



RULES FOR  
CLASSIFICATION OF

# SHIPS / HIGH SPEED, LIGHT CRAFT AND NAVAL SURFACE CRAFT

NEWBUILDINGS

MATERIALS AND WELDING

PART 2 CHAPTER 2

## METALLIC MATERIALS

JULY 2007

*This booklet includes the relevant amendments and corrections  
shown in the July 2009 version of Pt.0 Ch.1 Sec.3.*

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# CHANGES IN THE RULES

## General

The present edition of the rules includes additions and amendments approved by the Board as of June 2007, and supersedes the January 2005 edition of the same chapter.

The rule changes come into force as indicated below.

This chapter is valid until superseded by a revised chapter.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 adopted July 2009

### Coming into force 1 January 2010

- **Section 5 Welding Procedures**
  - In Table C2, footnote 2) has been amended.
- **Section 7 Non Destructive Testing of Welds**
  - In Table D2, footnote 1) has been amended.

## Main changes coming into force 1 January 2008

- **Section 1 – Rolled Steel for Structural Application**
  - This section has been completely rewritten and restructured. Changes in IACS UR W11 (hull steels) have been incorporated. Lessons learned from quality incidents with cracked and brittle hull steel plates have also been incorporated, see A305, A404, A501, A507 with cracked and brittle hull steel plates.
- **Section 6 – Bars for Chain Cables**
  - This section has been completely rewritten and restructured. Changes in IACS UR W18 (chain cables) have been incorporated.
- **Section 9 – Aluminium Alloys**
  - Changes in IACS UR W25 (aluminium alloys) have been incorporated. Most importantly, requirements for corrosion testing have been added.

## Corrections and Clarifications

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

Comments to the rules may be sent by e-mail to [rules@dnv.com](mailto:rules@dnv.com)

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## SECTION 1

### ROLLED STEEL FOR STRUCTURAL APPLICATION

#### A. General Requirements

##### A 100 Scope

**101** This sub-section specifies the general requirements for hot rolled steel plates, sections and bars to be used in the construction of hulls and other marine structures.

**102** The requirements apply to plates and wide flats not exceeding 150 mm in thickness and sections and bars not exceeding 50 mm in thickness. For greater thicknesses, variations in the requirements may be permitted for particular applications.

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

**104** As an alternative to 103, 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 a specific application. Generally, such materials shall comply with the appropriate requirements of Ch.1.

##### A 200 Grading system

**201** The steel products concerned are classified by strength into three groups: normal strength, high strength and extra high strength steel. Each strength group is further subdivided into grades, as given in B to D.

**202** Supplementary requirements for steel grades with specified through thickness properties – ‘Z’ grade steel – are given in E.

##### A 300 Manufacture

**301** All materials delivered with NV or works certificate shall be made at works approved by the Society for the type and grade of steel being supplied and for the relevant steelmaking and processing route. Rolling mills without own steelmaking may only use starting material supplied by works approved by the Society.

**302** Steel shall be manufactured by the open hearth, an electric or one of the basic oxygen processes or any other process involving secondary refining approved by the Society.

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

**304** Conditions of supply shall be in accordance with 500.

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

##### A 400 Chemical composition

**401** The chemical composition of each heat shall be determined on a sample taken preferably during the pouring of the heat and shall be within the specified limits in B to E. When multiple heats are tapped into a common ladle, the ladle anal-

ysis shall apply and be within the specified limits. Variations from the chemical compositions given may be allowed for grades supplied in the thermo-mechanical rolled condition or when thicknesses exceed 50 mm provided that these variations are approved.

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

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

**404** When recycled scrap is used in steelmaking, adequate controls shall be in place to prevent accumulation of harmful elements in the final product. The content of impurity elements such as tin, antimony and arsenic may be required determined.

##### Guidance note:

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

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

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

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

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

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

##### A 500 Condition of supply and heat treatment

**501** Conditions of supply shall be in accordance with requirements given in B to D and as defined in 502 to 506. Where alternative conditions are permitted, the manufacturer shall supply materials only in those conditions for which he has been approved.

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

**503** Normalising rolling (NR) is a rolling procedure in which the final rolling temperature is controlled within a certain range above the Ar<sub>3</sub> temperature so that the austenite completely re-crystallises. After the final pass, air cooling produces a fine grained ferrite-pearlite microstructure comparable to that obtained after normalising heat treatment.

**504** Thermo-mechanical rolling (TM) is a rolling procedure in which both the rolling temperatures and reductions and, when used, accelerated cooling conditions are controlled. Generally, a high proportion of the rolling reduction is carried out close to the Ar<sub>3</sub> temperature and may involve the rolling in the austenite-ferrite dual phase temperature region. After the final pass, either air cooling or accelerated cooling, excluding quenching, is used. Final rolling in the same temperature range as used for NR followed by accelerated cooling is considered to be a TM procedure. Unlike NR the properties conferred by TM cannot be reproduced by subsequent normalising heat treatment.

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

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

**507** It is the manufacturer's responsibility to ensure that the programmed rolling schedules for NR and TM are adhered to. Production records to this effect shall be made available to the surveyor on request. Where deviation from the programmed rolling schedules occurs, the manufacturer must ensure that each affected rolled piece is tested and that an investigation is carried out according to 305.

#### **A 600 Test material and test pieces for mechanical testing**

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

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

**603** Test material shall be taken from the following positions:

- *Plates and wide flats with a width  $\geq 600$  mm*  
The test material shall be taken at the square cut end approximately one-quarter width from an edge, see Fig. 1a.
- *Flats with a width  $< 600$  mm, bulb flats and other sections*  
The test material shall be taken at approximately one-third of the width from an edge, see Figs. 1b, 1c, 1d and 1e. For channels and beams, an alternative position is shown in Fig. 1d.

#### — *Bars and other similar products*

The test material shall be taken at a depth one-third of the radius below the surface or, in the case of non-cylindrical sections, at a depth one-third of the half-diagonal from the surface, see Fig. 1f.

**604** The following definitions relevant to orientation of test pieces apply:

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

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

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

#### — *Plates and wide flats with a width $\geq 600$ mm*

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

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

Tensile and impact test pieces shall be longitudinal.

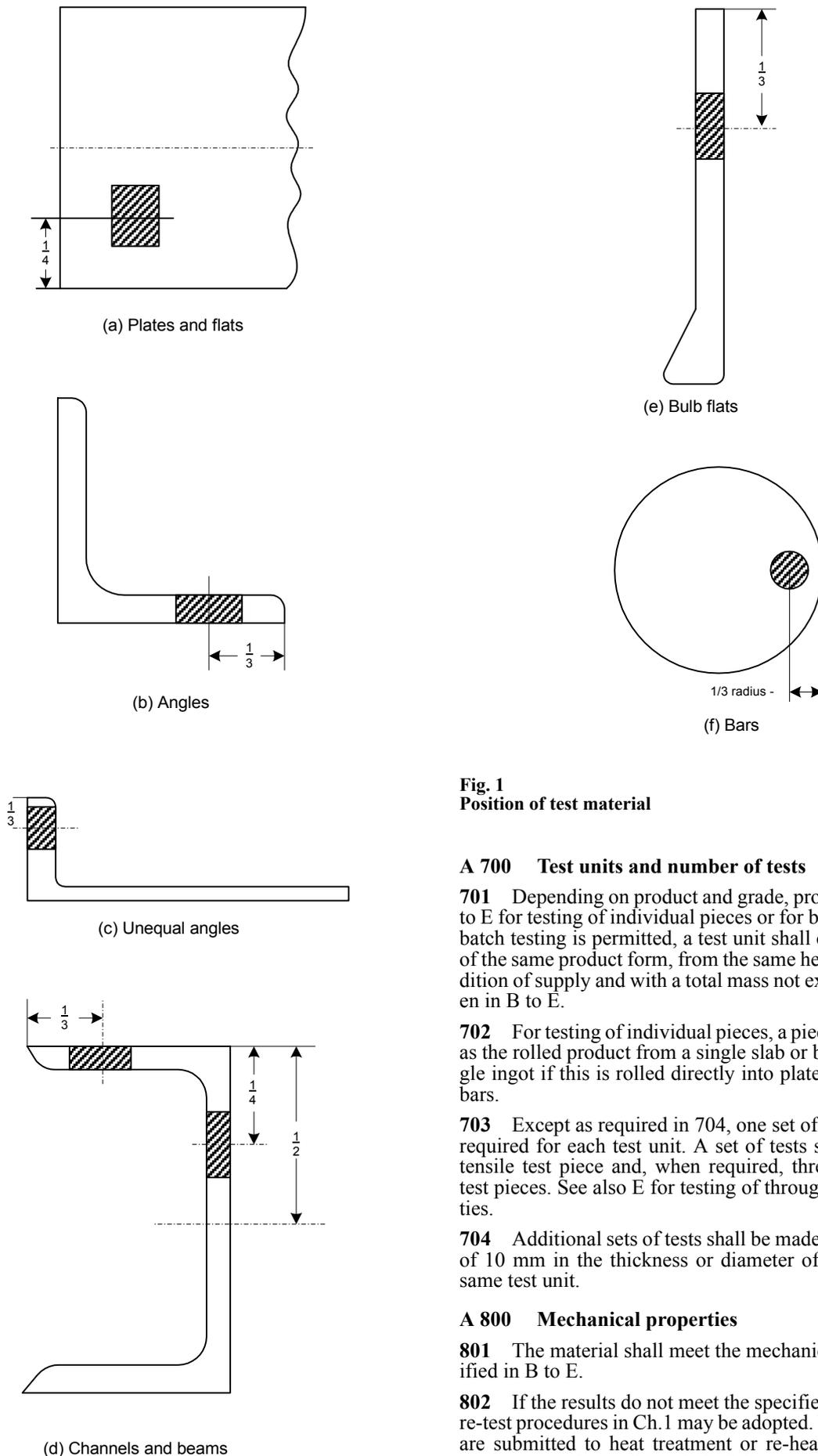
#### — *Bars and other similar products*

Tensile and impact test pieces shall be longitudinal.

**606** The preparation of test pieces and the procedures used for mechanical testing shall comply with the relevant requirements of Ch.1. See also 607 and 608.

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

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



**Fig. 1**  
**Position of test material**

**A 700 Test units and number of tests**

**701** Depending on product and grade, provision is made in B to E for testing of individual pieces or for batch testing. Where batch testing is permitted, a test unit shall consist of materials of the same product form, from the same heat, in the same condition of supply and with a total mass not exceeding limits given in B to E.

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

**703** Except as required in 704, one set of mechanical tests is required for each test unit. A set of tests shall consist of one tensile test piece and, when required, three Charpy V-notch test pieces. See also E for testing of through thickness properties.

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

**A 800 Mechanical properties**

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

**802** If the results do not meet the specified requirements, the re-test procedures in Ch.1 may be adopted. Where the products are submitted to heat treatment or re-heat treatment, all the tests previously performed shall be repeated and the results must meet the specified requirements.

## A 900 Inspection and tolerances

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

**902** Products shall have a workmanlike finish consistent with the method of manufacture and shall be free from cracks, shells and seams. Acceptance criteria for other imperfections such as rolled-in scale, indentations and roll marks, which may occur under normal manufacturing conditions, shall be EN 10163 Class A or equivalent standard.

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

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

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

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

**907** The manufacturer shall maintain records of inspections and dimensional measurements. The records shall be presented to the surveyor on request.

## A 1000 Repair

**1001** Surface defects may be removed by local grinding provided that:

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

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

**1002** Surface defects which cannot be dealt with as in 1001 may be repaired by chipping or grinding followed by welding, subject to the surveyor's consent and under his supervision, provided that:

- after removal of defects and before welding, the thickness of the product is in no place reduced by more than 20% of the nominal thickness,
- welding is carried out by qualified welders using qualified procedures,
- for plates supplied in NR or TM condition, qualification of procedures is based on satisfactory mechanical testing,
- each single weld does not exceed 0.125 m<sup>2</sup>,
- the total area of welding does not exceed 2% of the surface area of the side involved,
- the distance between any two welds is not less than their average width,
- the welds are made with an excess layer of beads and then ground flush with the product surface,
- when deemed necessary, the repaired product is normal-

- used or otherwise suitably post-weld heat treated,
- the weld repairs are subjected to suitable non-destructive testing.

**1003** The manufacturer shall maintain records of repairs and subsequent inspections traceable to each product repaired. The records shall be presented to the surveyor on request.

## A 1100 Identification

**1101** Every finished product shall be clearly marked by the manufacturer in at least one place with the Society's brand and the following particulars:

- a) manufacturer's name or trade mark,
- b) steel grade, e.g. NV E36. When products comply with the requirements of E, the grade shall include the suffix Z25 or Z35, e.g. NV E36Z25,
- c) identification number, heat number or other marking which will enable the full history of the product to be traced,
- d) if required by the purchaser, his order number or other identification mark.

