

RULES FOR CLASSIFICATION OF
**Ships / High Speed, Light Craft and
Naval Surface Craft**

PART 2 CHAPTER 2

NEWBUILDINGS
MATERIALS AND WELDING

Metallic Materials

JULY 2011

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The Rules lay down technical and procedural requirements related to obtaining and retaining a Class Certificate. It is used as a contractual document and includes both requirements and acceptance criteria.

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CHANGES

General

The present edition of the rules includes amendments and additions approved by the Executive Committee as of June 2011 and supersedes the January 2011 edition of the same chapter.

The rule changes come into force as described below.

Text affected by the main rule changes is highlighted in red colour in the electronic pdf version. However, where the changes involve a whole chapter, section or sub-section, only the title may be in red colour.

This chapter is valid until superseded by a revised chapter.

Main changes coming into force 1 January 2012

- **Sec.8 Iron Castings**

- Introduction of test sample figures for Grey Iron Castings and Spheroidal or Nodular Graphite Iron Castings.

- **Sec.10 Copper Alloy Castings**

- Amended with regard to introduction of specific requirements to chemical composition and mechanical requirements for Castings for Valves, Fittings and General Application.

- **In addition there are numerous minor updates, editorials and corrections to be found in:**

- Sec. 1 A, 1 B and 1 C
- Sec. 2 B, 2 C and 2 D
- Sec. 4 E
- Sec. 5 A and 5 C
- Sec. 7 A, 7 B, 7 E, 7 F and 7 G
- Sec. 8 B
- Sec. 9 A
- Sec. 10 B
- Sec. 11 A

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

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

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

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

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

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

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

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

A 500 Condition of supply and heat treatment

501 Conditions of supply shall be in accordance with requirements given in B to D and as defined in 502 to 506. Where alternative conditions are permitted, the manufacturer shall supply materials only in 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 Ar₃ temperature so that the austenite completely re-crystallises. After the final pass, air cooling produces a fine grained ferrite-pearlite microstructure comparable to that obtained after normalising heat treatment.

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

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

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

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

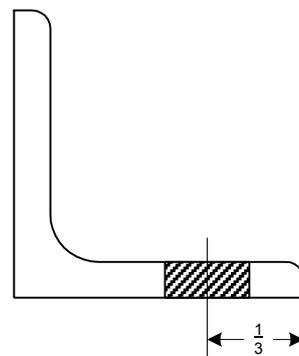
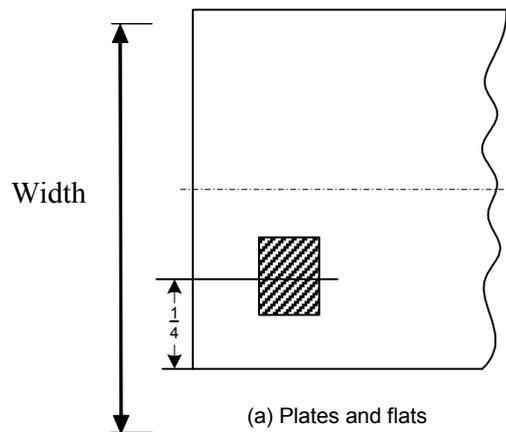
— *Bars and other similar products*

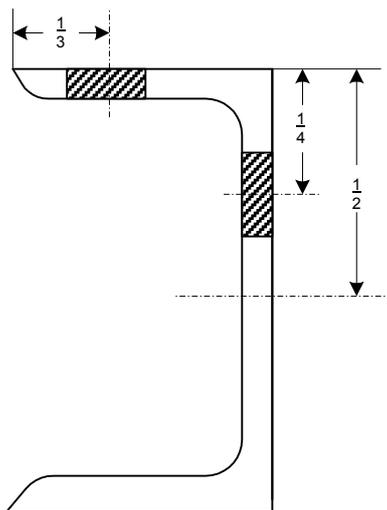
Tensile and impact test pieces shall be longitudinal.

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.

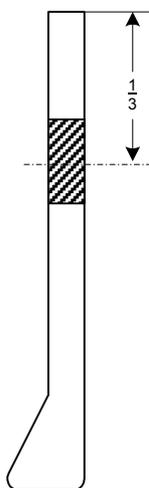
607 For impact test pieces, the notch shall be cut in a face of the test piece which was originally perpendicular to a rolled surface.

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.

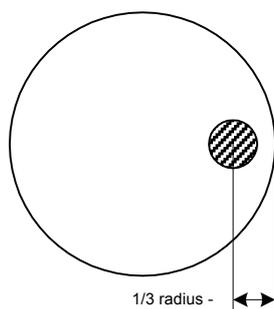




(d) Channels and beams



(e) Bulb flats



(f) Bars

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 piece (ref. A702) shall be at least 10 mm. At least 3 measuring points along a line at each side shall be made. Measurements shall be made by on-line automated methods or off-line manual methods. The number of pieces 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 m²,
- the total area of local grinding does not exceed 2% of the total surface area,
- the ground areas have smooth transitions to the surrounding surface.

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

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 m²,
- the total area of welding does not exceed 2% of the surface area of the side involved,
- the distance between any two welds is not less than their average width,

- the welds are made with an excess layer of beads and then ground flush with the product surface,
- when deemed necessary, the repaired product is normalised or otherwise suitably post-weld heat treated,
- the weld repairs are subjected to suitable non-destructive testing.

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

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 yield stress 235 MPa.

B 200 Chemical composition

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

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

| Table B2 Conditions of supply for normal strength steel | | | |
|---|-------------------|------------------------------|---|
| Grade | Thickness, t (mm) | Plates | Sections |
| A, B | t ≤ 50 | AR, NR, N, TM | AR, NR, N, TM |
| | 50 < t ≤ 150 | AR ¹⁾ , NR, N, TM | AR ¹⁾ , NR, N, TM |
| D | t ≤ 35 | AR, NR, N, TM | AR, NR, N, TM |
| | 35 < t ≤ 150 | NR, N, TM | AR ¹⁾ , NR, N, TM |
| E | t ≤ 150 | N, TM | AR ¹⁾ , NR ¹⁾ , 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.

| Table B3 Mechanical properties for normal strength steel | | | | | | | | | | |
|--|--|------------------------------------|---------------------------------------|------------------------------------|------------------|------------------|---------------------|------------------|----------------------|---|
| Grade | Yield stress R_{eH} minimum (MPa) | Tensile strength R_m (MPa) | Elongation A_5 minimum (%) | Impact energy, average minimum (J) | | | | | | |
| | | | | Temperature (°C) | t ≤ 50 (mm) | | 50 < t ≤ 70 (mm) | | 70 < t ≤ 150 (mm) | |
| NV A | 235 | 400 to 520 | 22 ³⁾ | +20 | L | T | L | T | L | T |
| NV B | | | | - | - | 34 ²⁾ | 24 ²⁾ | 41 ²⁾ | 27 ²⁾ | |
| NV D | | | | 27 ¹⁾ | 20 ¹⁾ | 34 | 24 | 41 | 27 | |
| NV E | | | | 27 | 20 | 34 | 24 | 41 | 27 | |
| | | | | 27 | 20 | 34 | 24 | 41 | 27 | |

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 |

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 ^{1) 2)} | 50 tonnes ²⁾ |
| D | $t \leq 150$ | 50 tonnes ^{1) 2)} | 50 tonnes ²⁾ |
| E | $t \leq 150$ | Each piece | 25 tonnes ³⁾ |

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

C. High Strength Steel

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 ¹⁾ for high strength steel

| Grade | C | Si | Mn | P | S | Cr | Mo | Ni | Cu | Al _{3) 4)} | Nb ₄₎ | V ₄₎ | Ti ₄₎ | N |
|--|------|------|----------------------------|-------|-------|------|------|------|------|---------------------|------------------|-----------------|------------------|---------------------|
| NV A27S, NV D27S, NV E27S | 0.18 | 0.50 | 0.70 to 1.60 | 0.035 | 0.035 | 0.20 | 0.08 | 0.40 | 0.35 | Min. 0.020 | 0.02 to 0.05 | 0.05 to 0.10 | 0.007 to 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 to 1.60 ²⁾ | 0.035 | 0.035 | 0.20 | 0.08 | 0.40 | 0.35 | Min. 0.020 | 0.02 to 0.05 | 0.05 to 0.10 | 0.007 to 0.05 | - |
| NV F27S, NV F32, NV F36, NV F40 | 0.16 | 0.50 | 0.90 to 1.60 | 0.025 | 0.025 | 0.20 | 0.08 | 0.80 | 0.35 | Min. 0.020 | 0.02 to 0.05 | 0.05 to 0.10 | 0.007 to 0.05 | 0.009 ⁵⁾ |

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

Table C2 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.

| Grade | Grain refining element | Thickness, <i>t</i> (mm) | Plates | Sections |
|-------------------------|--------------------------------|--------------------------|----------------------------------|---|
| NV A27S, NV A32, NV A36 | Al or any combinations with Al | <i>t</i> ≤ 20 | AR, NR, N, TM | AR, NR, N, TM |
| | | 20 < <i>t</i> ≤ 35 | AR ¹⁾ , NR, N, TM | AR, NR, N, TM |
| | | 35 < <i>t</i> ≤ 150 | NR, N, TM, QT | AR ¹⁾ , NR, N, TM, QT |
| | V and/or Nb | <i>t</i> ≤ 12.5 | AR, NR, N, TM | AR, NR, N, TM |
| 12.5 < <i>t</i> ≤ 150 | | NR, N, TM, QT | AR ¹⁾ , NR, N, TM, QT | |
| NV A40 | Any | <i>t</i> ≤ 12.5 | AR, NR, N, TM | AR, NR, N, TM |
| | | 12.5 < <i>t</i> ≤ 150 | NR, N, TM, QT | NR, N, TM, QT |
| NV D27S, NV D32, NV D36 | Al or any combinations with Al | <i>t</i> ≤ 20 | AR, NR, N, TM | AR, NR, N, TM |
| | | 20 < <i>t</i> ≤ 25 | AR ¹⁾ , NR, N, TM | AR, NR, N, TM |
| | | 25 < <i>t</i> ≤ 150 | NR, N, TM, QT | AR ¹⁾ , NR, N, TM, QT |
| | V and/or Nb | <i>t</i> ≤ 12.5 | AR, NR, N, TM | AR, NR, N, TM |
| 12.5 < <i>t</i> ≤ 150 | | NR, N, TM, QT | AR ¹⁾ , NR, N, TM, QT | |
| NV D40 | Any | <i>t</i> ≤ 150 | NR, N, TM, QT | NR, N, TM, QT |
| NV E27S, NV E32, NV E36 | Any | <i>t</i> ≤ 50 | N, TM, QT | AR ¹⁾ , NR ¹⁾ , N, TM, QT |
| | | 50 < <i>t</i> ≤ 150 | N, TM, QT | NR ¹⁾ , N, TM, QT |
| NV F27S, NV F32, NV F36 | Any | <i>t</i> ≤ 150 | N, TM, QT | NR ¹⁾ , N, TM, QT |
| NV E40, NV F40 | Any | <i>t</i> ≤ 150 | N, TM, QT | N, TM, QT |

