared for inspection. The surfaces are not to be hammered, peened or treated in any way which may obscure discontinuities.

902 Castings for which certification by the Society is required are to 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 are to 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 are to 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 is to 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 are to be carried out when the surface is in the final condition. Machined castings are to be tested after final machining. Where certification by DNV is required, the surveyor may request to be present during PT.

908 The foundry is to maintain records of the foundry's inspections traceable to each casting. The records are to 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 are to have a bottom radius of approximately three times the groove depth and are to be blended into the surrounding surface so as to avoid any sharp contours. Complete elimination of the defective material is to be verified by PT.

1002 Where repair by welding is permitted, the excavations are to be suitably shaped to allow good access for welding. The resulting grooves are to be subsequently ground smooth and complete elimination of the defective material is to be verified by PT.

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

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

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

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

A 1100 Identification

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

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

A 1200 Certification

1201 The manufacturer is to 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:

- Manufacturer's and purchaser's name, order number and vessel identification, where known.
- Description of castings and alloy type.
- Identification marking of castings.
- Heat number and chemical composition.
- Details of heat treatment, including temperatures and holding times.
- 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 is to comply with the limits given in a recognised standard approved by the Society for the application in question. The copper alloys are to have a satisfactory resistance to sea water corrosion, where applicable.

B 300 Heat treatment

301 The castings are to 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 are to comply with the recognised standard.

B 500 Inspection

501 Pressure retaining castings are to 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 are to 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 is to 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 are to 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 are to 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 is to 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 are to 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 is to 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 is to 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 are to be repaired in accordance with A1000 and as given in 602 to 610.

602 In general the repairs are to be carried out by mechanical means, e.g. by grinding or milling. Weld repairs are to 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 are to 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 is to 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 are to 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 are to 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 are to 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 is to 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 is to be welded. See Fig.1.

902 Prior to sectioning, the test assembly is to be visually inspected and liquid penetrant tested. Imperfections are to be assessed in accordance with 500.

903 Three macro-sections are to be prepared and etched on one side to clearly reveal the weld metal, the fusion line, and the heat affected zone. The sections are to 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 are to be prepared as shown in Fig.2. The tensile strength is to meet the specified minimum values given in Table C5. The location of fracture is to be reported, i.e. weld metal, HAZ or base material.

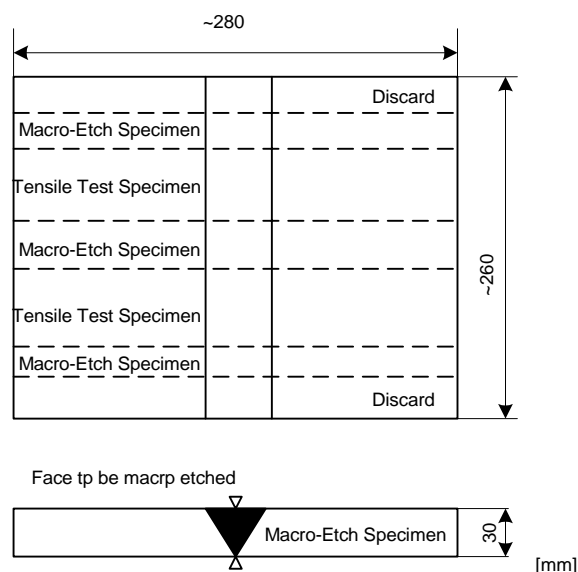


Fig. 1
Weld test assembly

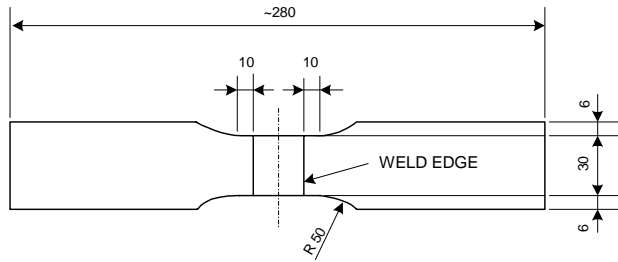


Fig. 2
Tensile test specimen for weld test assembly

Table C1 Chemical composition limits ¹⁾ for copper alloy propeller castings

Alloy type	Cu	Al	Mn	Fe	Ni	Zn	Sn	Pb	Cr	Mg	Si
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 (%) = $100 - (100 \text{ Cu} / 100 + A)$ where $A = \text{Sn} + 5 \text{ Al} - 0.5 \text{ Mn} - 0.1 \text{ Fe} - 2.3 \text{ Ni}$

Table C2 Mechanical properties for copper alloy propeller castings

Alloy type	Yield strength $R_{p0.2}$ minimum (N/mm ²)	Tensile strength R_m minimum (N/mm ²)	Elongation A_5 minimum (%)
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

Alloy type	Description
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

Severity zone	Maximum total number of indications	Indication type	Maximum number for each type ^{1) 2)}	Maximum dimension of indication (mm)
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

Alloy type	Tensile strength (N/mm ²)
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 are to 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 are to 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 are to 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 are to be made at works approved by DNV.

202 Tubes for class I and II pressure systems are to be seamless drawn. Tubes for class III pressure systems may be seamless drawn or welded.

A 300 Chemical composition

301 The chemical composition is to 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 are to be supplied in the annealed or half-hard condition.

402 Copper alloy tubes are to be supplied in the annealed condition.

A 500 Mechanical testing

501 Tubes are to be sampled and subjected to testing in accordance with the requirements of a recognised standard.

502 The mechanical properties are to comply with the requirements of a recognised standard and with the minimum values given in Table A2.

A 600 Inspection

601 Each tube is to 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 are to be suitably marked for identification by the manufacturer. Hard stamping of tubes is not permitted.

A 900 Certification

901 The manufacturer is to 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 and, where applicable, technological tests.
- Test pressure or results of eddy current tests.
- 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 are to 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 are to 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 are to be submitted in connection with the approval of the design for which the material is proposed.

B 200 Manufacture

201 All tubes are to be made at works approved by DNV.

202 Tubes for class I and II pressure systems are to be seamless. Tubes for class III pressure systems may be seamless or welded.

B 300 Certification

301 The manufacturer is to 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.