**1102** The particulars in 1101, but excluding the manufacturer's name or trade mark where this is embossed on finished products, shall be encircled with paint or otherwise marked so as to be easily recognisable.

**1103** Where a number of products are securely fastened together in bundles, the manufacturer may brand only the top product of each bundle or, alternatively, a firmly fastened durable label containing the identification may be attached to each bundle.

## A 1200 Certification

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

- a) purchaser's name, order number and, if known, the vessel identification,
- b) manufacturer's name,
- c) description of products and steel grade,
- d) identification marking of products,
- e) steel making process, heat number and chemical composition,
- f) condition of supply,
- g) results of mechanical tests,
- h) when products comply with the requirements of E, the results of through thickness tensile tests and ultrasonic tests,
- i) results of any supplementary and additional test requirements specified.

**1202** Before the inspection certificates or, pending final certification, shipping statements are signed by the surveyor, the manufacturer is required to provide a written declaration stating that the material has been made by an approved process and that it has been subjected to and has withstood satisfactorily the required tests. The following form of declaration will be accepted if stamped or printed on each inspection certificate or shipping statement with the name of the manufacturer and signed by an authorized representative of the manufacturer:

"We hereby certify that the material has been made by an approved process and has been satisfactorily tested in accordance with DNV Rules for Classification."

**1203** When steel is not produced at the works at which it is rolled, a certificate shall be supplied by the steelmaker stating the process of manufacture, the heat number and the chemical composition.

## B. Normal Strength Steel

yield stress 235 MPa.

### B 100 Scope

**101** These requirements are supplementary to A and apply to normal strength steel. Provision is made for four grades based on the specified impact toughness and with specified minimum

### B 200 Chemical composition

**201** The chemical composition and deoxidation practice shall comply with the limits given in Table B1.

Grade	C <sup>2)</sup>	Si	Mn <sup>2)</sup>	P	S	Al	Deoxidation practice
NV A	0.21 <sup>3)</sup>	0.50	Min. 2.5 x C	0.035	0.035	-	For t ≤ 50 mm: Any method except rimmed steel <sup>4)</sup> For t > 50 mm: Killed
NV B	0.21	0.35	Min. 0.80 <sup>5)</sup>	0.035	0.035	-	For t ≤ 50 mm: Any method except rimmed steel For t > 50 mm: Killed
NV D	0.21	0.10-0.35	Min. 0.60	0.035	0.035	-	For t ≤ 25 mm: Killed
NV E	0.18	0.10-0.35	Min. 0.70	0.035	0.035	Min. 0.020 <sup>6)</sup>	For t > 25 mm: Killed and fine grain treated
						Min. 0.020 <sup>6)</sup>	Killed and fine grain treated

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

### B 300 Condition of supply

**301** The condition of supply shall comply with the requirements given in Table B2.

Grade	Thickness, t (mm)	Plates	Sections
A, B	t ≤ 50	AR, NR, N, TM	AR, NR, N, TM
	50 < t ≤ 150	AR <sup>1)</sup> , NR, N, TM	AR <sup>1)</sup> , NR, N, TM
D	t ≤ 35	AR, NR, N, TM	AR, NR, N, TM
	35 < t ≤ 150	NR, N, TM	AR <sup>1)</sup> , NR, N, TM
E	t ≤ 150	N, TM	AR <sup>1)</sup> , NR <sup>1)</sup> , N, TM

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

### B 400 Mechanical properties

**401** The mechanical properties shall comply with the values given in Table B3.

**402** For tensile testing, the total mass of products in a test unit shall be maximum 50 tonnes. For impact testing, the maximum size of a test unit shall be as given in Table B4.

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

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

Thickness, mm	t ≤ 5	5 < t ≤ 10	10 < t ≤ 15	15 < t ≤ 20	20 < t ≤ 25	25 < t ≤ 30	30 < t ≤ 40	t > 40
All grades	14	16	17	18	19	20	21	22

## C. High Strength Steel

**Table B4 Test units for impact testing of normal strength steel**

Grade	Thickness, <i>t</i> (mm)	Plates	Sections
A	$t \leq 50$	Not required	Not required
	$50 < t \leq 150$	50 tonnes	Not required
B	$t \leq 25$	Not required	Not required
	$25 < t \leq 150$	50 tonnes <sup>1) 2)</sup>	50 tonnes <sup>2)</sup>
D	$t \leq 150$	50 tonnes <sup>1) 2)</sup>	50 tonnes <sup>2)</sup>
E	$t \leq 150$	Each piece	25 tonnes <sup>3)</sup>

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

### C 100 Scope

**101** These requirements are supplementary to A and apply to high strength steel. Provision is made for four strength levels with specified minimum yield stress 265 MPa, 315 MPa, 355 MPa and 390 MPa. Each strength level is further subdivided into four grades based on the specified impact toughness.

### C 200 Chemical composition

**201** The chemical composition shall comply with the limits given in Table C1. The steel grades shall be killed and fine grain treated except for NV A27S in thicknesses up to and including 25 mm, which may be semi-killed or killed without fine grain treatment.

**202** For TM steels, the carbon equivalent value shall comply with the limits given in Table C2.

**Table C1 Chemical composition limits <sup>1)</sup> for high strength steel**

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

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

**Table C2 Maximum carbon equivalent values for high strength steel supplied in TM condition**

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

### C 300 Condition of supply

**301** The condition of supply shall comply with the requirements given in Table C3.

**Table C3 Conditions of supply for high strength steel**

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

<sup>1)</sup> Products may be supplied in this condition when especially approved.

**C 400 Mechanical properties**

**401** The mechanical properties shall comply with the values given in Table C4.

**402** For tensile testing, the total mass of products in a test unit shall be maximum 50 tonnes. For impact testing, the maximum size of a test unit shall be as given in Table C5.

**Table C4 Mechanical properties for high strength steel**

Grade	Yield stress $R_{eH}$ minimum (MPa)	Tensile strength $R_m$ (MPa)	Elongation $A_5$ minimum (%)	Impact energy, longitudinal minimum (J)			
				Temperature (°C)	$t \leq 50$ (mm)	$50 < t \leq 70$ (mm)	$70 < t \leq 150$ (mm)
NV A27S NV D27S NV E27S NV F27S	265	400-530	22 <sup>1)</sup>	0 -20 -40 -60	27	34	41
NV A32 NV D32 NV E32 NV F32	315	440-570	22 <sup>1)</sup>	0 -20 -40 -60	31	38	46
NV A36 NV D36 NV E36 NV F36	355	470-620	21 <sup>1)</sup>	0 -20 -40 -60	34	41	50
NV A40 NV D40 NV E40 NV F40	390	510-660	20 <sup>1)</sup>	0 -20 -40 -60	41	45	55

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

Thickness, mm	$t \leq 5$	$5 < t \leq 10$	$10 < t \leq 15$	$15 < t \leq 20$	$20 < t \leq 25$	$25 < t \leq 30$	$30 < t \leq 40$	$t > 40$
Strength levels 27S and 32	14	16	17	18	19	20	21	22
Strength level 36	13	15	16	17	18	19	20	21
Strength level 40	12	14	15	16	17	18	19	20

**Table C5 Test units for impact testing of high strength steel**

Grade	Plates	Sections
Grades A and D of all strength levels	50 tonnes <sup>1) 2)</sup>	50 tonnes <sup>2)</sup>
Grades E and F of all strength levels	Each piece	25 tonnes <sup>3)</sup>

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

## D. Extra High Strength Steel

el is further subdivided into four grades based on the specified impact toughness.

### D 100 Scope

**101** These requirements are supplementary to A and apply to extra high strength steel. Provision is made for six strength levels with specified minimum yield stress 420 MPa, 460 MPa, 500 MPa, 550 MPa, 620 MPa and 690 MPa. Each strength level

### D 200 Chemical composition

**201** The chemical composition and deoxidation practice shall comply with the limits given in Table D1. The steel grades shall be killed and fine grain treated.

Grade	C	Si	Mn	P	S	Cr <sup>2)</sup>	Mo <sup>2)</sup>	Ni <sup>2)</sup>	Cu <sup>2)</sup>	Al <sup>3) 4)</sup>	Nb <sup>4)</sup>	V <sup>4)</sup>	Ti <sup>4)</sup>	N
Grade A of all strength levels	0.21	0.10-0.55	1.70	0.035	0.035	0.20	0.08	0.40	0.35	Min. 0.020	0.02 - 0.05	0.05 - 0.10	0.007 - 0.05	-
Grades D and E of all strength levels	0.20	0.10-0.55	1.70	0.030	0.030	0.20	0.08	0.40	0.35	Min. 0.020	0.02 - 0.05	0.05 - 0.10	0.007 - 0.05	-
Grade F of all strength levels	0.18	0.10-0.55	1.60	0.025	0.025	0.20	0.08	0.80	0.35	Min. 0.020	0.02 - 0.05	0.05 - 0.10	0.007 - 0.05	0.009 <sup>5)</sup>

- 1) Composition in percentage mass by mass maximum unless shown as a range or as a minimum.  
 2) The limits given do not apply when elements are intentionally added.  
 3) Total content. Acid soluble content, if determined instead, shall be minimum 0.015%.  
 4) The steel shall contain Al, Nb, V or Ti, either singly or in any combination. When used singly, the steel shall contain the specified minimum content of the element. When Al and Nb are used in combination, the minimum total Al content shall be 0.015% and the minimum Nb content shall be 0.010%. When Al and V are used in combination, the minimum total Al content shall be 0.015% and the minimum V content shall be 0.030%. The total content of Nb+V+Ti shall not exceed 0.12%.  
 5) 0.012% if Al is present.

### D 300 Condition of supply

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

### D 400 Mechanical properties

**401** The mechanical properties shall comply with the values given in Table D2. The extent of tensile and impact testing shall be each piece.

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

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

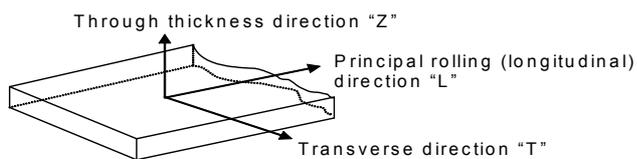
Thickness, mm	$t \leq 10$	$10 < t \leq 15$	$15 < t \leq 20$	$20 < t \leq 25$	$25 < t \leq 40$	$40 < t \leq 50$	$t > 50$
Strength level 420	11	13	14	15	16	17	18
Strength level 460	11	12	13	14	15	16	17
Strength levels 500 and 550	10	11	12	13	14	15	16
Strength level 620	9	11	12	12	13	14	15
Strength level 690	9	10	11	11	12	13	14

## E. Plates with Through Thickness Properties

### E 100 Scope

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

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



**Fig. 2**  
Through thickness tensile testing

### E 200 Manufacture

**201** All materials shall be manufactured at works approved by the Society for the grade of 'Z' quality steel being supplied.

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

### E 300 Chemical composition

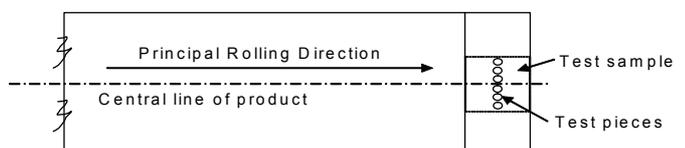
**301** The steel grades shall be killed and fine grain treated. The maximum sulphur content shall be 0.008% unless alternative methods of improving through thickness properties have been approved.

### E 400 Test material

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

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

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



**Fig. 3**  
Plate and wide flat sampling position

<i>Product</i>	<i>S &gt; 0.005%</i>	<i>S ≤ 0.005%</i>
Plates	Each piece (parent plate)	Maximum 50 t of products of the same heat, thickness and condition of supply
Wide flats of nominal thickness ≤ 25 mm	Maximum 10 t of products of the same heat, thickness and condition of supply	Maximum 50 t of products of the same heat, thickness and condition of supply
Wide flats of nominal thickness > 25 mm	Maximum 20 t of products of the same heat, thickness and condition of supply	Maximum 50 t of products of the same heat, thickness and condition of supply

**E 500 Mechanical testing**

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

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

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

**503** Where batch testing is permitted and the conditions for acceptance after retest in 502 are not met, the tested product

shall be rejected. The remaining products in the test unit may be resubmitted individually for test and accepted provided satisfactory results.

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

<i>Quality class</i>	<i>Z25</i>	<i>Z35</i>
Minimum average	25%	35%
Minimum individual	15%	25%

**E 600 Ultrasonic testing**

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

## SECTION 2

# ROLLED STEEL FOR BOILERS, PRESSURE VESSELS AND SPECIAL APPLICATIONS

### A. General

#### A 100 Scope

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

#### A 200 Method of manufacture

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

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

### B. Steel for Boilers and Pressure Vessels

#### B 100 Steel grades

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

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

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

The letters NV are followed by three figures which stand for the specified minimum tensile strength in N/mm<sup>2</sup>.