¹⁾ 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.

| Grade | Yield stress <i>R_{eH}</i> minimum (MPa) | Tensile strength <i>R_m</i> (MPa) | Elongation <i>A₅</i> minimum (%) | Impact energy, average minimum (J) | | | | | | |
|--|--|---|---|------------------------------------|--------------------|----------|-------------------------|----------|--------------------------|----------|
| | | | | Temperature (°C) | <i>t</i> ≤ 50 (mm) | | 50 < <i>t</i> ≤ 70 (mm) | | 70 < <i>t</i> ≤ 150 (mm) | |
| | | | | | <i>L</i> | <i>T</i> | <i>L</i> | <i>T</i> | <i>L</i> | <i>T</i> |
| NV A27S NV D27S NV E27S NV F27S | 265 | 400 to 530 | 22 ¹⁾ | 0 | 27 | 20 | 34 | 24 | 41 | 27 |
| -20 | | | | | | | | | | |
| -40 | | | | | | | | | | |
| -60 | | | | | | | | | | |
| NV A32 NV D32 NV E32 NV F32 | 315 | 440 to 570 | 22 ¹⁾ | 0 | 31 | 22 | 38 | 26 | 46 | 31 |
| -20 | | | | | | | | | | |
| -40 | | | | | | | | | | |
| -60 | | | | | | | | | | |
| NV A36 NV D36 NV E36 NV F36 | 355 | 470 to 620 | 21 ¹⁾ | 0 | 34 | 24 | 41 | 27 | 50 | 34 |
| -20 | | | | | | | | | | |
| -40 | | | | | | | | | | |
| -60 | | | | | | | | | | |
| NV A40 NV D40 NV E40 NV F40 | 390 | 510 to 660 | 20 ¹⁾ | 0 | 39 | 26 | 46 | 31 | 55 | 37 |
| -20 | | | | | | | | | | |
| -40 | | | | | | | | | | |
| -60 | | | | | | | | | | |

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

| Thickness, mm | <i>t</i> ≤ 5 | 5 < <i>t</i> ≤ 10 | 10 < <i>t</i> ≤ 15 | 15 < <i>t</i> ≤ 20 | 20 < <i>t</i> ≤ 25 | 25 < <i>t</i> ≤ 30 | 30 < <i>t</i> ≤ 40 | <i>t</i> > 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

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

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

D. Extra High Strength Steel

D 100 Scope

101 These requirements are supplementary to A and apply to extra high strength 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 is further subdivided into four grades based on the specified impact toughness.

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.

Table D1 Chemical composition limits ¹⁾ for extra high strength steel

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

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

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.

| Table D2 Mechanical properties for extra high strength steel ¹⁾ | | | | | | | |
|---|--|------------------------------------|---------------------------------------|--|------------------|----------------------|----------|
| 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 to 680 | 18 ²⁾ | 0 -20 -40 -60 | 28 | | |
| NV A460 NV D460 NV E460 NV F460 | 460 | 570 to 720 | 17 ²⁾ | 0 -20 -40 -60 | 31 | | |
| NV A500 NV D500 NV E500 NV F500 | 500 | 610 to 770 | 16 ²⁾ | 0 -20 -40 -60 | 33 | | |
| NV A550 NV D550 NV E550 NV F550 | 550 | 670 to 830 | 16 ²⁾ | 0 -20 -40 -60 | 37 | | |
| NV A620 NV D620 NV E620 NV F620 | 620 | 720 to 890 | 15 ²⁾ | 0 -20 -40 -60 | 41 | | |
| NV A690 NV D690 NV E690 NV F690 | 690 | 770 to 940 | 14 ²⁾ | 0 -20 -40 -60 | 46 | | |
| ¹⁾ Extra high strength steel grade NV 47 for Hull Structural Application in Container Ships is defined in Classification Notes No. 30.10 ²⁾ 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.

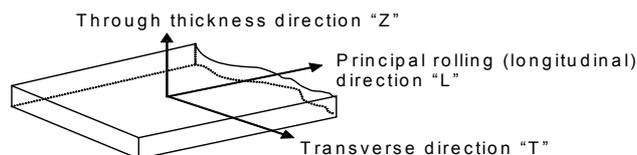


Fig. 2
Through thickness tensile testing

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.

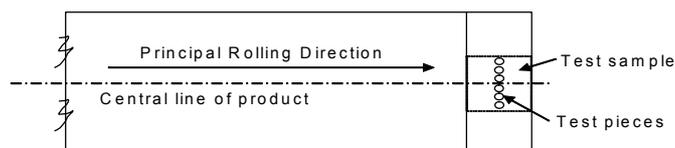


Fig. 3
Plate and wide flat sampling position

| Table E1 Test unit (batch) size dependent on product and sulphur content | | |
|---|--|--|
| <i>Product</i> | $S > 0.005\%$ | $S \leq 0.005\%$ |
| Plates | Each piece (parent plate) | Maximum 50 t of products of the same heat, thickness and condition of supply |
| Wide flats of nominal thickness ≤ 25 mm | Maximum 10 t of products of the same heat, thickness and condition of supply | Maximum 50 t of products of the same heat, thickness and condition of supply |
| Wide flats of nominal thickness > 25 mm | Maximum 20 t of products of the same heat, thickness and condition of supply | Maximum 50 t of products of the same heat, thickness and condition of supply |

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.

| Table E2 – Reduction of Area Acceptance Values | | |
|---|-----|-----|
| <i>Quality class</i> | Z25 | Z35 |
| 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/mm².

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

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

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

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

Example:

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

B 200 Chemical composition

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

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

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

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

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

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

B 300 Mechanical properties

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

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

Table B4: Carbon and carbon-manganese steels, normalised or normalised 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 normalised rolled- and thermo-mechanically treated steel grades shall be given the suffix CR and TM respectively instead of N.

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

| Grade | Chemical composition, (%) | | | | | | | | Deoxidation |
|-------------------|---------------------------|-------------|----------------------------|-----------|-----------|------------------------------|---------------------|----------------------------|----------------------|
| | C maximum | Si | Mn | P maximum | S maximum | Al _{ac.sol} | N maximum | Residual elements, maximum | |
| NV 360 - 0A, - 0N | 0.17 | ≤ 0.35 | 0.40 to ²⁾ 1.00 | 0.035 | 0.030 | ≤ 0.010 | 0.009 ¹⁾ | 6) | Semikilled or killed |
| NV 360 - 1 FN | 0.17 | ≤ 0.35 | 0.40 to ²⁾ 1.00 | 0.035 | 0.030 | 0.015 to ⁵⁾ 0.080 | 0.015 | 6) | Killed fine grained |
| NV 410 - 0A, - 0N | 0.20 | ≤ 0.35 | 0.50 to 1.30 | 0.035 | 0.030 | ≤ 0.010 | 0.009 ¹⁾ | 6) | Semikilled or killed |
| NV 410 - 1 FN | 0.20 | ≤ 0.35 | 0.50 to 1.30 | 0.035 | 0.030 | 0.015 to ⁵⁾ 0.080 | 0.015 | 6) | Killed fine grained |
| NV 460 - 0A, - 0N | 0.20 | ≤ 0.40 | 0.60 to ³⁾ 1.40 | 0.035 | 0.030 | ≤ 0.010 | 0.009 ¹⁾ | 6) | Semikilled or killed |
| NV 460 - 1 FN | 0.20 ⁴⁾ | ≤ 0.40 | 0.60 to ³⁾ 1.40 | 0.035 | 0.030 | 0.015 to ⁵⁾ 0.080 | 0.015 | 6) | Killed fine grained |
| NV 490 - 0N | 0.20 ⁴⁾ | 0.10 - 0.50 | 0.90 to 1.60 | 0.035 | 0.030 | ≤ 0.010 | 0.009 ¹⁾ | 6) | Killed |
| NV 490 - 1 FN | 0.20 ⁴⁾ | 0.10 - 0.50 | 0.90 to 1.60 | 0.035 | 0.030 | 0.015 to ⁵⁾ 0.080 | 0.015 | 6) | Killed fine grained |
| NV 510 - 1 FN | 0.22 | 0.10 - 0.60 | 1.00 to 1.60 | 0.035 | 0.030 | 0.015 to 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 $t \leq 100$ mm, C_{max} 0.22%.

5) Aluminium may be replaced by other grain refining elements.

6) Cr 0.20
Cu 0.35
Ni 0.40
Mo 0.08
Total 0.70

| Table B2 Alloy steels for boilers and pressure vessels. Chemical composition | | | | | | | | | |
|---|---------------------------|--------------|--------------|-----------|-----------|---------------------------|--------------|--------------|----------------------------|
| Grade | Chemical composition, (%) | | | | | | | | Residual elements, maximum |
| | C | Si | Mn | P maximum | S maximum | Al _{tot} maximum | Cr | Mo | |
| NV 0.3 Mo | 0.12 to 0.20 | 0.15 to 0.35 | 0.50 to 0.80 | 0.035 | 0.030 | 0.012 | < 0.30 | 0.25 to 0.35 | Cu 0.25 Ni 0.30 |
| NV 1 Cr 0.5 Mo | 0.10 to 0.18 | 0.15 to 0.35 | 0.40 to 0.80 | 0.035 | 0.030 | 0.020 | 0.70 to 1.30 | 0.40 to 0.60 | |
| NV 2.25 Cr 1 Mo | 0.08 to 0.18 | 0.15 to 0.50 | 0.40 to 0.80 | 0.035 | 0.030 | 0.020 | 2.00 to 2.50 | 0.90 to 1.10 | |

| Table B3 Carbon and carbon-manganese steels for boilers and pressure vessels, as rolled condition. Mechanical properties | | | | | | | |
|---|---|---|-----------|------------------------------|-----------------------|------------------------|--------------------------|
| Grade | Tensile strength R_m (N/mm ²) | Yield stress, R_{eH} or $R_{p0.2}$ (N/mm ²) minimum for thickness, (mm) | | Elongation A_5 (%) minimum | KV, average | | |
| | | ≤ 16 | > 16 ≤ 25 | | Test temperature (°C) | Transverse (J) minimum | Longitudinal (J) minimum |
| NV 360 - 0A | 360 to 480 | 205 | 195 | 26 | 20 | 20 | 27 |
| NV 410 - 0A | 410 to 530 | 235 | 225 | 24 | 20 | 20 | 27 |
| NV 460 - 0A | 460 to 580 | 285 | 255 | 22 | 20 | 20 | 27 |

| Table B4 Carbon and carbon-manganese steels for boilers and pressure vessels, normalised or normalised rolled condition. Mechanical properties | | | | | | | | | |
|---|---|---|-----------|-----------|------------|------------------------------|-----------------------|------------------------|--------------------------|
| Grade | Tensile strength R_m (N/mm ²) | Yield stress, R_{eH} or $R_{p0.2}$ (N/mm ²) minimum for thickness, (mm) | | | | Elongation A_5 (%) minimum | KV, average | | |
| | | ≤ 16 | > 16 ≤ 40 | > 40 ≤ 63 | > 63 ≤ 100 | | Test temperature (°C) | Transverse (J) minimum | Longitudinal (J) minimum |
| NV 360 - 0N | 360 to 480 | 205 | 195 | 185 | 175 | 26 ¹⁾ | 20 | 20 | 27 |
| NV 360 - 1 FN | 360 to 480 | 235 | 215 | 195 | 2) | 26 ¹⁾ | 0 | 20 | 27 |
| NV 410 - 0N | 410 to 530 | 235 | 225 | 215 | 205 | 24 ¹⁾ | 20 | 20 | 27 |
| NV 410 - 1 FN | 410 to 530 | 265 | 245 | 235 | 2) | 24 ¹⁾ | 0 | 20 | 27 |
| NV 460 - 0N | 460 to 580 | 285 | 255 | 245 | 235 | 22 ¹⁾ | 20 | 20 | 27 |
| NV 460 - 1 FN | 460 to 580 | 295 | 285 | 275 | 2) | 22 ¹⁾ | 0 | 20 | 27 |
| NV 490 - 0N | 490 to 610 | 305 | 275 | 265 | 255 | 21 ¹⁾ | 20 | 22 | 31 |
| NV 490 - 1 FN | 490 to 610 | 315 | 315 | 305 | 2) | 21 | 0 | 22 | 31 |
| NV 510 - 1 FN | 510 to 650 ³⁾ | 355 | 345 | 335 | 315 | 20 | 0 | 22 | 31 |

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

| Table B5 Alloy steels for boilers and pressure vessels. Mechanical properties | | | | | | | | |
|--|---|--|-----------|-----------|------------------------------|-----------------------|------------------------|--------------------------|
| Grade | Tensile strength R_m (N/mm ²) | Yield strength R_{eH} or $R_{p0.2}$ (N/mm ²) minimum for thickness, (mm) ²⁾ | | | Elongation A_5 (%) minimum | KV, average | | |
| | | ≤ 16 | > 16 ≤ 40 | > 40 ≤ 63 | | Test temperature (°C) | Transverse (J) minimum | Longitudinal (J) minimum |

| | | | | | | | | |
|---|------------|-----|-----|-----|------------------|----|----|----|
| NV 0.3 Mo | 440 to 590 | 260 | 250 | 250 | 24 ¹⁾ | 20 | 20 | 27 |
| NV 1 Cr 0.5 Mo | 470 to 620 | 305 | 305 | 305 | 20 ¹⁾ | 20 | 22 | 31 |
| NV 2.25 Cr 1 Mo | 480 to 630 | 275 | 265 | 265 | 18 ¹⁾ | 20 | 20 | 27 |
| <p>1) For thicknesses 40 - 63 mm, the minimum value is 1 unit lower and for thicknesses 63 - 100 mm, 2 units lower.</p> <p>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.</p> | | | | | | | | |

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

| Grade | | Thickness (mm) 1) | Minimum R_{eL} or $R_{p0.2}$ (N/mm ²) Temperature, (°C) | | | | | | | | |
|-------------------------------------|-----------------|----------------------|--|-----|-----|-----|-----|-----|-----|-----|-----|
| | | | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 |
| C- and C/Mn-steels, normalised | NV 360 - 0N | < 16 | 175 | 172 | 168 | 150 | 124 | 117 | 115 | 113 | |
| | | 16 ≤ 40 | 171 | 169 | 162 | 144 | 124 | 117 | 115 | 113 | |
| | | > 40 ≤ 63 | 162 | 158 | 152 | 141 | 124 | 117 | 115 | 113 | |
| | NV 360 - 1 FN | <16 | 204 | 185 | 165 | 145 | 127 | 116 | 110 | 106 | |
| | | >16 ≤ 40 | 196 | 183 | 164 | 145 | 127 | 116 | 110 | 106 | |
| | | > 40 ≤ 63 | 179 | 172 | 459 | 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 ²) for steel grades | | | | | | | | | |
|---------------------|--|--------------|--|--------------|--------------|--------------|----------------|--------------|-----------------|--------------|
| | NV 360 - 0N NV 360 - 1FN NV 410 - 0N NV 410 - 1FN | | NV 460 - 0N NV 460 - 1FN NV 490 - 0N NV 490 - 1FN NV 510 - 1FN | | NV 0.3 Mo | | NV 1 Cr 0.5 Mo | | NV 2.25 Cr 1 Mo | |
| | 100 000 h | 200 000 h | 100 000 h | 200 000 h | 100 000 h | 200 000 h | 100 000 h | 200 000 h | 100 000 h | 200 000 h |
| 380 | 165 | 145 | 227 | 206 | | | | | | |
| 390 | 148 | 129 | 203 | 181 | | | | | | |
| 400 | 132 | 115 | 179 | 157 | | | | | | |
| 410 | 118 | 101 | 157 | 135 | | | | | | |
| 420 | 103 | 89 | 136 | 115 | | | | | | |
| 430 | 91 | 78 | 117 | 97 | | | | | | |
| 440 | 79 | 67 | 100 | 82 | | | | | | |
| 450 | 69 | 57 | 85 | 70 | 239 | 217 | - | - | 221 | 203 |
| 460 | 59 | 48 | 73 | 60 | 208 | 188 | - | - | 204 | 186 |
| 470 | 50 | 40 | 63 | 52 | 178 | 159 | - | - | 186 | 169 |
| 480 | 42 | 33 | 55 | 44 | 148 | 130 | 210 | 180 | 170 | 152 |
| 490 | | | 47 | 37 | 123 | 105 | 177 | 148 | 153 | 135 |
| 500 | | | 41 | 30 | 101 | 84 | 146 | 122 | 137 | 119 |
| 510 | | | | | 81 | 69 | 121 | 99 | 122 | 103 |
| 520 | | | | | 66 | 55 | 99 | 79 | 107 | 89 |
| 530 | | | | | 53 | 45 | 81 | 64 | 93 | 77 |
| 540 | | | | | | | 67 | 52 | 79 | 68 |
| 550 | | | | | | | 54 | 42 | 69 | 58 |
| 560 | | | | | | | 43 | 34 | 59 | 50 |
| 570 | | | | | | | 35 | - | 51 | 43 |
| 580 | | | | | | | | | 44 | - |

| Grade | Heat treatment or condition of supply |
|---|---|
| NV 360 0A NV 410 0A NV 460 0A | As rolled |
| NV 360 - 0N ₃ - 1 FN NV 410 - 0N ₃ - 1 FN NV 460 - 0N ₃ - 1 FN NV 490 - 0N ₃ - 1 FN NV 510 - 1 FN | Normalised/normalised rolled ¹⁾ Thermo-mechanically treated |
| NV 0.3 Mo | Normalised |
| NV 1 Cr 0.5 Mo NV 2.25 Cr 1 Mo | Normalised and tempered |

1) See 402.

C. Steel for Low Temperature Service

C 100 Steel grades

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

C 200 Chemical composition

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

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

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

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

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

analysis using the following formula when applicable:

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

C 300 Mechanical properties

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

Table C3: Carbon-manganese steels

Table C4: Nickel alloy steels

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

302 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, normalised rolled and thermo-mechanically treated steel grades shall be given the suffix QT, NR, and TM respectively instead of N.

Guidance note:

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

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

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

1) For the steel grades NV 2 - 3, NV 2 - 4, NV 2 - 4L, NV 4 - 3, NV 4 - 4 and NV 4 - 4L a Ni-content up to 1.25% may be approved.
2) For thicknesses exceeding 40 mm, Mn = 0.40 to 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 NV4 - 4 or NV 4 - 4L.
4) Aluminium may be either partly or totally replaced by other grain refining elements.

| Table C2 Nickel alloy steels for low temperature service. Chemical composition | | | | | | | |
|--|---------------------------|--------------|--------------|-----------|-----------|--------------|-------------------|
| Grade | Chemical composition, (%) | | | | | | |
| | C maximum | Si | Mn | S maximum | P maximum | Ni | Al _{tot} |
| NV 1.5 Ni | 0.14 | 0.10 to 0.35 | 0.30 to 1.50 | 0.025 | 0.025 | 1.30 to 1.70 | ≥ 0.018 |
| NV 3.5 Ni | 0.12 | 0.10 to 0.35 | 0.30 to 0.70 | 0.025 | 0.025 | 3.25 to 3.75 | ≥ 0.018 |
| NV 5 Ni | 0.12 | 0.10 to 0.35 | 0.30 to 0.80 | 0.025 | 0.025 | 4.70 to 5.30 | ≥ 0.018 |
| NV 9 Ni | 0.10 | 0.10 to 0.35 | 0.30 to 0.90 | 0.025 | 0.025 | 8.50 to 10.0 | ≥ 0.018 |

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

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

| Table C4 Nickel alloy steels for low temperature service. Mechanical properties ¹⁾ | | | | | | | | | |
|--|---------------------------------------|---|-----------|---------------------------------------|---|---------------------------------------|------------------------|--------------------------|------------------------|
| Grade | Tensile strength (N/mm ²) | Yield stress (N/mm ²) minimum for thickness, (mm) | | Elongation A ₅ (%) minimum | Impact energy KV, average ²⁾ | | | | Min design temperature |
| | | ≤ 30 | > 30 ≤ 40 | | Thickness (mm) | Test temperature (°C) ³⁾⁴⁾ | Transverse (J) minimum | Longitudinal (J) minimum | |
| NV 1.5 Ni ⁵⁾ | 470 to 640 | 275 | 265 | 22 | ≤ 25 > 25 ≤ 30 > 30 ≤ 35 > 35 ≤ 40 | - 65 - 70 - 75 - 80 | 27 | 41 | -60°C |
| NV 3.5 Ni ⁵⁾ | 540 to 690 | 345 | 335 | 22 | ≤ 25 > 25 ≤ 30 > 30 ≤ 35 > 35 ≤ 40 | - 95 - 100 - 105 - 110 | 27 | 41 | -90°C |
| NV 5 Ni ⁵⁾ | 570 to 710 | 390 | 380 | 21 | ≤ 25 > 25 ≤ 30 > 30 ≤ 35 > 35 ≤ 40 | - 110 - 115 - 120 - 125 | 27 | 41 | -105°C |
| NV 9 Ni | 640 to 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.

| Table C5 Heat treatment of steels for low temperature service | |
|--|--|
| Grade | Heat treatment/condition of supply |
| NV 360 - 2FN NV 2 - 2 NV 2 - 3 NV 2 - 4 NV 2 - 4L NV 4 - 2 NV 4 - 3 NV 4 - 4 NV 4 - 4L | Plates: normalised ¹⁾ Sections: normalised, thermo-mechanically treated or normalised rolled ²⁾ |
| NV 1.5 Ni NV 3.5 Ni NV 5 Ni | Normalised, normalised and tempered or quenched and tempered |
| NV 9 Ni | Double normalised and tempered or quenched and tempered ³⁾ |

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

D. Stainless Steel

D 100 Steel grades

101 Requirements are specified for seven grades of austenitic and two grades of duplex (ferritic/austenitic) stainless steels.

Steel grades with chemical composition and mechanical properties deviating from these specifications may be accepted for the purpose in question after consideration in each separate case.