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

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

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

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

Example:

NV 360—1FN means a steel grade with specified minimum tensile strength 360 N/mm<sup>2</sup> impact tested at 0°C, fine grain treated and normalised.

#### B 200 Chemical composition

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

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

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

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

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

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

#### B 300 Mechanical properties

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

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

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

Table B5: Alloy steels

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

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

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

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

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

#### B 400 Heat treatment

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

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

<b>Table B1 Carbon and carbon-manganese steels for boilers and pressure vessels. Chemical composition</b>									
Grade	Chemical composition, (%)								Deoxidation
	C maximum	Si	Mn	P maximum	S maximum	Al <sub>ac.sol</sub>	N maximum	Residual elements, maximum	
NV 360 - 0A, - 0N	0.17	≤ 0.35	0.40 - <sup>2)</sup> 1.00	0.035	0.030	≤ 0.010	0.009 <sup>1)</sup>	6)	Semikilled or killed
NV 360 - 1 FN	0.17	≤ 0.35	0.40 - <sup>2)</sup> 1.00	0.035	0.030	0.015 - <sup>5)</sup> 0.080	0.015	6)	Killed fine grained
NV 410 - 0A, - 0N	0.20	≤ 0.35	0.50 - 1.30	0.035	0.030	≤ 0.010	0.009 <sup>1)</sup>	6)	Semikilled or killed
NV 410 - 1 FN	0.20	≤ 0.35	0.50 - 1.30	0.035	0.030	0.015 - <sup>5)</sup> 0.080	0.015	6)	Killed fine grained
NV 460 - 0A, - 0N	0.20	≤ 0.40	0.60 - <sup>3)</sup> 1.40	0.035	0.030	≤ 0.010	0.009 <sup>1)</sup>	6)	Semikilled or killed
NV 460 - 1 FN	0.20 <sup>4)</sup>	≤ 0.40	0.60 - <sup>3)</sup> 1.40	0.035	0.030	0.015 - <sup>5)</sup> 0.080	0.015	6)	Killed fine grained
NV 490 - 0N	0.20 <sup>4)</sup>	0.10 - 0.50	0.90 - 1.60	0.035	0.030	≤ 0.010	0.009 <sup>1)</sup>	6)	Killed
NV 490 - 1 FN	0.20 <sup>4)</sup>	0.10 - 0.50	0.90 - 1.60	0.035	0.030	0.015 - <sup>5)</sup> 0.080	0.015	6)	Killed fine grained
NV 510 - 1 FN	0.22	0.10 - 0.60	1.00 - 1.60	0.035	0.030	0.015 - 0.080	0.015	6)	Killed fine grained

1) For electric furnace steel, maximum 0.012.  
2) For thicknesses exceeding 40 mm, Mn = 0.40 - 1.20%.  
3) If high temperature properties of Table B7 are specified, Mn content shall be 0.80 - 1.40%.  
4) For thickness t > 30 mm and t ≤ 100 mm, C<sub>max</sub> 0.22%.  
5) Aluminium may be replaced by other grain refining elements.  
6) Cr 0.20  
Cu 0.35  
Ni 0.40  
Mo 0.08  
Total 0.70

<b>Table B2 Alloy steels for boilers and pressure vessels. Chemical composition</b>									
Grade	Chemical composition, (%)								Residual elements, maximum
	C	Si	Mn	P maximum	S maximum	Al <sub>tot</sub> maximum	Cr	Mo	
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	

<b>Table B3 Carbon and carbon-manganese steels for boilers and pressure vessels, as rolled condition. Mechanical properties</b>							
Grade	Tensile strength R <sub>m</sub> (N/mm <sup>2</sup> )	Yield stress, R <sub>eH</sub> or R <sub>p0.2</sub> (N/mm <sup>2</sup> ) minimum for thickness, (mm)		Elongation A <sub>5</sub> (%) 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 <sup>2</sup> )	Yield strength, $R_{eH}$ or $R_{p0.2}$ (N/mm <sup>2</sup> ) minimum for thickness, (mm)				Elongation $A_5$ , (%) minimum	KV, average		
		≤ 16	> 16 ≤ 40	> 40 ≤ 63	> 63 ≤ 100		Test temperature (°C)	Transverse (J) minimum	Longitudinal (J) minimum
NV 360 - 0N	360 - 480	205	195	185	175	26 <sup>1)</sup>	20	20	27
NV 360 - 1 FN	360 - 480	235	215	195	2)	26 <sup>1)</sup>	0	20	27
NV 410 - 0N	410 - 530	235	225	215	205	24 <sup>1)</sup>	20	20	27
NV 410 - 1 FN	410 - 530	265	245	235	2)	24 <sup>1)</sup>	0	20	27
NV 460 - 0N	460 - 580	285	255	245	235	22 <sup>1)</sup>	20	20	27
NV 460 - 1 FN	460 - 580	295	285	275	2)	22 <sup>1)</sup>	0	20	27
NV 490 - 0N	490 - 610	305	275	265	255	21 <sup>1)</sup>	20	22	31
NV 490 - 1 FN	490 - 610	315	315	305	2)	21	0	22	31
NV 510 - 1 FN	510 - 650 <sup>3)</sup>	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 <sup>2</sup> )	Yield strength $R_{eH}$ or $R_{p0.2}$ (N/mm <sup>2</sup> ) minimum for thickness, (mm) <sup>2)</sup>			Elongation $A_5$ , (%) minimum	KV, average		
		≤ 16	> 16 ≤ 40	> 40 ≤ 63		Test temperature (°C)	Transverse (J) minimum	Longitudinal (J) minimum
NV 0.3 Mo	440 - 590	260	250	250	24 <sup>1)</sup>	20	20	27
NV 1 Cr 0.5 Mo	470 - 620	305	305	305	20 <sup>1)</sup>	20	22	31
NV 2.25 Cr 1 Mo	480 - 630	275	265	265	18 <sup>1)</sup>	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.

<b>Table B6 Steels for boilers and pressure vessels. Minimum lower yield stress (<math>R_{eL}</math>) or 0.2% proof stress (<math>R_{p0.2}</math>) values at high temperatures for design purposes</b>											
Grade		Thickness (mm) <sup>1)</sup>	Minimum $R_{eL}$ or $R_{p0.2}$ (N/mm <sup>2</sup> ) 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	
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		
NV 510 - 1 FN	≤ 63	-	-	265	245	225	205	175	155		
C- and C/ Mn-steels as rolled	NV 360 - 0A	≤ 25	150	150	145	125	110	105			
	NV 410 - 0A	≤ 25	180	180	170	150	130	125			
	NV 460 - 0A	≤ 25	210	210	200	180	160	150			
Alloy steels	NV 0.3 Mo	< 63	237	232	218	200	167	153	148	143	139
	NV 1 Cr 0.5 Mo	< 63	270	259	248	237	216	203	199	194	188
	NV 2.25 Cr 1 Mo	< 63	249	241	233	224	219	212	207	194	180

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

Temperature (°C)	Stress to rupture, (N/mm <sup>2</sup> ) 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	-

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 <sup>1)</sup> Thermo-mechanically treated
NV 0.3 Mo	Normalised
NV 1 Cr 0.5 Mo NV 2.25 Cr 1 Mo	Normalised and tempered

1) See 402.

### C. Steel for Low Temperature Service

#### C 100 Steel grades

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

#### C 200 Chemical composition

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

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

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

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

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

following formula when applicable:

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

#### C 300 Mechanical properties

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

Table C3: Carbon-manganese steels

Table C4: Nickel alloy steels

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

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

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

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

**C 400 Heat treatment**

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

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

**Guidance note:**

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

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

<b>Table C1 Carbon-manganese steels for low temperature service. Chemical composition</b>								
Grade	Chemical composition, %							Residual elements
	C maximum	Si	Mn	S maximum	P maximum	Al <sup>4)</sup> total	N maximum	
NV 360 - 2FN	0.17	0.10 0.35	0.40 1.00 <sup>2)</sup>	0.025	0.030	≥ 0.018	0.015	
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 <sup>3)</sup>	0.025	0.030	≥ 0.018	0.015	
NV 2 - 4L	0.14	0.10 0.40	0.70 1.60 <sup>3)</sup>	0.025	0.030	≥ 0.018	0.015	Cr 0.20 maximum Cu 0.35 maximum Ni 0.40 maximum <sup>1)</sup> Mo 0.08 maximum Cr+Mo+Cu 0.45 maximum
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 <sup>3)</sup>	0.025	0.030	≥ 0.018	0.015	
NV 4 - 4L	0.16	0.10 0.40	0.70 1.60 <sup>3)</sup>	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.

<b>Table C2 Nickel alloy steels for low temperature service. Chemical composition</b>							
Grade	Chemical composition, (%)						
	C maximum	Si	Mn	S maximum	P maximum	Ni	Al <sub>tot</sub>
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

<b>Table C3 Carbon-manganese steels for low temperature service. Mechanical properties <sup>1)</sup></b>									
Grade	Tensile strength (N/mm <sup>2</sup> )	Yield stress (N/mm <sup>2</sup> ) minimum for thickness, (mm)		Elongation A <sub>5</sub> (%) minimum	Impact energy KV, average <sup>2)</sup>			Min design temperature	
		≤ 16	> 16 ≤ 40		Thickness (mm)	Test temperature (°C) <sup>3)4)5)</sup>	Transverse (J) minimum		Longitudinal (J) minimum
NV 360 - 2FN	360 - 480	235	215	26	≤ 25 > 25 ≤ 30 > 30 ≤ 35 > 35 ≤ 40	- 20 - 25 - 30 - 35	27	41	-15°C
NV 2 - 2	400 - 490	265	255	24	≤ 25 > 25 ≤ 30 > 30 ≤ 35 > 35 ≤ 40	- 20 - 25 - 30 - 35	27	41	-15°C
NV 2 - 3	400 - 490	265	255	24	≤ 25 > 25 ≤ 30 > 30 ≤ 35 > 35 ≤ 40	- 40 - 45 - 50 - 55	27	41	-35°C
NV 2 - 4	400 - 490	265	255	24	≤ 25 > 25 ≤ 30 > 30 ≤ 35 > 35 ≤ 40	- 55 - 60 - 65 - 70	27	41	-50°C
NV 2 - 4L	400 - 490	265	255	24	≤ 25 > 25 ≤ 30 > 30 ≤ 35 > 35 ≤ 40	- 60 - 65 - 70 - 75	27	41	-55°C
NV 4 - 2	490 - 610	335	325	21	≤ 25 > 25 ≤ 30 > 30 ≤ 35 > 35 ≤ 40	- 20 - 25 - 30 - 35	27	41	-15°C
NV 4 - 3	490 - 610	335	325	21	≤ 25 > 25 ≤ 30 > 30 ≤ 35 > 35 ≤ 40	- 40 - 45 - 50 - 55	27	41	-35°C
NV 4 - 4	490 - 610	335	325	21	≤ 25 > 25 ≤ 30 > 30 ≤ 35 > 35 ≤ 40	- 55 - 60 - 65 - 70	27	41	-50°C
NV 4 - 4L	490 - 610	335	325	21	≤ 25 > 25 ≤ 30 > 30 ≤ 35 > 35 ≤ 40	- 60 - 65 - 70 - 75	27	41	-55°C

1) These requirements are applicable to products up to maximum 40 mm thickness. For thicknesses exceeding 40 mm the requirements shall be agreed.  
2) The specified impact toughness requirements also apply in the heat affected zone of welded connections and it is recommended that the steel is ordered with sufficient margin.  
3) Materials for tanks or parts of tanks completely thermally stress relieved after welding may for all thicknesses up to t ≤ 40 mm be tested at a temperature 5°C below the minimum design temperature.  
4) Materials for liquefied gas carriers, see Pt.5 Ch.5 Sec.2 Table D2 of the Rules for Classification of Ships.  
5) For thickness 25 < t ≤ 40 mm the impact test temperature shall be stamped on the products and stated in the certificate.