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

D 200 Chemical composition

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

D 300 Mechanical properties

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

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

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

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

D 400 Heat treatment

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

D 500 Intercrystalline corrosion tests

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

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

| Table D1 Austenitic and duplex stainless steels. Chemical composition | | | | | | | | | |
|---|---------------------------|---------------|---------------|--------------|--------------|--------------|--------------|------------------|-----------------------|
| Grade | Chemical composition, (%) | | | | | | | | |
| | C maximum | Si maximum | Mn maximum | P maximum | S maximum | Cr | Ni | Mo ¹⁾ | Other |
| <i>Austenitic</i> | | | | | | | | | |
| NV 304 L | 0.03 | 1.0 | 2.0 | 0.045 | 0.030 | 18.0 to 20.0 | 8.0 to 12.0 | - | |
| NV 316 L | 0.03 | 1.0 | 2.0 | 0.045 | 0.030 | 16.5 to 18.5 | 10.0 to 15.0 | 2.0 to 3.0 | |
| NV 316 L N | 0.03 | 1.0 | 2.0 | 0.045 | 0.030 | 16.5 to 18.5 | 10.0 to 14.5 | 2.0 to 3.0 | N 0.14 - 0.22 |
| NV 317 L | 0.03 | 1.0 | 2.0 | 0.045 | 0.030 | 18.0 to 20.0 | 11.0 to 15.0 | 3.0 to 4.0 | |
| NV 317 L N | 0.03 | 1.0 | 2.0 | 0.045 | 0.030 | 18.0 to 20.0 | 12.5 to 15.0 | 3.0 to 4.0 | N 0.14 - 0.22 |
| NV 321 | 0.08 | 1.0 | 2.0 | 0.045 | 0.030 | 17.0 to 19.0 | 9.0 to 12.0 | - | Ti 5xC ≤ Ti ≤ 0.70 |
| NV 347 | 0.08 | 1.0 | 2.0 | 0.045 | 0.030 | 17.0 to 19.0 | 9.0 to 13.0 | - | 10xC ≤ Nb ≤ 1.0 |
| <i>Duplex</i> | | | | | | | | | |
| UNS S31803 | 0.03 | 1.0 | 2.0 | 0.030 | 0.020 | 21.0 to 23.0 | 4.5 to 6.5 | 2.5 to 3.5 | N 0.14 - 0.20 |
| UNS S32750 | 0.03 | 0.80 | 1.2 | 0.035 | 0.020 | 24.0 to 26.0 | 6.0 - 8.0 | 3.0 to 5.0 | N 0.24 - 0.32 |

1) For stainless steel plates of grades 316L and 316LN to be used in cargo tanks of chemical carriers, the Mo-content shall not be less than 2.5%, ref. Pt.5 Ch.4 Sec.2 A103.

| Table D2 Austenitic and duplex stainless steel. Mechanical properties | | | | | | |
|---|--|---|-------------------|-------------------------------------|---|------------------------------------|
| Grade | Tensile strength (N/mm ²) R _m | Yield stress ¹⁾ (N/mm ²), minimum | | Elongation (%) A ₅ | Impact energy Charpy V-notch ²⁾ | |
| | | R _{p0.2} | R _{p1.0} | | Test temperature (°C) | minimum average (J) |
| <i>Austenitic</i> | | | | | | |
| NV 304 L | 450 to 700 | 175 | 215 | 40 | - 196 | transverse: 27 longitudinal: 41 |
| NV 316 L | 450 to 700 | 195 | 235 | 40 | | |
| NV 316 L N | 600 to 800 | 300 | 340 | 40 | | |
| NV 317 L | 500 to 700 | 195 | 235 | 40 | | |
| NV 317 L N | 600 to 800 | 300 | 340 | 40 | | |
| NV 321 | 500 to 750 | 205 | 245 | 40 | | |
| NV 347 | 500 to 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_{p0.2} and R_{p1.0} respectively, shall be documented for austenitic stainless steels.
2) Verification of impact values for austenitic stainless steels is required only for materials intended for design temperatures below -105°C.

E. Testing

E 100 General

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

102 Test samples shall be taken from positions as required according to Sec.1 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/mm².

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

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

E 300 Tensile testing at high temperatures

301 When determination of lower yield stress or proof stress at high temperatures is required according to B302, the testing shall be carried out in compliance with ISO 6892-2.

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

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

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

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

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

E 400 Impact testing

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

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

402 The required minimum values specified in B, C and D refer to standard test pieces 10 × 10 mm. Where it is impossible to use a standard test piece, the larger of the following pieces shall be used: 10 × 7.5 mm, 10 × 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/mm², and three times the thickness of the plate when the tensile strength is more than 490 N/mm². Two bend tests shall be taken from each plate. On single clad plates, one test piece shall be bent with the cladding in tension and the other with the cladding in compression. On double clad plates, the test pieces shall be bent, so that both cladding metals are tested both ways.

D 500 Shear testing

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

D 600 Ultrasonic testing

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

D 700 Corrosion testing

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

Guidance note:

By adding approximately 50 gram electrolytic copper to 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 dm² for plates up to 15 mm in thickness and 8 dm² for plates over 15 mm or several bonding defects amounting to more than 2% of the surface of the plate revealed.

F. Identification of Materials

F 100 Branding

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

SECTION 4 STEEL PIPES

A. General Requirements

A 100 Scope

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

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

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

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

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

A 200 Manufacture

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

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

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

A 300 Chemical composition

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

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

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

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

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

A 400 Heat treatment

401 The pipes shall be supplied in a condition in accordance with the requirements of the relevant standard. Unless 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, corrosion testing in accordance with ASTM G48 Method A or an equivalent standard is required.

402 Test specimen surfaces shall have a finish representative of the pipe's delivery condition. The test temperature shall be $+20^{\circ}\text{C}$ for type 22Cr duplex and $+50^{\circ}\text{C}$ 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^2 .

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 | | | |
|--|-------------------------------------|------------------------------|---------------------------|
| <i>Steel type</i> | <i>Min. design temperature (°C)</i> | <i>Charpy V-notch</i> | |
| | | <i>Test temperature (°C)</i> | <i>Average energy (J)</i> |
| 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, JIS G3463.

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.

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

A 300 Manufacture

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

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

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

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

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

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

— for forgings made from ingots or from forged blooms or billets, 3:1 where $L > D$ and 1.5:1 where $L < D$

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

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

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

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

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

| <i>Inclusion group</i> | <i>Series</i> | <i>Limiting value</i> |
|------------------------|---------------|-----------------------|
| Type A | Fine | 1 |
| | Thick | 1 |
| Type B | Fine | 1.5 |
| | Thick | 1 |
| Type C | Fine | 1 |
| | Thick | 1 |
| Type D | Fine | 1 |
| | Thick | 1 |
| Type DS | N.A. | 1 |

A 400 Chemical composition

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

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

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

A 500 Heat treatment

501 All forgings shall be heat treated for mechanical properties as specified in B to H (stated already in Ch.1 Sec.1 B300).

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.

Test pieces shall be taken in such a way that no part of the gauge length is machined from material closer than 12.5 mm to any heat treated surface. For impact testing, this requirement shall apply to the complete test piece.

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.

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:

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

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

B 400 Mechanical testing

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

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

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

B 500 Inspection

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

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

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

1) Composition in percentage mass by mass maximum unless shown as a range or as a minimum.
 2) 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. For low temperature service forgings (DAT(-X°C)), Ni content is permitted up to maximum 0.8%.
 4) One or more of the elements shall comply with the minimum content.

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

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

C. Forgings for Shafting and Machinery

C 100 Scope

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

C 200 Chemical composition

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

C 300 Heat treatment

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

- 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.

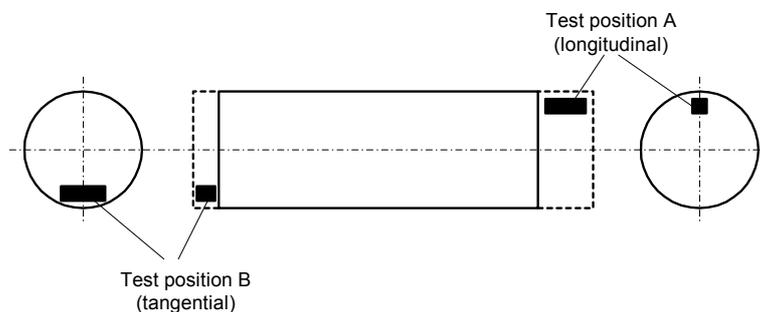


Fig. 1
Plain shaft

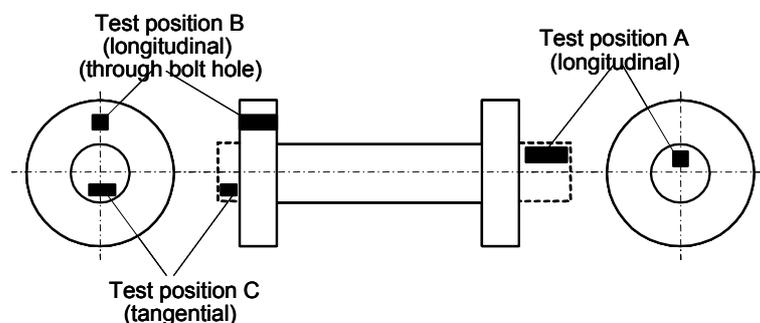


Fig. 2
Flanged shaft

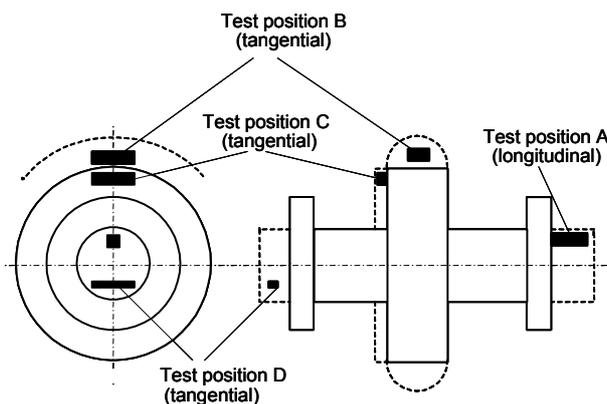


Fig. 3
Flanged shaft with collar

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

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

| Steel type | Tensile strength R_m minimum (N/mm ²) | Yield stress R_e minimum (N/mm ²) | Elongation A_5 minimum (%) | | Reduction of area Z minimum (%) | | Charpy V-notch ¹⁾ ²⁾ Energy (J) | |
|------------|---|---|------------------------------------|-----------|---|-----------|---|-----------|
| | | | <i>l</i> | <i>ta</i> | <i>l</i> | <i>ta</i> | <i>l</i> | <i>ta</i> |
| C and C-Mn | 400 | 200 | 26 | 19 | 50 | 35 | - | - |
| | 440 | 220 | 24 | 18 | 50 | 35 | - | - |
| | 480 | 240 | 22 | 16 | 45 | 30 | - | - |
| | 520 | 260 | 21 | 15 | 45 | 30 | - | - |
| | 560 | 280 | 20 | 14 | 40 | 27 | - | - |
| | 600 | 300 | 18 | 13 | 40 | 27 | - | - |
| | 640 | 320 | 17 | 12 | 40 | 27 | - | - |
| | 680 | 340 | 16 | 12 | 35 | 24 | - | - |
| | 720 | 360 | 15 | 11 | 35 | 24 | - | - |
| Alloy | 760 | 380 | 14 | 10 | 35 | 24 | - | - |
| | 600 | 360 | 18 | 14 | 50 | 35 | 41 | 24 |
| | 700 | 420 | 16 | 12 | 45 | 30 | 32 | 22 |
| | 800 | 480 | 14 | 10 | 40 | 27 | 32 | 22 |
| | 900 | 630 | 13 | 9 | 40 | 27 | 27 | 18 |
| | 1 000 | 700 | 12 | 8 | 35 | 24 | 25 | 16 |
| 1 100 | 770 | 11 | 7 | 35 | 24 | 21 | 13 | |

1) Testing shall be carried out at +20°C.
2) For propeller shafts intended for ships with ice class notations reference is made to Pt.5 Ch.1.
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:

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

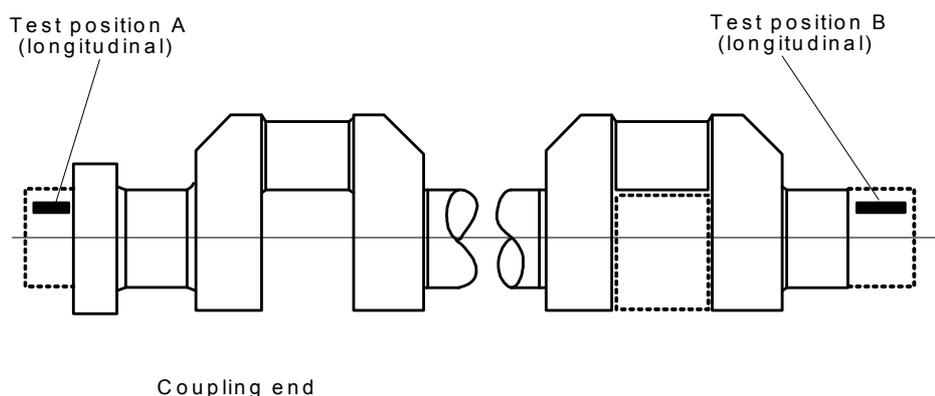


Fig. 4
Solid forged crankshaft

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.

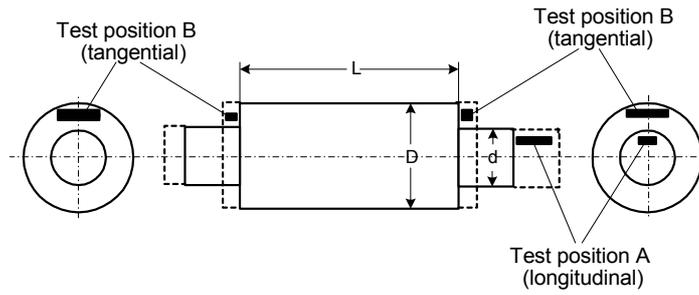


Fig. 5
Pinion

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

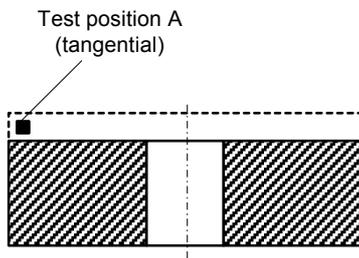


Fig. 6
Gear wheel

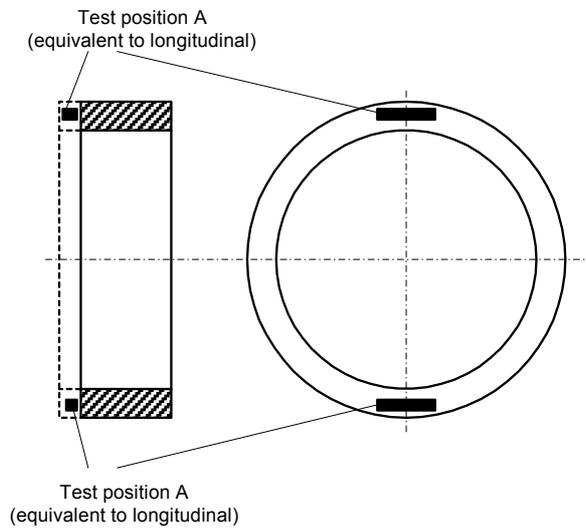


Fig. 7
Gear rim (made by expanding)

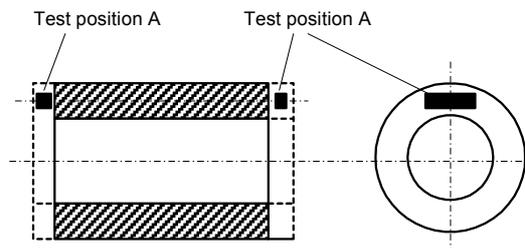


Fig. 8
Hollow pinion

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 ²⁾ | Mo ²⁾ | Ni ²⁾ | Cu ²⁾ | Al ³⁾ | Total residuals |
|------------|------|--------------|--------------|-------|-------|------------------|------------------|------------------|------------------|------------------|-----------------|
| C and C-Mn | 0.23 | 0.15 to 0.40 | 0.50 to 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 to 0.90 | 0.030 | 0.030 | 0.30 | 0.45 to 0.65 | 0.40 | 0.30 | | - |
| 1Cr ½Mo | 0.20 | | 0.30 to 0.80 | 0.030 | 0.030 | 0.80 to 1.25 | 0.45 to 0.65 | 0.40 | 0.30 | 0.02 | - |
| 2¼Cr 1Mo | 0.15 | 0.50 | 0.30 to 0.80 | 0.030 | 0.030 | 2.00 to 2.50 | 0.90 to 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 R_e minimum (N/mm ²) | Tensile strength R_m (N/mm ²) | Elongation A_5 minimum (%) | Reduction of area Z minimum (%) |
|-----------------------|-------|---|--|------------------------------------|---|
| C and C-Mn | 450H | 240 | 450 to 600 | 22 | 35 |
| | 490H | 275 | 490 to 640 | 18 | 30 |
| ½Mo | - | 275 | 480 to 630 | 18 | 35 |
| 1Cr ½Mo | - | 275 | 480 to 630 | 18 | 35 |
| 2 ¼Cr 1Mo, Normalised | - | 315 | 520 to 670 | 18 | 35 |
| 2 ¼Cr 1Mo, QT | - | 380 | 580 to 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.

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

1) Composition in percentage mass by mass maximum unless shown as a range or as a minimum.
 2) Elements are considered as residual elements unless shown as a range or as a minimum.
 3) Aluminium total content. Other grain refining elements may be used for carbon and carbon-manganese steel, see 200.

| Table G2 Mechanical properties for ferritic steel forgings for low temperature service | | | | | | | |
|---|-------|--|---|------------------------------------|--|---------------------|---------------|
| Steel type | Grade | Yield stress R_e or $R_{p0.2}$ minimum (N/mm ²) | Tensile strength R_m (N/mm ²) | Elongation A_5 minimum (%) | Reduction of area Z minimum (%) | Charpy V-notch | |
| | | | | | | Temperature (°C) | Energy (J) |
| C and C-Mn | 450L | 240 | 450 to 600 | 22 | 40 | -60 ¹⁾ | 27 |
| | 490L | 275 | 490 to 640 | 20 | 40 | -60 ¹⁾ | 27 |
| 3 ½ Ni | - | 275 | 490 to 640 | 20 | 35 | -95 | 34 |
| 5 Ni | - | 380 | 540 to 690 | 20 | 35 | -110 | 34 |
| 9 Ni | - | 480 | 640 to 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.

| Table A1 Material requirements for bars for chain cables | | | | | |
|--|--|---|-------------------------|------------------------------------|--|
| <i>Grade</i> | | | <i>NV K1</i> | <i>NV K2</i> | <i>NV K3</i> |
| 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 to 1.60 | 0.50 to 1.60 | 0.60 to 1.90 |
| | Silicon | % | 0.15 to 0.35 | 0.15 to 0.55 | 0.15 to 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 ²⁾ |
| | 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 to 490 | 490 to 690 | Minimum 690 |
| | Elongation A_5 (%) | | Minimum 25 | Minimum 22 | Minimum 17 |
| | Reduction of area Z (%) | | - | - | Minimum 40 |
| | Average impact energy (J) and test temperature | | - | Minimum 27; 0°C ₁₎ | Minimum 60; 0°C |
| ¹⁾ Impact tests may be waived when the chain cable shall be supplied normalised. ²⁾ 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.

| Table C1 Dimensional tolerance of rolled bars | | |
|--|-----------------------------------|---|
| <i>Nominal diameter (mm)</i> | <i>Tolerance on diameter (mm)</i> | <i>Tolerance on roundness ($d_{max} - d_{min}$) (mm)</i> |
| < 25 | -0 +1.0 | 0.6 |
| 25 to 35 | -0 +1.2 | 0.8 |
| 36 to 50 | -0 +1.6 | 1.1 |
| 51 to 80 | -0 +2.0 | 1.5 |
| 81 to 100 | -0 +2.6 | 1.95 |
| 101 to 120 | -0 +3.0 | 2.25 |
| 121 to 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 (stated in Ch.1 Sec.1 B300).

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 m², or
- castings have leaked on hydrostatic testing.

All other weld repairs are considered minor.

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

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

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

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

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

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

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

A 1100 Identification

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

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

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

A 1200 Certification

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

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

B. Castings for Hull Structures and Equipment

B 100 Scope

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

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

B 200 Chemical composition

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

B 300 Heat treatment

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

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

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

B 400 Mechanical properties

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

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

B 500 Inspection

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

| Steel type | C | Si | Mn | P | S | Cr ³⁾ | Mo ³⁾ | Ni ³⁾ | Cu ³⁾ | V ³⁾ | Total residuals |
|------------|--------------------|------|--------------|-------|-------|----------------------------|----------------------------|----------------------------|------------------|-----------------|-----------------|
| C and C-Mn | 0.23 ⁴⁾ | 0.60 | 0.50 to 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 to 1.70 | 0.035 | 0.030 | Minimum 0.40 ⁵⁾ | Minimum 0.15 ⁵⁾ | Minimum 0.40 ⁵⁾ | 0.30 | 0.12 | - |

1) Composition in percentage mass by mass maximum unless shown as a range or as a minimum.
 2) Castings not intended for welding may be supplied to the composition limits given in Table C1.
 3) Elements are considered as residual elements unless shown as a range or as a minimum. For low temperature service castings (DAT(-X°C)), Ni content is permitted up to maximum 0.8%.
 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 ²) | Tensile strength R_m minimum (N/mm ²) | Elongation A_5 minimum (%) | Reduction of area Z minimum (%) | Charpy V-notch ¹⁾ | |
|------------|-------------|---|---|------------------------------|-----------------------------------|------------------------------|------------|
| | | | | | | Temperature (°C) | Energy (J) |
| C and C-Mn | 410 W | 235 | 410 | 24 | 40 | 0 | 27 |
| | 450 W | 255 | 450 | 22 | 35 | 0 | 27 |
| | 480 W | 275 | 480 | 20 | 30 | 0 | 27 |
| Alloy | 550 W | 355 | 550 | 18 | 30 | 0 | 32 |
| | 620 W | 430 | 620 | 16 | 30 | 0 | 32 |

1) 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:

- 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.