Grade	Tensile strength (N/mm <sup>2</sup> )	Yield stress (N/mm <sup>2</sup> ) minimum for thickness, (mm)		Elongation A <sub>5</sub> (%) minimum	Impact energy KV, average <sup>2)</sup>				Min design temperature
		≤ 30	> 30 ≤ 40		Thickness (mm)	Test temperature (°C) <sup>3)4)</sup>	Transverse (J) minimum	Longitudinal (J) minimum	
NV 1.5 Ni <sup>5)</sup>	470 - 640	275	265	22	≤ 25 > 25 ≤ 30 > 30 ≤ 35 > 35 ≤ 40	- 65 - 70 - 75 - 80	27	41	-60°C
NV 3.5 Ni <sup>5)</sup>	540 - 690	345	335	22	≤ 25 > 25 ≤ 30 > 30 ≤ 35 > 35 ≤ 40	- 95 - 100 - 105 - 110	27	41	-90°C
NV 5 Ni <sup>5)</sup>	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 shall be agreed.  
 2) The specified impact toughness requirements also apply in the heat affected zone of welded connections and it is recommended that the steel is ordered with sufficient margin.  
 3) Materials for 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 shall be stamped on the products and stated in the certificate.  
 5) In certain cases the materials shall be subjected to Pellini's drop weight test according to 302.

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 <sup>1)</sup> Sections: normalised, thermo-mechanically treated or controlled rolled <sup>2)</sup>
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 <sup>3)</sup>

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

### D 300 Mechanical properties

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

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

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

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

### D 400 Heat treatment

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

### D 500 Intercrystalline corrosion tests

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

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

<b>Table D1 Austenitic and duplex stainless steels. Chemical composition</b>									
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

<b>Table D2 Austenitic and duplex stainless steel. Mechanical properties</b>						
Grade	Tensile strength (N/mm <sup>2</sup> ) R <sub>m</sub>	Yield stress <sup>1)</sup> (N/mm <sup>2</sup> ), minimum		Elongation (%) A <sub>5</sub>	Impact energy Charpy V-notch <sup>2)</sup>	
		R <sub>p0.2</sub>	R <sub>p1.0</sub>		Test temperature (°C)	minimum average (J)
<i>Austenitic</i>						
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		
<i>Duplex</i>						
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%, R<sub>p0.2</sub> and R<sub>p1.0</sub> respectively, shall be documented for austenitic stainless steels.  
2) Verification of impact values for austenitic stainless steels is required only for materials intended for design temperatures below - 105°C.

## E. Testing

### E 100 General

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

**102** Test samples shall be taken from positions as required according to Sec.1 A600.

### E 200 Tensile testing at ambient temperature

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

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

**202** For plates, one tensile test piece shall be taken from each rolled plate provided the weight of the piece does not exceed 2 500 kg.

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

When the weight exceeds 2 500 kg, tensile test pieces shall be taken from both ends of the rolled plate.

**203** When test pieces are required from each end of a rolled plate, the difference between the values obtained for the tensile strength shall not exceed 60 N/mm<sup>2</sup>.

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

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

### E 300 Tensile testing at high temperatures

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

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

The intervals used for estimation of strain rate from measure-

ments of strain shall not exceed 6 seconds.

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

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

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

#### **E 400 Impact testing**

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

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

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

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

**403** The impact test pieces shall be situated so that the distance between the centre line of the test piece and the plate surface is not less than 1/4 of the plate thickness, where practicable.

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

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

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

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

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

#### **E 500 Drop weight testing**

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

#### **E 600 Testing of through thickness properties**

**601** When steel with improved through thickness properties

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

#### **E 700 Intercrystalline corrosion testing**

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

### **F. Inspection, Dimensional Tolerances and Surface Condition**

#### **F 100 Inspection**

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

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

**102** Plates and other products shall be subjected to a thorough, visual inspection on both sides by the manufacturer to ensure freedom from defects and harmful imperfections. Examination by means of suitable non-destructive methods such as magnetic particle, dye penetrant and/or ultrasonic inspection may be required.

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

#### **F 200 Tolerances**

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

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

#### **F 300 Surface condition and rectification of defects**

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

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

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

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

## SECTION 3 CLAD STEEL PLATES

### A. General

#### A 100 Scope

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

#### A 200 Heat treatment

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

### B. Base Material

#### B 100 General

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

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

### C. Cladding Metal

#### C 100 General

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

#### C 200 Chemical composition

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

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

### D. Testing

#### D 100 General

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

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

#### D 200 Tensile testing

201 One set of tensile tests consists of two tests:

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

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

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

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

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

#### D 300 Impact testing

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

#### D 400 Bend testing

401 The bend test pieces shall be bent 180°C around a former without showing signs of cracking or loosening of the cladding metal from the base material. The diameter of the former shall be twice the plate thickness when the tensile strength of the plate is less than 490 N/mm<sup>2</sup>, and three times the thickness of the plate when the tensile strength is more than 490 N/mm<sup>2</sup>. Two bend tests shall be taken from each plate. On single clad plates, one test piece shall be bent with the cladding in tension and the other with the cladding in compression. On double clad plates, the test pieces shall be bent, so that both cladding metals are tested both ways.

#### D 500 Shear testing

501 If a shear test is required to decide the shear strength between the base and the cladding metal, one shear test shall be made from each plate in accordance with ASTM A 264. The shear strength shall be at least 140 N/mm<sup>2</sup>.

#### D 600 Ultrasonic testing

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

#### D 700 Corrosion testing

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

**Guidance note:**

By adding approximately 50 gram electrolytic copper to 1 000 millilitres solution, the boiling time can be reduced to 15 hours. The base material shall be removed before the testing.

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

**D 800 Inspection — tolerances**

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

**E. Repair and Rejection**

**E 100 Surface defects**

**101** Minor surface defects and bonding defects which do not exceed the limits specified in 203, may be repaired by means of welding. Bonding defects along the edges shall be repaired.

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

Approved filler metal and welding processes shall be used.

**E 200 Rejection**

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

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

**203** The plate will be rejected if:

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

**F. Identification of Materials**

**F 100 Branding**

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

## SECTION 4 STEEL PIPES

### A. General Requirements

#### A 100 Scope

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

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

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

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

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

#### A 200 Manufacture

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

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

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

#### A 300 Chemical composition

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

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

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

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

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

#### A 400 Heat treatment

**401** The pipes shall be supplied in a condition in accordance with the requirements of the relevant standard. Unless otherwise required by the standard, hot finished or as-welded pipes

need not be heat treated.

#### A 500 Mechanical testing

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

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

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

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

#### A 600 Leak tightness testing

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

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

#### A 700 Inspection

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

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

#### A 800 Repair

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

#### A 900 Identification

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

#### A 1000 Certification

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

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

## B. Pressure Pipes

### B 100 Scope

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

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

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

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

### B 200 Manufacture

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

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

## C. Stainless Steel Pipes

### C 100 Scope

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

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

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

### C 200 Manufacture

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

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

### C 300 Mechanical testing

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

### C 400 Corrosion testing

**401** For ferritic-austenitic (duplex) stainless steel pipes, cor-

rosion testing in accordance with ASTM G48 Method A or an equivalent standard is required.

**402** Test specimen surfaces shall have a finish representative of the pipe's delivery condition. The test temperature shall be +20°C for type 22Cr duplex and +50°C for type 25Cr duplex, respectively. No pitting on specimen surfaces is allowed when viewed at 20 times magnification. The specimen mass loss shall be less than 4.0 g/m<sup>2</sup>.

## D. Pipes for Low-temperature Service

### D 100 Scope

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

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

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

### D 200 Manufacture

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

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

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

### D 300 Mechanical testing

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

Table D1 Charpy V-notch impact properties			
Steel type	Min. design temperature (°C)	Charpy V-notch	
		Test temperature (°C)	Average energy (J)
C and C-Mn	-55	1)	27
2 ¼ Ni	-65	-70	34
3 ½ Ni	-90	-95	34
9 Ni	-165	-196	41

1) The test temperature shall be 5°C below the design temperature or -20°C whichever is lower.

## E. Boiler and Superheater Tubes

### E 100 Scope

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

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

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

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

#### **E 200 Manufacture**

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

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

### **F. Piping Fittings**

#### **F 100 Scope**

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

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

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

- EN 10253
- ASTM A234, A403, A420, A744, A815, A960, A961
- DIN 2605, DIN 2609, DIN 2615, DIN 2616, DIN 2617

JIS B2312, JIS B2313, JIS B2316.

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

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

#### **F 200 Materials and manufacture**

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

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

#### **F 300 Testing and inspection**

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

#### **F 400 Certification**

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

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

## SECTION 5 STEEL FORGINGS

### A. General Requirements

#### A 100 Scope

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

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

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

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

#### A 200 Grading system

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

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

##### Guidance note:

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

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#### A 300 Manufacture

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

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

**303** For forgings with specified minimum ultimate tensile strength 800 N/mm<sup>2</sup> or above, the molten steel shall be vacuum treated prior to or during pouring of the ingot in order to remove objectionable gases, particularly hydrogen and oxygen, and improve steel cleanliness. Other processes may be accepted provided adequate cleanliness is documented.

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

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

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

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

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

**307** For crankshafts, where grain flow is specified in the most favourable direction with regard to the mode of stressing in service, the proposed method of manufacture requires special approval by the Society. In such cases, tests will be required to demonstrate that satisfactory mechanical properties and grain flow are obtained.

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

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

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

#### A 400 Chemical composition

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

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

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

#### A 500 Heat treatment

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

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

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

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

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

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

#### A 600 Test material and test pieces for mechanical testing

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

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

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

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

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

*Longitudinal test:* longitudinal axis of test piece parallel to the

principal direction of fibre deformation.

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

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

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

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

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

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

#### A 700 Test units and number of tests

**701** Normalised or solution heat treated forgings with mass 1 000 kg or more and quenched and tempered forgings with mass 500 kg or more shall be individually tested. The limits refer to the as forged or rough machined mass at time of heat treatment but exclude the test material.

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

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

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

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

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

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

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

#### A 800 Mechanical properties

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

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

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

#### A 900 Inspection

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

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

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

**904** Forgings are subject to non-destructive testing where specified in B to H. For non-destructive testing of finished machined components, see the relevant construction rules. All tests shall be carried out by personnel qualified and certified in accordance with recognised standards or schemes, e.g. ISO 9712, EN 473 or ASNT. Non-destructive testing shall be performed in accordance with the general practice of recognised standards, e.g.:

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

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

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

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

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

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

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

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

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

#### Guidance note:

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

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

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

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

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

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

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

#### A 1000 Repair

**1001** Defects may be removed by grinding or by chipping and grinding provided the component dimensions are acceptable and the repair is made in accordance with any applicable requirements of the relevant construction rules. See also 1002. The resulting grooves shall have a bottom radius of approximately three times the groove depth and shall be blended into the surrounding surface so as to avoid any sharp contours. Complete elimination of the defective material shall be verified by magnetic particle testing or liquid penetrant testing.

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

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

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

#### A 1100 Identification

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

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

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

#### A 1200 Certification

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

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

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

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

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

## B. Forgings for Hull Structures and Equipment

### B 100 Scope

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

### B 200 Chemical composition

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

### B 300 Heat treatment

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

### B 400 Mechanical testing

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

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

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

### B 500 Inspection

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

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

**Table B1 Chemical composition limits <sup>1)</sup> for steel forgings for hull structures and equipment <sup>2)</sup>**

Steel type	C	Si	Mn	P	S	Cr <sup>3)</sup>	Mo <sup>3)</sup>	Ni <sup>3)</sup>	Cu <sup>3)</sup>	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 <sup>4)</sup>	Minimum 0.15 <sup>4)</sup>	Minimum 0.40 <sup>4)</sup>	0.30	-

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

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

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

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

$l$  = longitudinal,  $t$  = transverse

### C. Forgings for Shafting and Machinery

#### C 100 Scope

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

#### C 200 Chemical composition

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

#### C 300 Heat treatment

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

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

#### C 400 Mechanical testing

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

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

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

#### C 500 Inspection

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

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

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

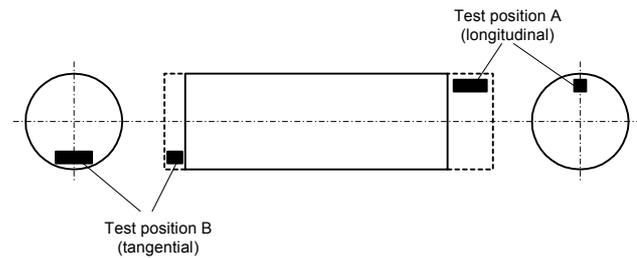


Fig. 1  
Plain shaft

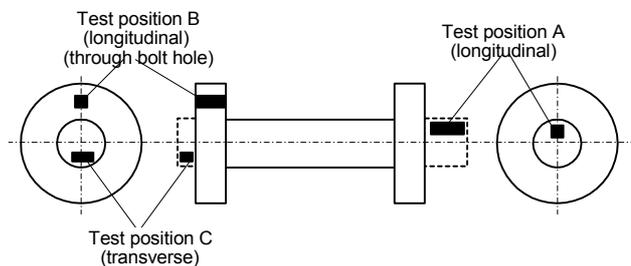


Fig. 2  
Flanged shaft

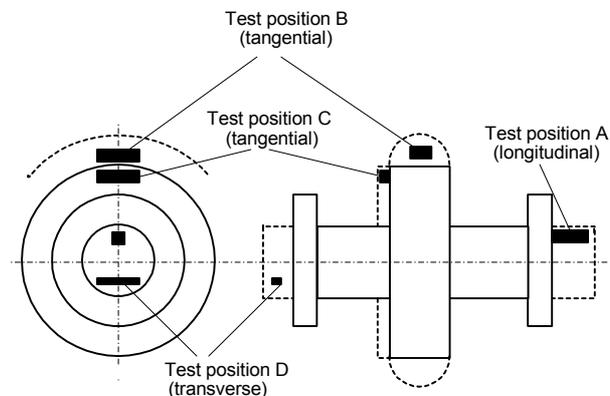


Fig. 3  
Flanged shaft with collar

Steel type	C	Si	Mn	P	S	Cr <sup>3)</sup>	Mo <sup>3)</sup>	Ni <sup>3)</sup>	Cu <sup>3)</sup>	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 <sup>4)</sup>	Minimum 0.15 <sup>4)</sup>	Minimum 0.40 <sup>4)</sup>	0.30	-

- 1) Composition in percentage mass by mass maximum unless shown as a range or as a minimum.
- 2) Other specifications may also be approved, see A103. Forgings intended for welding shall comply with the composition limits given in Table B1.
- 3) Elements are considered as residual elements unless shown as a range or as a minimum.
- 4) One or more of the elements shall comply with the minimum content.