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.

| <i>Steel type</i> | <i>C</i> | <i>Si</i> | <i>Mn</i> | <i>P</i> | <i>S</i> | <i>Cr</i> ³⁾ | <i>Mo</i> ³⁾ | <i>Ni</i> ³⁾ | <i>Cu</i> ³⁾ | <i>Total residuals</i> |
|-------------------|----------|-----------|--------------|----------|----------|-------------------------------|-------------------------------|-------------------------------|-------------------------|------------------------|
| C and C-Mn | 0.40 | 0.60 | 0.50 to 1.60 | 0.040 | 0.040 | 0.30 | 0.15 | 0.40 | 0.30 | 0.85 |
| Alloy | 0.45 | 0.60 | 0.50 to 1.60 | 0.035 | 0.030 | Minimum 0.40 ⁴⁾ | Minimum 0.15 ⁴⁾ | Minimum 0.40 ⁴⁾ | 0.30 | - |

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

| Steel type | Steel grade | Yield stress R_e minimum (N/mm ²) | Tensile strength, R_m minimum (N/mm ²) | Elongation A_5 minimum (%) | Reduction of area Z minimum (%) | Charpy V-notch | |
|------------|-------------|---|--|------------------------------------|---|---------------------|---------------|
| | | | | | | 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 cm², which may be square or rectangular with the major dimension not exceeding 250 mm.

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

D 600 Repair

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

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

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

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

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

606 Repair welding is generally permitted in severity zone C.

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

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

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

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

D 700 Welding procedure qualification test

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

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

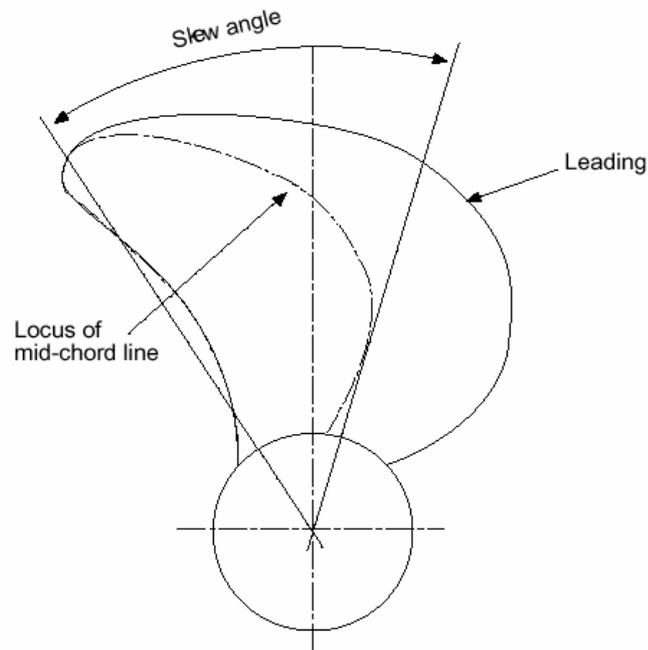


Fig. 1
Definition of skew angle

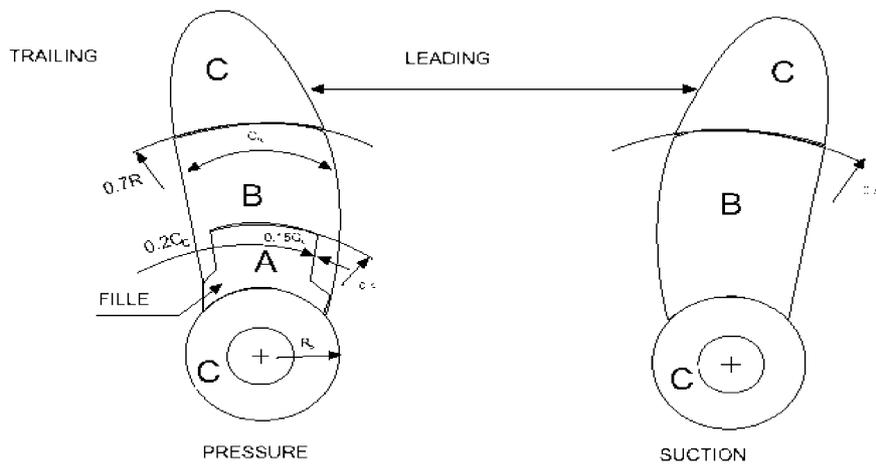


Fig. 2
Severity zones for low skew propellers and separately cast blades

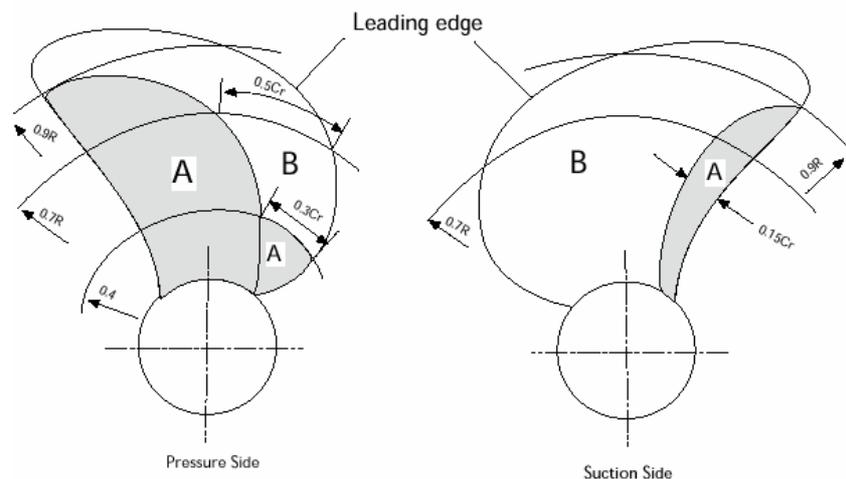


Fig. 3
Severity zones for high skew propellers and separately cast blades

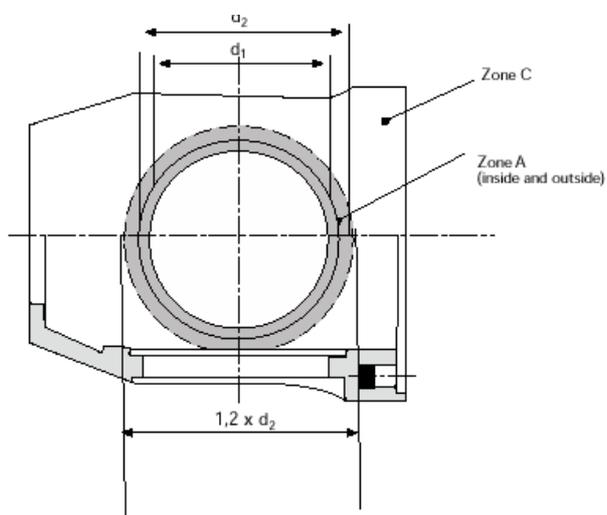


Fig. 4
Severity zones for separately cast propeller hubs

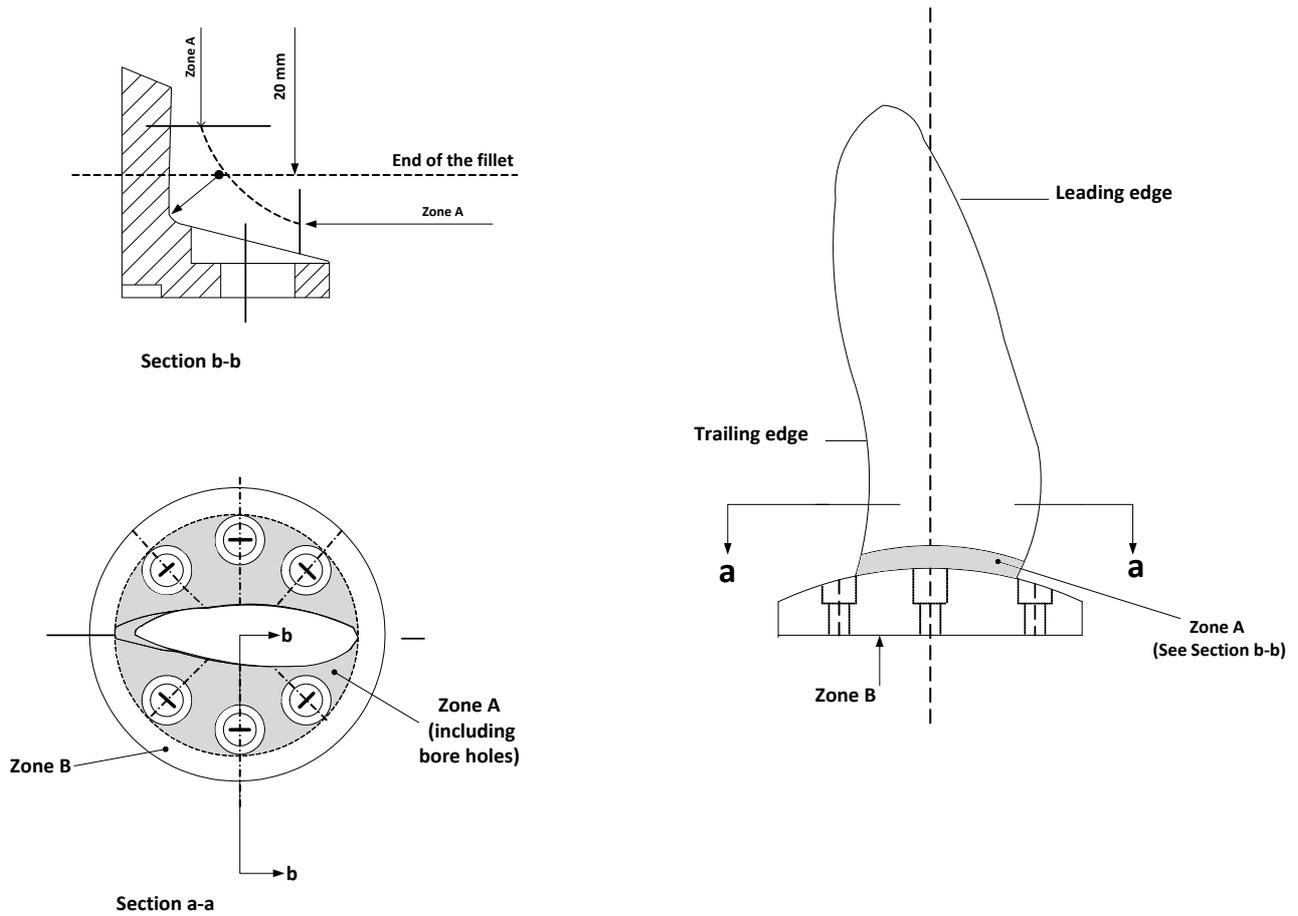


Fig. 5
Severity zones for controllable pitch propellers

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

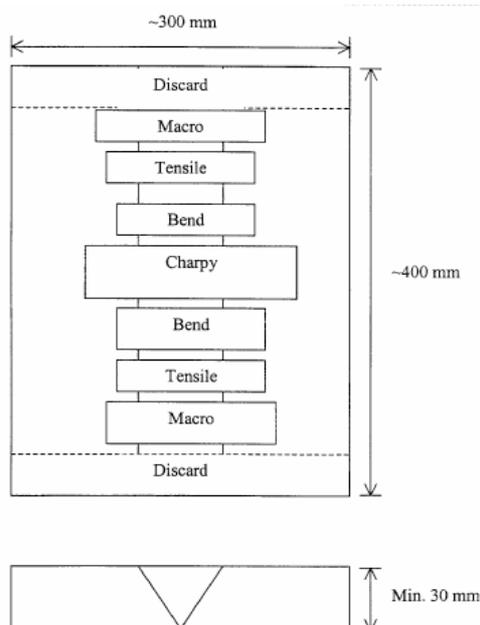


Fig. 6
Welding procedure qualification test assembly

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

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

| <i>Alloy type</i> | <i>Proof stress</i> $R_{p0.2}$ minimum (N/mm ²) | <i>Tensile strength</i> R_m minimum (N/mm ²) | <i>Elongation</i> A_5 minimum (%) | <i>Reduction of area</i> Z minimum (%) | <i>Charpy V-notch ¹⁾</i> | |
|-------------------|---|--|---|--|-------------------------------------|------------------------------|
| | | | | | <i>Temperature</i> (°C) | <i>Energy minimum</i> (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 ²⁾ | 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/mm².

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

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

E. Castings for Boilers, Pressure Vessels and Piping Systems

E 100 Scope

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

E 200 Chemical composition

201 The chemical composition 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:

- 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 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 ²⁾ | Mo ²⁾ | Ni ²⁾ | Cu ²⁾ | V ²⁾ | Total residuals |
|------------|------|------|--------------|-------|-------|------------------|------------------|------------------|------------------|-----------------|-----------------|
| C and C-Mn | 0.25 | 0.60 | 0.50 to 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 to 1.00 | 0.035 | 0.035 | 0.30 | 0.40 to 0.65 | 0.40 | 0.40 | 0.05 | - |
| 1Cr ½Mo | 0.20 | 0.60 | 0.50 to 1.00 | 0.035 | 0.035 | 1.00 to 1.50 | 0.45 to 0.65 | 0.40 | 0.40 | 0.05 | - |
| 2¼Cr 1Mo | 0.20 | 0.60 | 0.40 to 0.90 | 0.035 | 0.035 | 2.00 to 2.75 | 0.90 to 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 R_e minimum (N/mm ²) | Tensile strength R_m (N/mm ²) | Elongation A_5 minimum (%) | Reduction of area Z minimum (%) |
|-----------------------|-------|---|--|------------------------------------|---|
| C and C-Mn | 450H | 240 | 450 to 600 | 22 | 35 |
| | 490H | 275 | 490 to 640 | 18 | 30 |
| ½Mo | - | 250 | 450 to 600 | 21 | 35 |
| 1Cr ½Mo | - | 275 | 480 to 630 | 17 | 35 |
| 2 ¼Cr 1Mo, Normalised | - | 275 | 480 to 630 | 17 | 35 |
| 2 ¼Cr 1Mo, QT | - | 380 | 580 to 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.

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

| Steel type | Grade | Yield stress <i>R_e</i> or <i>R_{p0.2}</i> minimum (N/mm ²) | Tensile strength <i>R_m</i> (N/mm ²) | Elongation <i>A₅</i> minimum (%) | Charpy V-notch | |
|------------|-------|--|---|---|---------------------|---------------|
| | | | | | Temperature (°C) | Energy (J) |
| C and C-Mn | 450L | 240 | 450 to 600 | 22 | -60 ¹⁾ | 27 |
| | 490L | 275 | 490 to 640 | 20 | -60 ¹⁾ | 27 |
| 2 ½ Ni | - | 275 | 490 to 640 | 20 | -70 | 34 |
| 3 ½ Ni | - | 275 | 490 to 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.

| 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 to 21.0 | - | 8.0 to 12.0 |
| GX 5 CrNi 19 9 (304) | 0.08 | 2.0 | 1.5 | 0.040 | 0.030 | 18.0 to 21.0 | - | 8.0 to 11.0 |
| GX 6 CrNiNb 19 10 (347) ²⁾ | 0.08 | 2.0 | 1.5 | 0.040 | 0.030 | 18.0 to 21.0 | - | 9.0 to 12.0 |

| | | | | | | | | |
|--|------|-----|-----|-------|-------|--------------|------------|-------------|
| GX 2 CrNiMo 19 11 2 (316L) | 0.03 | 1.5 | 1.5 | 0.040 | 0.030 | 17.0 to 21.0 | 2.0 to 3.0 | 9.0 to 13.0 |
| GX 5 CrNiMo19 11 2 (316) | 0.08 | 1.5 | 1.5 | 0.040 | 0.030 | 17.0 to 21.0 | 2.0 to 3.0 | 9.0 to 12.0 |
| GX 5 CrNiMo19 11 3 (317) | 0.08 | 1.5 | 1.5 | 0.040 | 0.030 | 17.0 to 21.0 | 3.0 to 4.0 | 9.0 to 13.0 |
| 1) Composition in percentage mass by mass maximum unless shown as a range or as a minimum. | | | | | | | | |
| 2) Niobium content shall be minimum 8 times the Carbon content and maximum 1.00%. | | | | | | | | |

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

SECTION 8 IRON CASTINGS

A. General

A 100 Scope

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

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

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

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

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

A 200 Quality of castings

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

A 300 Manufacture

301 All castings delivered with NV or works certificate shall be made at foundries 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 nondestructive 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 Test material, sufficient for the required tests and for possible re-test purposes, shall be provided for each casting or batch of castings.

202 The test samples shall generally be one of the standard types detailed in Figs. 1, 2 and 3 with a thickness of 25 mm. Test samples of other dimensions, as detailed in Figs. 1, 2 and 3 may, however, be specially required for some components.

203 At least one test sample shall be provided for each casting and unless otherwise required may be either gated to the casting or separately cast. Alternatively test material of other suitable dimensions may be provided integral with the casting.

204 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.

205 As an alternative to 202, 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, cast from the same ladle of treated metal. One separately cast test sample shall be provided for each multiple of 2,0 tonnes of fettled castings in the batch.

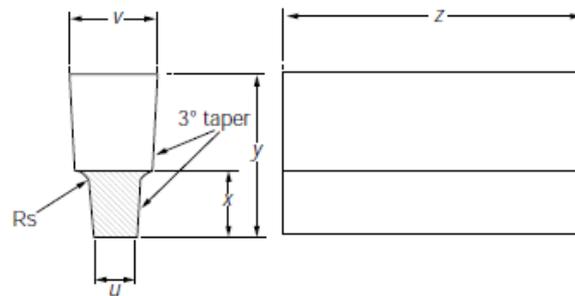


Fig. 1 Type A test samples (U-type)

| Dimensions | Standard sample | Alternative samples when specially required | | |
|------------|-------------------------|---|-----|-----|
| u (mm) | 25 | 12 | 50 | 75 |
| v (mm) | 55 | 40 | 90 | 125 |
| x (mm) | 40 | 30 | 60 | 65 |
| y (mm) | 100 | 80 | 150 | 165 |
| z | To suit testing machine | | | |
| R_s | Approximately 5mm | | | |

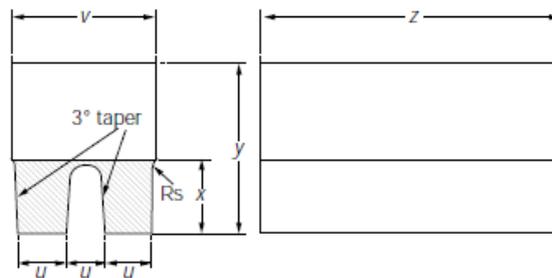


Fig. 2 Type B test samples (double U-type)

| Dimensions | Standard sample |
|------------|-------------------------|
| u (mm) | 25 |
| v (mm) | 90 |
| x (mm) | 40 |
| y (mm) | 100 |
| z | To suit testing machine |
| R_s | Approximately 5mm |

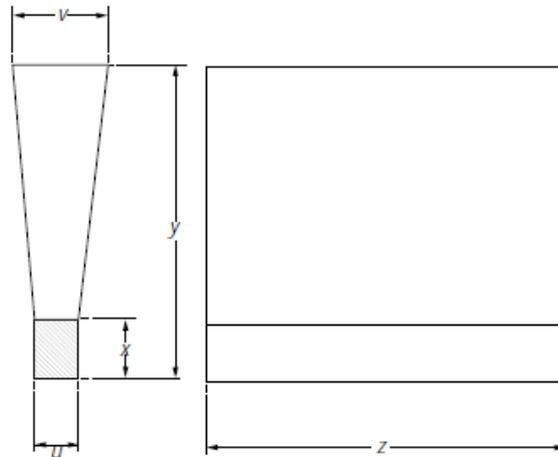


Fig. 3 Type C test samples (Y-type)

| Dimensions | Standard sample | Alternative samples when specially required | | |
|--|-------------------------|---|-----------|-----------|
| u (mm) | 25 | 12 | 50 | 75 |
| v (mm) | 55 | 40 | 100 | 125 |
| x (mm) | 40 | 25 | 50 | 65 |
| y (mm) | 140 | 135 | 150 | 175 |
| z | To suit testing machine | | | |
| Thickness of mould surrounding test sample | 40mm min. | 40mm min. | 80mm min. | 80mm min. |

206 Where separately cast test samples are used, they shall be cast in moulds made from the same type of material as used for the castings and shall be taken towards the end of pouring of the castings.

The samples shall not be stripped from the moulds until the temperature is below 500°C.

207 All test samples shall be suitably marked to identify them with the castings which they represent.

208 Where castings are supplied in the heat treated condition, the test samples shall be heat treated together with the castings which they represent.

209 One tensile test specimen shall be prepared from each test sample and shall be machined to the dimensions given in Ch.1.

210 All tensile tests shall be carried out using test procedures in accordance with Ch.1. Unless otherwise agreed all tests shall be carried out in the presence of the surveyor.

211 Impact tests may additionally be required and in such cases a set of three test specimens of agreed type shall be prepared from each sample. Where Charpy V-notch test specimens are used, the dimensions and testing procedures shall be in accordance with Ch.1.