Steel type	Tensile strength $R_m$ minimum (N/mm <sup>2</sup> )	Yield stress $R_e$ minimum (N/mm <sup>2</sup> )	Elongation $A_5$ minimum (%)			Reduction of area $Z$ minimum (%)			Charpy V-notch <sup>1) 2)</sup> 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	-	-	-
Alloy	760	380	14	12	10	35	30	24	-	-	-
	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
	1 000	700	12	10	8	35	30	24	25	19	16
	1 100	770	11	9	7	35	30	24	21	15	13

1) Testing shall be carried out at +20°C.  
2) For propeller shafts intended for ships with class notations covered under Pt.5 Ch.1 Sec.3, Sec.4 and Sec.8, Charpy V-notch impact testing shall be carried out in the longitudinal direction for all steel types at minus 10°C and the average energy value shall be minimum 27 J.

$l$  = longitudinal,  $t$  = transverse,  $ta$  = tangentially

## D. Forgings for Crankshafts

### D 100 Scope

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

### D 200 Chemical composition

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

### D 300 Heat treatment

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

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

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

### D 400 Mechanical testing

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

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

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

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

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

### D 500 Inspection

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

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

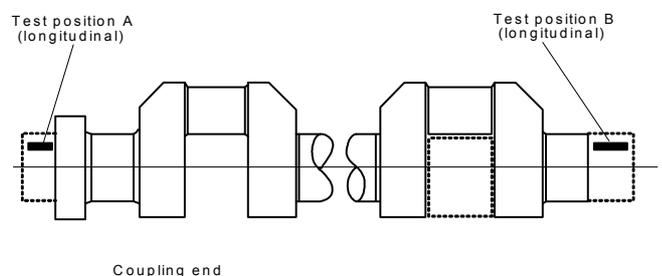


Fig. 4  
Solid forged crankshaft

## E. Forgings for Gearing

### E 100 Scope

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

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

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

**E 200 Chemical composition**

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

**E 300 Heat treatment**

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

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

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

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

**E 400 Mechanical testing of forgings not intended for carburising**

**401 Pinions**

Where the finished machined diameter of the toothed portion exceeds 200 mm, tangential tests shall be taken adjacent to the toothed portion (test position B in Fig. 5). Where the dimensions preclude the preparation of tests from this position, transverse tests shall be taken from the end of the journal (test position C in Fig. 5). If, however, the journal diameter is 200 mm or less, longitudinal tests shall be taken (test position A in Fig. 5). Where the finished length of the toothed portion exceeds 1 250 mm, tests shall be taken from each end.

**402 Small pinions**

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

**403 Gear wheels**

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

**404 Gear wheel rims (made by expanding)**

Tangential tests shall be taken (from one of the test positions A in Fig. 7). Where the finished diameter exceeds 2 500 mm or the mass (as heat treated but excluding test material) exceeds 3 tonnes, tests shall be taken from two diametrically opposite positions.

**405 Hollow pinions**

Tangential tests shall be taken (test position A in Fig. 8). Where the finished length of the toothed portion exceeds 1 250 mm, tests shall be taken from each end.

**406 Batch testing of small forgings**

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

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

**E 500 Testing of forgings for carburising applications**

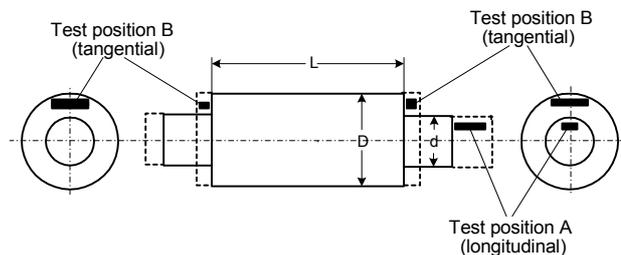
**501** When forgings shall be carburised after machining, sufficient test material shall be provided for final tests after completion of carburising and hardening, as agreed with the purchaser.

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

**E 600 Inspection**

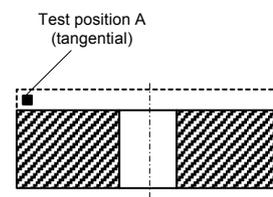
**601** Magnetic particle or liquid penetrant testing of finished machined forgings shall be carried out as specified in Pt.4 Ch.4 Sec2.

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

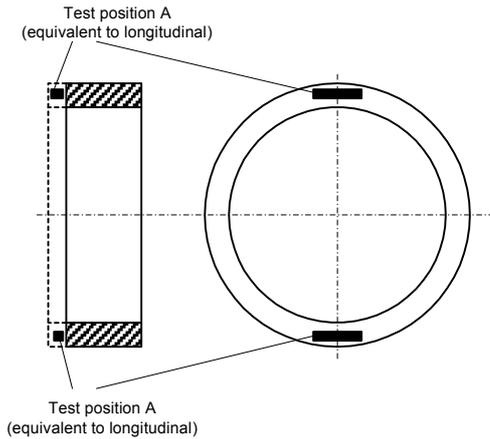


**Fig. 5 Pinion**

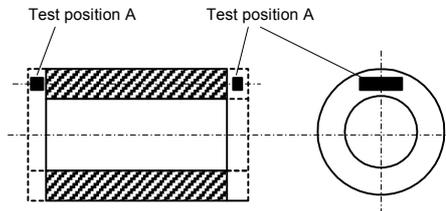
- $L$  = length of toothed portion
- $D$  = diameter of toothed portion
- $d$  = journal diameter



**Fig. 6 Gear wheel**



**Fig. 7**  
**Gear rim (made by expanding)**



**Fig. 8**  
**Hollow pinion**

## F. Forgings for Boilers, Pressure Vessels and Piping Systems

### F 100 Scope

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

alloy steels.

### F 200 Chemical composition

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

### F 300 Heat treatment

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

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

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

### F 400 Mechanical properties

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

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

### F 500 Inspection

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

**502** Normalised forgings with mass 1 000 kg or more and quenched and tempered forgings with mass 500 kg or more are subject to ultrasonic testing.

### F 600 Pressure testing

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

Steel type	C	Si	Mn	P	S	Cr <sup>2)</sup>	Mo <sup>2)</sup>	Ni <sup>2)</sup>	Cu <sup>2)</sup>	Al <sup>3)</sup>	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.

Steel type	Grade	Yield stress <i>R<sub>e</sub></i> minimum (N/mm <sup>2</sup> )	Tensile strength <i>R<sub>m</sub></i> (N/mm <sup>2</sup> )	Elongation <i>A<sub>5</sub></i> minimum (%)	Reduction of area <i>Z</i> minimum (%)
C and C-Mn	450H	240	450 - 600	22	35
	490H	275	490 - 640	18	30
½Mo	-	275	480 - 630	18	35
1Cr ½Mo	-	275	480 - 630	18	35
2 ¼Cr 1Mo, Normalised	-	315	520 - 670	18	35
2 ¼Cr 1Mo, QT	-	380	580 - 730	16	35

### G. Ferritic Steel Forgings for Low Temperature Service

#### G 100 Scope

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

#### G 200 Chemical composition

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

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

#### G 300 Heat treatment

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

a) Normalised.

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

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

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

#### G 400 Mechanical properties

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

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

#### G 500 Inspection

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

**502** Normalised forgings with mass 1 000 kg or more and quenched and tempered forgings with mass 500 kg or more are subject to ultrasonic testing.

#### G 600 Pressure testing

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

Steel type	C	Si	Mn	P	S	Cr <sup>2)</sup>	Mo <sup>2)</sup>	Ni	Cu <sup>2)</sup>	Al <sup>3)</sup>	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.

Steel type	Grade	Yield stress $R_e$ or $R_{p0.2}$ minimum (N/mm <sup>2</sup> )	Tensile strength $R_m$ (N/mm <sup>2</sup> )	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 <sup>1)</sup>	27
	490L	275	490 - 640	20	40	-60 <sup>1)</sup>	27
3 ½ Ni	-	275	490 - 640	20	35	-95	34
5 Ni	-	380	540 - 690	20	35	-110	34
9 Ni	-	480	640 - 790	18	35	-196	34

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

## H. Stainless Steel Forgings

### H 100 Scope

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

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

### H 200 Manufacture

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

### H 300 Mechanical properties

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

### H 400 Inspection

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

## SECTION 6 BARS FOR CHAIN CABLES

### A. General

#### A 100 Scope

**101** This section specifies the requirements for hot rolled steel bars of grades NV K1, NV K2 and NV K3 intended for chain cable links and accessories.

#### A 200 Manufacture

**201** All bars shall be made at works approved by the Society.

#### A 300 Chemical composition

**301** The chemical composition of each heat shall be determined and comply with the overall limits given in Table A1

and, where applicable, the approved specification.

#### A 400 Mechanical properties

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

#### A 500 Heat treatment

**501** Unless otherwise approved, the bars shall be delivered in the as rolled condition. For mechanical testing, bar material shall be tested in the condition of heat treatment used for the chain as advised by the chain manufacturer and indicated in Table A1.

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 for finished chain cables		As welded or normalised	As welded or normalised	Quenched and tempered, normalised or normalised and tempered	
Chemical composition	Carbon	%	Maximum 0.20	Maximum 0.24	Maximum 0.33
	Manganese	%	0.40 - 1.60	0.50 - 1.60	0.60 - 1.90
	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
	Aluminium	%	-	0.020 - 0.065	0.020 - 0.065 <sup>2)</sup>
	Nitrogen	%	-	-	Maximum 0.015
Mechanical properties	Yield stress $R_{eH}$ or proof stress $R_{p0.2}$ (MPa)	-	Minimum 295	Minimum 410	
	Tensile strength $R_m$ (MPa)	370 - 490	490 - 690	Minimum 690	
	Elongation A5 (%)	Minimum 25	Minimum 22	Minimum 17	
	Reduction of area Z (%)	-	-	Minimum 40	
	Average impact energy (J) and test temperature	-	Minimum 27; 0°C <sup>1)</sup>	Minimum 60; 0°C	

<sup>1)</sup> Impact tests may be waived when the chain cable shall be supplied normalised.  
<sup>2)</sup> One or more of the elements Al, Nb or V must be present in sufficient amount.

### B. Testing

#### B 100 Test units, test material and number of tests

**101** Bars of the same nominal diameter shall be presented in test units of 50 tonnes or fraction thereof from the same heat.

**102** Test material shall consist of a suitable length from one bar in each test unit. Where chain cables are supplied heat treated, see A501, the test material shall be simulated heat treated in full cross-section. Test material shall be suitably marked for identification with the bars represented.

**103** For each test unit, one tensile and, where required, three Charpy V-notch test pieces shall be taken in the longitudinal direction at a depth one third radius below the surface. For Charpy testing, the notch shall be cut in a face of the test piece which was originally approximately perpendicular to the rolled surface.

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

#### B 200 Mechanical properties

**201** The mechanical properties shall comply with the values given in Table A1.

**202** If the results do not meet the specified requirements the re-test procedures in Ch.1 may be adopted. Where bars and the associated test material are submitted to re-heat treatment, all the tests previously performed shall be repeated and the results must meet the specified requirements.

### C. Inspection, Tolerances and Repair

#### C 100 Inspection and tolerances

**101** Surface inspection and verification of dimensions are the responsibility of the manufacturer.

**102** The diameter and roundness shall be within the tolerances given in Table C1.

<b>Table C1 Dimensional tolerance of rolled bars</b>		
<i>Nominal diameter (mm)</i>	<i>Tolerance on diameter (mm)</i>	<i>Tolerance on roundness (<math>d_{max} - d_{min}</math>) (mm)</i>
< 25	-0 +1.0	0.6
25 – 35	-0 +1.2	0.8
36 – 50	-0 +1.6	1.1
51 – 80	-0 +2.0	1.5
81 – 100	-0 +2.6	1.95
101 – 120	-0 +3.0	2.25
121 – 160	-0 +4.0	3.00

**C 200 Repair**

**201** Surface defects may be repaired by grinding provided the admissible tolerance is not exceeded.

**D. Identification and Certification**

**D 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 heat.

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

**D 200 Certification**

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

- purchaser's name, order number and vessel identification, where known
- manufacturer's name
- number and dimensions of bars and steel grade
- identification marking of bars
- heat number and chemical composition
- results of mechanical tests
- details of heat treatment of test material, where applicable
- results of any supplementary and additional test requirements specified.

## SECTION 7 STEEL CASTINGS

### A. General Requirements

#### A 100 Scope

**101** Subsection A specifies the general requirements for steel castings to be used in the construction of hulls, equipment, machinery, boilers, pressure vessels and piping systems.

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

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

#### A 200 Grading system

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

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

##### Guidance note:

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

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#### A 300 Manufacture

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

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

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

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

#### A 400 Chemical composition

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

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

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

The content of such elements shall be reported.

#### A 500 Heat treatment

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

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

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

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

#### A 600 Test blocks and test pieces for mechanical testing

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

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

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

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

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

#### A 700 Test units and number of tests

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

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

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

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

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

## A 800 Mechanical properties

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

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

## A 900 Inspection

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

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

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

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

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

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

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

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

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

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

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

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

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

## Guidance note:

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

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

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

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

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

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

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

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

## A 1000 Repair

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

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

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

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

- of the section thickness or 25 mm, whichever is smaller, or
- the area of the groove based on length times width exceeds 0.125 m<sup>2</sup>, or
- castings have leaked on hydrostatic testing.

All other weld repairs are considered minor.

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

**1005** Minor weld repairs do not require the approval of the Society before the repair is commenced but must be recorded on sketches showing the extent and positions of the repairs. The records shall be presented to the surveyor on request.

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

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

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

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

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

#### **A 1100 Identification**

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

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

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

#### **A 1200 Certification**

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

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

where known.

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

## **B. Castings for Hull Structures and Equipment**

### **B 100 Scope**

**101** The requirements in B are supplementary to A and apply to steel castings for hull structures and equipment such as stem, stern frames, rudder members, propeller shaft supports and anchors. Provision is made for carbon and carbon-manganese steel and alloy steel grades suitable for assembly by welding.

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

### **B 200 Chemical composition**

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

### **B 300 Heat treatment**

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

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

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

### **B 400 Mechanical properties**

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

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

**B 500 Inspection**

and ultrasonic testing.

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

Steel type	C	Si	Mn	P	S	Cr <sup>3)</sup>	Mo <sup>3)</sup>	Ni <sup>3)</sup>	Cu <sup>3)</sup>	V <sup>3)</sup>	Total residuals
C and C-Mn	0.23 <sup>4)</sup>	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 <sup>5)</sup>	Minimum 0.15 <sup>5)</sup>	Minimum 0.40 <sup>5)</sup>	0.30	0.12	-

1) Composition in percentage mass by mass maximum unless shown as a range or as a minimum.  
 2) Castings not intended for welding may be supplied to the composition limits given in Table C1.  
 3) Elements are considered as residual elements unless shown as a range or as a minimum.  
 4) An increase is permitted up to maximum 0.30% provided that the Manganese content is reduced to maximum 1.20%.  
 5) One or more of the elements shall comply with the minimum content.

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

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

**C. Castings for Machinery****C 100 Scope**

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

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

**C 200 Chemical composition**

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

**C 300 Heat treatment**

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

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

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

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

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

**C 400 Mechanical properties**

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

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

**C 500 Inspection**

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

Steel type	C	Si	Mn	P	S	Cr <sup>3)</sup>	Mo <sup>3)</sup>	Ni <sup>3)</sup>	Cu <sup>3)</sup>	Total residuals
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 <sup>4)</sup>	Minimum 0.15 <sup>4)</sup>	Minimum 0.40 <sup>4)</sup>	0.30	-

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

Steel type	Steel grade	Yield stress $R_e$ minimum (N/mm <sup>2</sup> )	Tensile strength, $R_m$ minimum (N/mm <sup>2</sup> )	Elongation $A_5$ minimum (%)	Reduction of area $Z$ minimum (%)	Charpy V-notch	
						Temperature (°C)	Energy (J)
C and C-Mn	410	205	410	24	38	-	-
	450	225	450	22	30	-	-
	480	240	480	20	27	-	-
	520	260	520	18	25	-	-
Alloy	550	340	550	16	35	20	32
	600	400	600	16	35	20	32
	690	490	690	13	30	20	32

## D. Castings for Propellers

### D 100 Scope

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

### D 200 Chemical composition

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

### D 300 Heat treatment

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

### D 400 Mechanical testing

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

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

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

### D 500 Inspection

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

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

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

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

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

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

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

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

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

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

**510** For the purpose of evaluating PT indications, the surface shall be divided into reference areas of 100 cm<sup>2</sup>, which may be square or rectangular with the major dimension not exceeding 250 mm.

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

**D 600 Repair**

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

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

**603** Weld repairs require the approval of the Society before the repair is commenced. Proposals for weld repairs shall be accompanied by sketches or photographs showing the extent and positions of the repairs. Welds having an area less than 5 cm<sup>2</sup> shall be avoided.

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

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

**606** Repair welding is generally permitted in severity zone C.

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

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

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

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

**D 700 Welding procedure qualification test**

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

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

essed in accordance with 500.

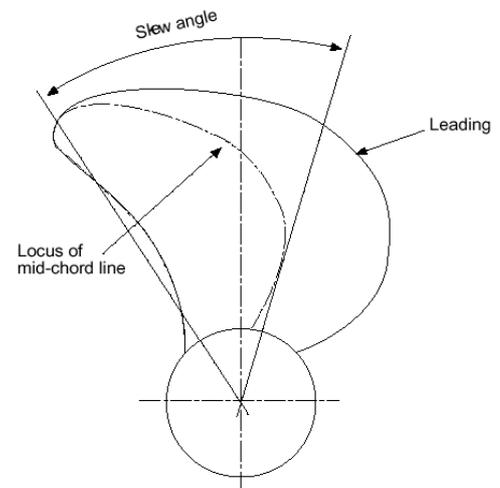
**703** Two macro-sections shall be prepared and etched on one side to clearly reveal the weld metal, the fusion line, and the heat affected zone. The sections shall be examined by eye (aided by low power hand lens if desired) for any imperfections present in the weld metal and HAZ. Cracks or lack of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

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

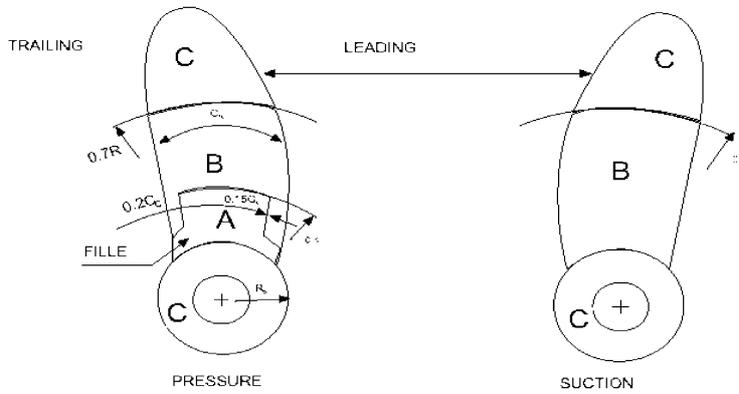
**705** Two transverse side bend test pieces shall be prepared. The former diameter shall be 4 times the thickness except for austenitic steels, in which case the former diameter shall be 3 times the thickness. The test piece, when visually inspected after bending, shall show no surface imperfections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

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

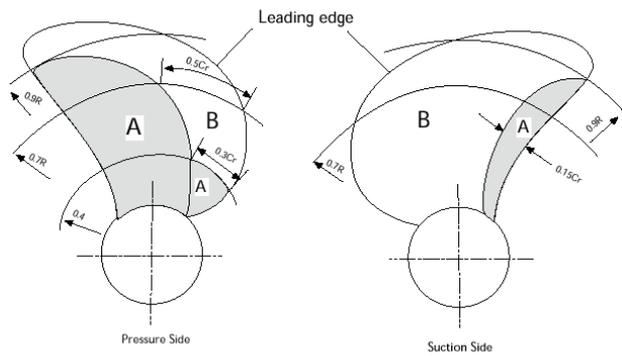
**707** One of the macro-sections shall be used for HV5 hardness testing. Indentations shall traverse 2 mm below the surface. At least three individual indentations shall be made in the weld metal, the HAZ (both sides) and in the base material (both sides). The values shall be reported for information.



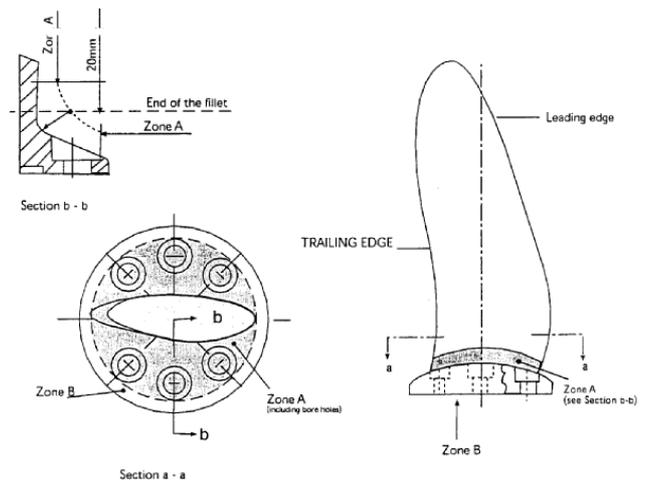
**Fig. 1**  
**Definition of skew angle**



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

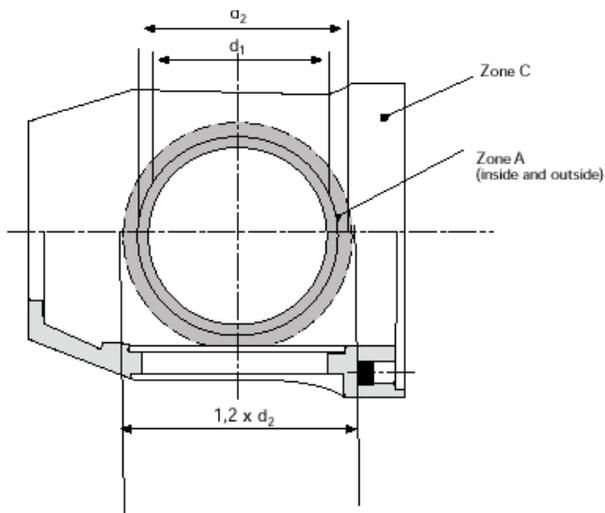


**Fig. 3**  
 Severity zones for high skew propellers and separately cast blades

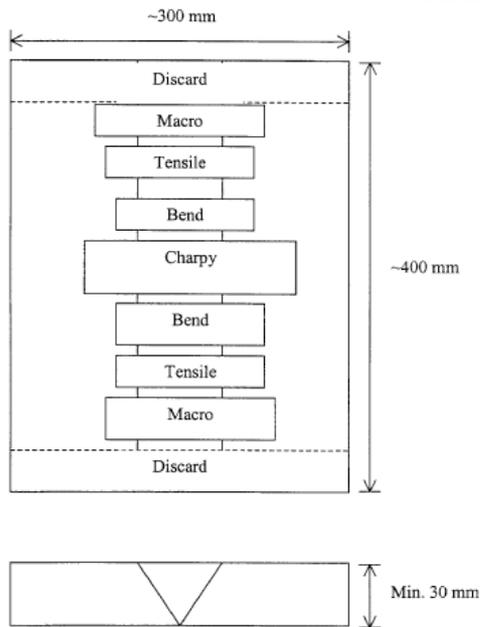


**Fig. 5**  
 Severity zones for controllable pitch propellers

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



**Fig. 4**  
 Severity zones for separately cast propeller hubs



**Fig. 6**  
Welding procedure qualification test assembly

Alloy type	C	Si	Mn	P	S	Cr	Mo	Ni
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.

Alloy type	Proof stress $R_{p0.2}$ minimum (N/mm <sup>2</sup> )	Tensile strength $R_m$ minimum (N/mm <sup>2</sup> )	Elongation $A_5$ minimum (%)	Reduction of area $Z$ minimum (%)	Charpy V-notch <sup>1)</sup>	
					Temperature (°C)	Energy minimum (J)
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 <sup>2)</sup>	440	30	40	-	-

1) Testing is required only for class notations covered under Pt.5 Ch.1 Sec.3, Sec.4 and Sec.8.  
2)  $R_{p1.0}$  value is 205 N/mm<sup>2</sup>.

Severity zone	Maximum number of indications	Indication type	Maximum number for each type <sup>1) 2)</sup>	Maximum length 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.

## E. Castings for Boilers, Pressure Vessels and Piping Systems

### E 100 Scope

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

### E 200 Chemical composition

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

### E 300 Heat treatment

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

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

302 Alloy steel castings shall be normalised and tempered or

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

### E 400 Mechanical properties

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

### E 500 Inspection

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

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

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

### E 600 Pressure testing

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

Steel type	C	Si	Mn	P	S	Cr <sup>2)</sup>	Mo <sup>2)</sup>	Ni <sup>2)</sup>	Cu <sup>2)</sup>	V <sup>2)</sup>	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.

Steel type	Grade	Yield stress <i>R<sub>e</sub></i> minimum (N/mm <sup>2</sup> )	Tensile strength <i>R<sub>m</sub></i> (N/mm <sup>2</sup> )	Elongation <i>A<sub>5</sub></i> minimum (%)	Reduction of area <i>Z</i> minimum (%)
C and C-Mn	450H	240	450 - 600	22	35
	490H	275	490 - 640	18	30
½Mo	-	250	450 - 600	21	35
1Cr ½Mo	-	275	480 - 630	17	35
2 ¼Cr 1Mo, Normalised	-	275	480 - 630	17	35
2 ¼Cr 1Mo, QT	-	380	580 - 730	16	35

## F. Ferritic Steel Castings for Low Temperature Service

### F 100 Scope

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

### F 200 Chemical composition

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

### F 300 Heat treatment

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

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

### F 400 Mechanical properties

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

### F 500 Inspection

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

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

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

### F 600 Pressure testing

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

**Table F1 Chemical composition limits <sup>1)</sup> for ferritic steel castings for low temperature service**

Steel type	C	Si	Mn	P	S	Cr <sup>2)</sup>	Mo <sup>2)</sup>	Ni	Cu <sup>2)</sup>	V <sup>2)</sup>	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 <sup>2</sup> )	Tensile strength $R_m$ (N/mm <sup>2</sup> )	Elongation $A_5$ minimum (%)	Charpy V-notch	
					Temperature (°C)	Energy (J)
C and C-Mn	450L	240	450 - 600	22	-60 <sup>1)</sup>	27
	490L	275	490 - 640	20	-60 <sup>1)</sup>	27
2 ½ Ni	-	275	490 - 640	20	-70	34
3 ½ Ni	-	275	490 - 640	20	-95	34

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

## G. Stainless Steel Castings

### G 100 Scope

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

### G 200 Chemical composition

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

### G 300 Heat treatment

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

### G 400 Mechanical properties

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

### G 500 Inspection

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

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

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

**Table G1 Chemical composition limits <sup>1)</sup> 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) <sup>2)</sup>	0.08	2.0	1.5	0.040	0.030	18.0 - 21.0	-	9.0 - 12.0
GX 2 CrNiMo 19 11 2 (316L)	0.03	1.5	1.5	0.040	0.030	17.0 - 21.0	2.0 - 3.0	9.0 - 13.0
GX 5 CrNiMo 19 11 2 (316)	0.08	1.5	1.5	0.040	0.030	17.0 - 21.0	2.0 - 3.0	9.0 - 12.0
GX 5 CrNiMo 19 11 3 (317)	0.08	1.5	1.5	0.040	0.030	17.0 - 21.0	3.0 - 4.0	9.0 - 13.0

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

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

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

## SECTION 8 IRON CASTINGS

### A. General

#### A 100 Scope

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

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

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

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

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

#### A 200 Quality of castings

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

#### A 300 Manufacture

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

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

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

#### A 400 Chemical composition

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

#### A 500 Heat treatment

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

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

#### A 600 Testing

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

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

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

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

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

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

#### A 700 Visual and non-destructive examination

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

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

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

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

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

#### A 800 Repair of defects

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

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

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

### B. Nodular Cast Iron

#### B 100 Scope

This subsection gives the specific requirements to nodular cast iron

#### B 200 Test material

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

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

#### B 300 Mechanical properties

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

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

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

**B 400 Metallographic examination**

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

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 <sup>1)</sup> <i>R<sub>m</sub></i> minimum (N/mm <sup>2</sup> )	Proof stress <sup>2)</sup> <i>R<sub>p0.2</sub></i> minimum (N/mm <sup>2</sup> )	Elongation <i>A<sub>5</sub></i> (%)	Average impact energy, <i>KV</i>		Hardness (HB)	Predominant structure
				minimum <sup>3)</sup> (J)	test temperature (°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 shall not 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 shall be used unless otherwise agreed and generally shall be in the form of bars 30 mm

in diameter and of suitable length.

**C 300 Mechanical properties**

**301** Only the tensile strength shall be determined and the results obtained from tests shall comply with the minimum value specified for the casting being supplied. The specified minimum tensile strength shall not be less than 200 N/mm<sup>2</sup>.

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

## SECTION 9 ALUMINIUM ALLOYS

### A. Wrought Aluminium Alloys

#### A 100 Scope

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

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

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

#### A 200 Aluminium grades and temper conditions

**201** The alloy grades are listed in Table A1. The numerical designation (grade) of aluminium alloys are based on those of the Aluminium Association. Temper conditions (delivery heat treatment) are defined in EN 515 or ANSI H35.1.

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

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

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

#### A 300 Manufacture

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

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

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

#### A 400 Chemical composition

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

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

#### A 500 Test material and test pieces for mechanical testing

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

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

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

#### A 600 Test units and number of tests

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

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

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

#### A 700 Mechanical properties

**701** The mechanical properties shall comply with the values given in Table A2 and Table A3, as applicable. Other temper conditions with related mechanical properties may be accepted by the Society after consideration in each particular case.

#### A 800 Press weld testing

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

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

**803** Where verification is by drift expansion test, the test pieces shall be cut with the ends perpendicular to the axis of the profile. The edges of the end may be rounded by filing. The minimum length of the test piece shall be twice the external diameter of the profile or 50 mm, whichever is greater. Testing

shall be carried out at ambient temperature and shall consist of expanding the end of the profile by means of a conical mandrel having an included angle of at least 60°. The test is considered to be unacceptable if it fails with a clean split along the weld line.

#### A 900 Corrosion testing

**901** Rolled 5000 series alloys of grade 5083, 5383, 5059, 5086 and 5456 in the H116 and H321 tempers intended for use in marine hull construction or in marine applications where frequent direct contact with seawater is expected shall be tested with respect to exfoliation and inter-granular corrosion resistance.

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

**903** Upon satisfactory establishment of the relationship between microstructure and resistance to corrosion, the reference photomicrographs and the results of the corrosion tests shall be approved by the Society. Production practices shall not be changed after approval of the reference micrographs.

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

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

#### A 1000 Inspection and tolerances

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

**1002** Permissible underthickness tolerances for rolled and extruded products are given in Table A5 and Table A6, respectively. Dimensional tolerances other than those given shall comply with a recognised standard.

**1003** The underthickness tolerance acceptable for classification shall be considered as the lower limit of a "plus-minus" range of thickness tolerances which could be found in the normal production of a plant producing rolled or extruded products, on average, to the nominal thickness.

#### A 1100 Repair

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

#### A 1200 Identification

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

- Manufacturer's name or trade mark.
- Alloy grade and temper condition.
- Identification number, heat number or other marking which will enable the full history of the product to be traced.
- DNV's certificate number, where applicable and as furnished by the surveyor.

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

#### A 1300 Certification

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

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

**Table A1 Chemical composition limits <sup>1)</sup> for wrought aluminium alloys**

Grade	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Other elements <sup>2)</sup>	
									Each	Total
NV-5052	0.25	0.40	0.10	0.10	2.2 – 2.8	0.15 – 0.35	0.10	-	0.0	0.15
NV-5059	0.45	0.50	0.25	0.6 – 1.2	5.0 – 6.0	0.25	0.40 – 0.9	0.20	0.05 <sup>5)</sup>	0.15 <sup>5)</sup>
NV-5083	0.40	0.40	0.10	0.40 – 1.0	4.0 – 4.9	0.05 – 0.25	0.25	0.15	0.05	0.15
NV-5086	0.40	0.50	0.10	0.20 – 0.7	3.5 – 4.5	0.05 – 0.25	0.25	0.15	0.05	0.15
NV-5154A	0.50	0.50	0.10	0.50	3.1 – 3.9	0.25	0.20	0.20	0.05	0.15
NV-5383	0.25	0.25	0.20	0.7 – 1.0	4.0 – 5.2	0.25	0.40	0.15	0.05 <sup>4)</sup>	0.15 <sup>4)</sup>
NV-5454	0.25	0.40	0.10	0.50 – 1.0	2.4 – 3.0	0.05 – 0.20	0.25	0.20	0.05	0.15
NV-5456	0.25	0.40	0.10	0.50-1.0	4.7-5.5	0.05-0.20	0.25	0.20	0.05	0.15
NV-5754	0.40	0.40	0.10	0.50 <sup>3)</sup>	2.6 – 3.6	0.30 <sup>3)</sup>	0.20	0.15	0.05	0.15
NV-6005A	0.50 - 0.9	0.35	0.30	0.50 <sup>6)</sup>	0.40 - 0.7	0.30 <sup>6)</sup>	0.20	0.10	0.05	0.15
NV-6060	0.30 - 0.6	0.10 - 0.30	0.10	0.10	0.35 - 0.6	0.05	0.15	0.10	0.05	0.15

	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-6061	0.40 - 0.8	0.7	0.15 - 0.40	0.15	0.8 - 1.2	0.04 - 0.35	0.25	0.15	0.05	0.15
NV-6063	0.20 - 0.6	0.35	0.10	0.10	0.45 - 0.9	0.10	0.10	0.10	0.05	0.15
NV-6082	0.7 - 1.3	0.50	0.10	0.40 - 1.0	0.6 - 1.2	0.25	0.20	0.10	0.05	0.15

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

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

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

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

Grade	Temper	Thickness, <i>t</i> (mm)	Yield strength <i>R<sub>p0.2</sub></i> min. (MPa)	Tensile strength <i>R<sub>m</sub></i> min. or range (MPa)	Elongation <sup>1)</sup>	
					<i>A<sub>50 mm</sub></i> min. (%)	<i>A<sub>5d</sub></i> min. (%)
NV-5059	H112	$t \leq 50$	200	330	10	10
NV-5083	0	$t \leq 50$	110	270 - 350	14	12
	H111	$t \leq 50$	165	275	12	10
	H112	$t \leq 50$	110	270	12	10
NV-5086	0	$t \leq 50$	95	240 – 315	14	12
	H111	$t \leq 50$	145	250	12	10
	H112	$t \leq 50$	95	240	12	10
NV-5383	0	$t \leq 50$	145	290	17	17
	H111	$t \leq 50$	145	290	17	17
	H112	$t \leq 50$	190	310	13	13
NV-6005A	T4	$t \leq 50$	90	180	15	13
	T5	$t \leq 50$	215	260	9	8
	T6	$t \leq 10$	215	260	8	6
		$10 < t \leq 50$	200	250	8	6
NV-6060	T4	$t \leq 50$	60	120	16	14
	T5	$t \leq 50$	100	140	8	6
	T6	$t \leq 50$	140	170	8	6
NV-6061	T4	$t \leq 50$	110	180	15	13
	T5	$t \leq 50$	205	240	6	7
	T6	$t \leq 50$	240	260	10	8
NV-6063	T4	$t \leq 50$	65	130	14	12
	T5	$t \leq 50$	110	150	8	7
	T6	$t \leq 50$	170	205	10	9
NV-6082	T4	$t \leq 0$	110	205	14	12
	T5	$t \leq 50$	230	270	8	6
	T6	$t \leq 5$	250	290	6	
		$5 < t \leq 50$	260	310	10	8

<sup>1)</sup> Elongation in 50 mm applies for thicknesses up to and including 12.5 mm and in 5d for thicknesses over 12.5 mm.

Nominal thickness, <i>t</i> (mm)	Width of plate ( <i>w</i> ) (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

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

## SECTION 10 COPPER ALLOY CASTINGS

### A. General Requirements

#### A 100 General

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

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

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

#### A 200 Grading system

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

#### A 300 Manufacture

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

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

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

#### A 400 Chemical composition

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

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

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

#### A 500 Heat treatment

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

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

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

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

#### A 600 Test blocks and test pieces for mechanical testing

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

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

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

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

#### A 700 Test units and number of tests

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

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

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

#### A 800 Mechanical properties

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

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

#### A 900 Inspection

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

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

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

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

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

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

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

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

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

#### **A 1000 Repair**

**1001** Defects may be removed by chipping, milling or grinding. Chipping or milling shall always be followed by grinding. The resulting grooves shall have a bottom radius of approximately three times the groove depth and shall be blended into the surrounding surface so as to avoid any sharp contours. Complete elimination of the defective material shall be verified by PT.

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

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

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

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

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

#### **A 1100 Identification**

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

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

#### **A 1200 Certification**

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

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

h) Test pressure, where applicable.

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

## **B. Castings for Valves, Fittings and General Application**

### **B 100 Scope**

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

### **B 200 Chemical composition**

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

### **B 300 Heat treatment**

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

### **B 400 Mechanical properties**

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

**402** The mechanical properties shall comply with the recognised standard.

### **B 500 Inspection**

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

### **B 600 Repair**

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

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

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

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

All other weld repairs are considered minor

**604** Major weld repairs require the approval of the Society before the repair is commenced. Proposals for major weld repairs shall be accompanied by sketches or photographs showing the extent and positions of the repairs.

**605** Minor weld repairs do not require the approval of the Society before the repair is commenced but must be recorded on sketches showing the extent and positions of the repairs. The records shall be presented to the surveyor on request.

## **C. Castings for Propellers**

### **C 100 Scope**

**101** These requirements are supplementary to subsection A and apply to copper alloy castings for propellers and separately cast blades and hubs.

**102** These requirements may also be used for the repair of propellers damaged in service, subject to prior agreement with the Society.

**C 200 Chemical composition**

**201** The chemical composition shall comply with the limits given in Table C1.

**C 300 Heat treatment**

**301** Propeller castings need generally not to be heat treated except as specified in 600.

**C 400 Mechanical testing**

**401** The mechanical properties shall meet the requirements in Table C2.

**C 500 Inspection**

**501** The castings are subject to inspection in accordance with A900 and as given in 502 to 504.

**502** For all propellers, separately cast blades and hubs, the surfaces covered by severity zones A, B and C are subject to PT. For definition of skew and description of severity zones, see the relevant parts of Sec.7. Testing of zone A shall be undertaken in the presence of the surveyor whilst testing of zones B and C may be witnessed by the surveyor upon his request.

**503** For the purpose of evaluating PT indications, the surface shall be divided into reference areas of 100 cm<sup>2</sup>, which may be square or rectangular with the major dimension not exceeding 250 mm.

**504** The indications detected may, with respect to their size and number, not exceed the values given in Table C4. Weld repairs are, independent of their location, always to be assessed according to zone A.

**C 600 Repair**

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

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

**603** Weld repairs require the approval of the Society before the repair is commenced. Proposals for weld repairs shall be accompanied by sketches or photographs showing the extent and positions of the repairs.

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

**605** Defects in severity zone B that are not deeper than t/40 mm (t is the minimum local thickness according to the rules) or 2 mm, whichever is greatest, may be removed by grinding. Those defects that are deeper may be repaired by welding.

**606** Repair welding is generally permitted in severity zone C.

**607** Repair welding of propellers with skew angle equal to 0° is generally permitted on the blade faces, and may also be repaired at the root area if so agreed with the Surveyor.

**608** Before welding is started, a detailed welding procedure specification shall be submitted covering the weld preparation, welding parameters, filler metals, preheating, post weld heat treatment and inspection procedures. Recommendations for welding are given in Table C3.

**609** The scope of the welding procedure qualification test is given in 900.

**610** With the exception of NiAl-Bronze all weld repairs shall be stress relief heat treated, in order to avoid stress corrosion cracking. The temperatures for the heat treatment is given in Table C3. The cooling rate shall not exceed 50°C/h until a temperature of 200°C is reached.

**C 700 Identification**

**701** Castings shall be identified in accordance with A1100 and with the following additional particulars:

- a) Ice class symbol, where applicable.
- b) Skew angle for high skew propellers.
- c) Date of final inspection.

**C 800 Certification**

**801** Castings shall be certified in accordance with A1200 and giving the following additional particulars:

- a) Description of the casting with drawing number.
- b) Diameter, number of blades, pitch, direction of turning.
- c) Skew angle for high skew propellers.
- d) Final mass.

**802** The manufacturer shall provide records of weld repairs as detailed in A1000.

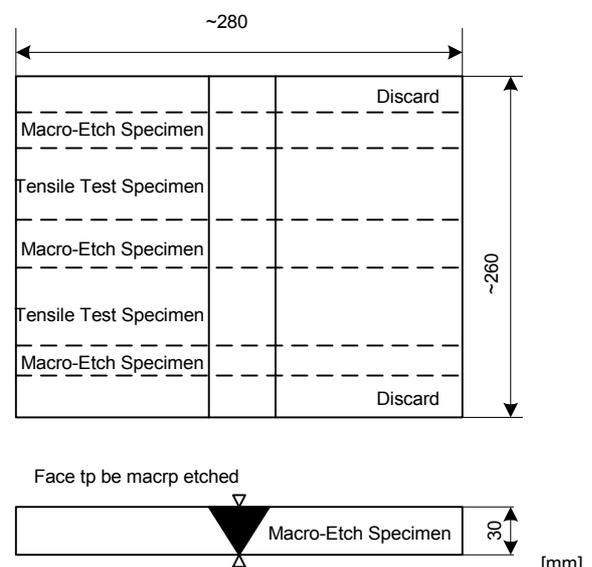
**C 900 Welding procedure qualification**

**901** For qualification of procedures, a test assembly of minimum 30 mm thickness shall be welded. See Fig.1.

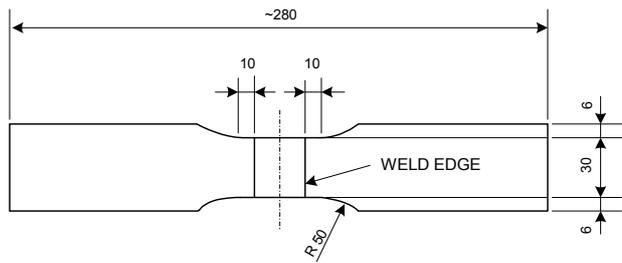
**902** Prior to sectioning, the test assembly shall be visually inspected and liquid penetrant tested. Imperfections shall be assessed in accordance with 500.

**903** Three macro-sections shall be prepared and etched on one side to clearly reveal the weld metal, the fusion line, and the heat affected zone. The sections shall be visually inspected for any imperfections present in the weld metal and HAZ. Inclusions or pores greater than 3 mm and cracks or lack of fusion are not permitted.

**904** Two tensile test pieces shall be prepared as shown in Fig.2. The tensile strength shall meet the specified minimum values given in Table C5. The location of fracture shall be reported, i.e. weld metal, HAZ or base material.



**Fig. 1**  
**Weld test assembly**



**Fig. 2**  
Tensile test specimen for weld test assembly

Alloy type	Cu	Al	Mn	Fe	Ni	Zn	Sn	Pb	Cr	Mg	Si
Mn-bronze <sup>2)</sup> , 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 <sup>2)</sup> , 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  $A = \text{Sn} + 5 \text{ Al} - 0.5 \text{ Mn} - 0.1 \text{ Fe} - 2.3 \text{ Ni}$

Alloy type	Yield strength $R_{p0.2}$ minimum (N/mm <sup>2</sup> )	Tensile strength $R_m$ minimum (N/mm <sup>2</sup> )	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

Alloy type	Description
Mn-bronze, Cu1	Use Al-bronze <sup>1)</sup> 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 <sup>2)</sup> 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

Severity zone	Maximum total number of indications	Indication type	Maximum number for each type <sup>1) 2)</sup>	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.

Alloy type	Tensile strength (N/mm <sup>2</sup> )
Mn-Bronze (brass)	370
MnNi-Bronze (brass)	410
NiAl-Bronze (bronze)	500
MnAl-Bronze (bronze)	550

## SECTION 11 NON-FERROUS TUBES

### A. Copper and Copper Alloy Tubes

#### A 100 Scope

**101** This subsection specifies requirements for copper and copper alloy tubes to be used in shipboard systems. Provision is made for phosphorus-deoxidised copper, aluminium brass and copper-nickel alloys.

**102** Tubes shall be in accordance with recognised standards, e.g. ASTM B 111, ASTM B 543, DIN 17671, DIN 1785, JIS H 3300 and JIS H 3320 provided that supplementary requirements contained herein are also met. Recognition of other standards is subject to submission to the Society for evaluation.

**103** Where required by the relevant design and construction parts of the rules, tubes shall comply with the requirements of Ch.1 and the requirements of this subsection.

**104** Where the use of material with differing requirements is proposed, particulars of chemical composition, mechanical properties and heat treatment shall be submitted in connection with the approval of the design for which the material is proposed.

#### A 200 Manufacture

**201** Tubes for class I and II pressure systems shall be made at works approved by DNV.

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

#### A 300 Chemical composition

**301** The chemical composition shall comply with the requirements of a recognised standard and with the limits for principal elements given in Table A1.

#### A 400 Heat treatment

**401** Copper tubes shall be supplied in the annealed or half-hard condition.

**402** Copper alloy tubes shall be supplied in the annealed condition.

#### A 500 Mechanical testing

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

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

#### A 600 Inspection

**601** Each tube shall be subjected to eddy current testing or pressure testing in accordance with the requirements of a recognised standard.

#### A 700 Repair

**701** Defects may be removed by grinding providing the dimensional tolerances are not exceeded. Repair by welding is not permitted.

#### A 800 Identification

**801** Tubes shall be suitably marked for identification by the manufacturer. Hard stamping of tubes is not permitted.

#### A 900 Certification

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

- a) Purchaser's name, order number and vessel identification, where known.
- b) Manufacturer's name.
- c) Description of tubes and material quality.
- d) Identification marking of tubes.
- e) Heat number and chemical composition.
- f) Results of mechanical tests and, where applicable, technological tests.
- g) Test pressure or results of eddy current tests.
- h) Results of any supplementary and additional test requirements specified.

<i>Designation</i>	<i>Cu</i>	<i>As</i>	<i>P</i>	<i>Pb</i>	<i>Fe</i>	<i>Zn</i>	<i>Ni</i>	<i>Al</i>	<i>Mn</i>
Phosphorus-deoxidised copper	Minimum 99.9 <sup>2)</sup>	-	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 <sup>3)</sup>	Remainder	-	-	-	1.0 - 2.0	-	9.0 - 11.0	-	0.5 - 1.0
Copper-Nickel 70-30 <sup>3)</sup>	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%.

<i>Designation</i>	<i>Condition</i>	<i>Yield strength R<sub>p0.2</sub> minimum (N/mm<sup>2</sup>)</i>	<i>Tensile strength R<sub>m</sub> minimum (N/mm<sup>2</sup>)</i>	<i>Elongation A<sub>5</sub> minimum (%)</i>
Phosphorus-deoxidised copper	Annealed	100	220	40
	Half-hard	150	250	20
Aluminium brass	Annealed	120	330	35
Copper-Nickel 90-10	Annealed	100	290	30
Copper-Nickel 70-30	Annealed	120	360	30

## **B. Titanium and Titanium Alloy Tubes**

### **B 100 Scope**

**101** This subsection specifies requirements for titanium and titanium alloy tubes to be used in shipboard systems. Provision is made for grade 1 and grade 2 unalloyed titanium and grade 9 titanium alloy.

**102** Tubes shall be in accordance with recognised standards, e.g. ASTM B 338, ASTM B 861 and ASTM B 862 provided that supplementary requirements contained herein are also met. Recognition of other standards is subject to submission to the Society for evaluation.

**103** Where required by the relevant design and construction parts of the rules, tubes shall comply with the requirements of Ch.1 and the requirements of this subsection.

**104** Where the use of material with differing requirements is proposed, particulars of chemical composition, mechanical properties and heat treatment shall be submitted in connection with the approval of the design for which the material is proposed.

### **B 200 Manufacture**

**201** All tubes shall be made at works approved by DNV.

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

### **B 300 Certification**

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

- a) Purchaser's name, order number and vessel identification, where known.
- b) Manufacturer's name.
- c) Description of tubes and material quality.
- d) Identification marking of tubes.
- e) Heat number and chemical composition.
- f) Results of mechanical tests.
- g) Test pressure.
- h) Results of any supplementary and additional test requirements specified.