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 ¹⁾ R_m minimum (N/mm ²) | Proof stress ²⁾ $R_{p0.2}$ minimum (N/mm ²) | Elongation A_5 (%) | Average impact energy, KV | | Hardness (HB) | Predominant structure |
|-------|--|---|----------------------------|------------------------------|-----------------------------|------------------|--------------------------------------|
| | | | | minimum ³⁾ (J) | test temperature (°C) | | |
| NV 1 | 350 | 220 | 22 | 12(9) | - 40 | 110 to 170 | Ferrite |
| NV 2 | 400 | 250 | 18 | 12(9) | - 20 | 140 to 200 | Ferrite |
| 370 | 370 | 230 | 17 | | | 120 to 180 | Ferrite |
| 400 | 400 | 250 | 12 | | | 140 to 200 | Ferrite |
| 500 | 500 | 320 | 7 | | | 170 to 240 | Ferrite/ pearlite |
| 600 | 600 | 370 | 3 | | | 190 to 270 | Pearlite/ ferrite |
| 700 | 700 | 420 | 2 | | | 230 to 300 | Pearlite |
| 800 | 800 | 480 | 2 | | | 250 to 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 Test material sufficient for the required tests and for possible re-tests shall be provided for each casting or batch of castings.

202 Separately cast test samples shall be used unless otherwise agreed between the manufacturer and purchaser and generally shall be in the form of bars 30 mm in diameter and of a suitable length.

They shall be cast from the same ladle as the castings in moulds of the same type of material as the moulds for the castings and shall not be stripped from the moulds until the metal temperature is below 500°C. When two or more test samples are cast simultaneously in a single mould, the bars shall be at least 50 mm apart as given in Fig. 1.

203 Integrally cast samples may be used when a casting is more than 20 mm thick and its mass exceeds 200 Kg, subject to agreement between the manufacturer and the purchaser. The type and location of the sample shall be selected to provide approximately the same cooling conditions as for the casting it represents and also subject to agreement.

204 With the exception of 207, at least one test sample shall be cast with each batch.

205 With the exception of 206, a batch consists of the castings poured from a single ladle of metal, provided that they are all of similar type and dimensions. A batch should not normally exceed two tonnes of fettled castings and a single casting will constitute a batch if its mass is 2 tonnes or more.

206 For continuous melting of the same grade of cast iron in large tonnages the mass of a batch may be increased to the output of 2 hours of pouring.

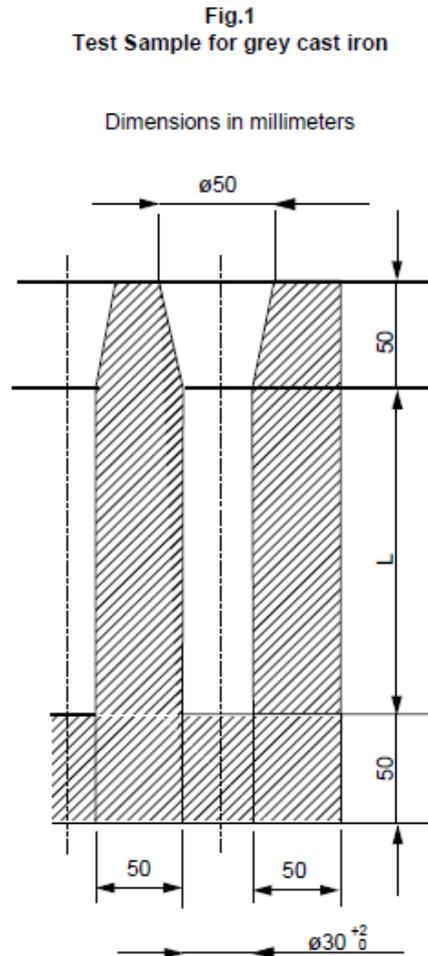
207 If one grade of cast iron is melted in large quantities and if production is carefully monitored by systematic checking of the melting process, such as chill testing, chemical analysis or thermal analysis, test samples may be taken at longer intervals.

208 All test samples shall be suitably marked to identify them with the castings which they represent.

209 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-test samples the sample shall not be cut off from the casting until after the heat treatment.

210 One tensile test specimen shall be prepared from each test sample and for 30mm diameter samples is to be machined to the dimensions given in Ch.1. Where test samples of other dimensions are specially required, the tensile test specimens shall be machined to agreed dimensions.

211 All tensile tests shall be carried out using test procedures in accordance with Ch.1. Unless otherwise agreed all tests shall be carried out in the presence of the surveyor.



C 300 Mechanical properties

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

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

SECTION 9 ALUMINIUM ALLOYS

A. Wrought Aluminium Alloys

A 100 Scope

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

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

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

104 Plates and sections less than 3.0 mm thick or above 50.0 mm thick may be manufactured and tested in accordance with the requirements of an acceptable national specification.

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/cm², 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 A4 and Table A5, 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.

| Grade | Si | Fe | Cu | Mn | Mg | Cr | Zn | Ti | Other elements ²⁾ | |
|----------|-------------|--------------|--------------|--------------------|-------------|--------------------|-------------|------|------------------------------|--------------------|
| | | | | | | | | | Each | Total |
| NV-5052 | 0.25 | 0.40 | 0.10 | 0.10 | 2.2 to 2.8 | 0.15 to 0.35 | 0.10 | - | 0.0 | 0.15 |
| NV-5059 | 0.45 | 0.50 | 0.25 | 0.6 to 1.2 | 5.0 to 6.0 | 0.25 | 0.40 to 0.9 | 0.20 | 0.05 ⁵⁾ | 0.15 ⁵⁾ |
| NV-5083 | 0.40 | 0.40 | 0.10 | 0.40 to 1.0 | 4.0 to 4.9 | 0.05 to 0.25 | 0.25 | 0.15 | 0.05 | 0.15 |
| NV-5086 | 0.40 | 0.50 | 0.10 | 0.20 to 0.7 | 3.5 to 4.5 | 0.05 to 0.25 | 0.25 | 0.15 | 0.05 | 0.15 |
| NV-5154A | 0.50 | 0.50 | 0.10 | 0.50 | 3.1 to 3.9 | 0.25 | 0.20 | 0.20 | 0.05 | 0.15 |
| NV-5383 | 0.25 | 0.25 | 0.20 | 0.7 to 1.0 | 4.0 to 5.2 | 0.25 | 0.40 | 0.15 | 0.05 ⁴⁾ | 0.15 ⁴⁾ |
| NV-5454 | 0.25 | 0.40 | 0.10 | 0.50 to 1.0 | 2.4 to 3.0 | 0.05 to 0.20 | 0.25 | 0.20 | 0.05 | 0.15 |
| NV-5456 | 0.25 | 0.40 | 0.10 | 0.50 to 1.0 | 4.7 to 5.5 | 0.05 to 0.20 | 0.25 | 0.20 | 0.05 | 0.15 |
| NV-5754 | 0.40 | 0.40 | 0.10 | 0.50 ³⁾ | 2.6 to 3.6 | 0.30 ³⁾ | 0.20 | 0.15 | 0.05 | 0.15 |
| NV-6005A | 0.50 to 0.9 | 0.35 | 0.30 | 0.50 ⁶⁾ | 0.40 to 0.7 | 0.30 ⁶⁾ | 0.20 | 0.10 | 0.05 | 0.15 |
| NV-6060 | 0.30 to 0.6 | 0.10 to 0.30 | 0.10 | 0.10 | 0.35 to 0.6 | 0.05 | 0.15 | 0.10 | 0.05 | 0.15 |
| NV-6061 | 0.40 to 0.8 | 0.7 | 0.15 to 0.40 | 0.15 | 0.8 to 1.2 | 0.04 to 0.35 | 0.25 | 0.15 | 0.05 | 0.15 |
| NV-6063 | 0.20 to 0.6 | 0.35 | 0.10 | 0.10 | 0.45 to 0.9 | 0.10 | 0.10 | 0.10 | 0.05 | 0.15 |
| NV-6082 | 0.7 to 1.3 | 0.50 | 0.10 | 0.40 to 1.0 | 0.6 to 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.

| Table A2 Mechanical properties for rolled aluminium alloys | | | | | | |
|---|----------------------|-----------------------------|--|---|--------------------------------------|-----------------------------------|
| Grade | Temper | Thickness, <i>t</i> (mm) | Yield strength <i>R_{p0.2}</i> min. or range (MPa) | Tensile strength <i>R_m</i> min. or range (MPa) | Elongation ¹⁾ | |
| | | | | | <i>A_{50 mm}</i> min. (%) | <i>A_{5d}</i> min. (%) |
| NV-5052 | 0 | <i>t</i> ≤ 50 | 65 | 165 to 215 | 19 | 18 |
| | H32 | <i>t</i> ≤ 6 | 130 | 210 to 260 | 10 | |
| | | 6 < <i>t</i> ≤ 50 | 130 | 210 to 260 | 12 | 12 |
| | H34 | <i>t</i> ≤ 6 | 150 | 230 to 280 | 7 | |
| 6 < <i>t</i> ≤ 50 | | 150 | 230 to 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 to 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 to 295 | 305 to 385 | 12 | 10 |
| NV-5086 | 0 | <i>t</i> ≤ 50 | 95 | 240 to 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 to 275 | 17 | 16 |
| | H32 | <i>t</i> ≤ 6 | 180 | 250 to 305 | 8 | |
| | | 6 < <i>t</i> ≤ 50 | 180 | 250 to 305 | 10 | 9 |
| H34 | <i>t</i> ≤ 50 | 200 | 270 to 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 to 285 | 17 | 16 |
| | H32 | <i>t</i> ≤ 6 | 180 | 250 to 305 | 8 | |
| | | 6 < <i>t</i> ≤ 50 | 180 | 250 to 305 | 10 | 9 |
| H34 | <i>t</i> ≤ 50 | 200 | 270 to 325 | 8 | 7 | |
| NV-5456 | 0 | <i>t</i> ≤ 6.3 | 130 to 205 | 290 to 365 | 16 | |
| | | 6.3 < <i>t</i> ≤ 50 | 125 to 205 | 285 to 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 to 315 | 315 to 405 | 12 | |
| | 12.5 < <i>t</i> ≤ 40 | 215 to 305 | 305 to 385 | | 10 | |
| | 40 < <i>t</i> ≤ 50 | 200 to 295 | 285 to 370 | | 10 | |
| NV-5754 | 0 | <i>t</i> ≤ 50 | 80 | 190 to 240 | 18 | 17 |
| | H32 | <i>t</i> ≤ 50 | 130 | 220 to 270 | 10 | 9 |
| | H34 | <i>t</i> ≤ 6 | 160 | 240 to 280 | 8 | |
| | | 6 < <i>t</i> ≤ 50 | 160 | 240 to 280 | 10 | 8 |

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

Table A3 Mechanical properties for extruded aluminium alloys

| Grade | Temper | Thickness, <i>t</i> (mm) | Yield strength <i>R_{p0.2}</i> min. (MPa) | Tensile strength <i>R_m</i> min. or range (MPa) | Elongation ¹⁾ | |
|----------|--------|-----------------------------|---|---|--------------------------------------|-----------------------------------|
| | | | | | <i>A_{50 mm}</i> min. (%) | <i>A_{5d}</i> min. (%) |
| NV-5059 | H112 | $t \leq 50$ | 200 | 330 | 10 | 10 |
| NV-5083 | 0 | $t \leq 50$ | 110 | 270 to 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 to 315 | 14 | 12 |
| | H111 | $t \leq 50$ | 145 | 250 | 12 | 10 |
| | H112 | $t \leq 50$ | 95 | 240 | 12 | 10 |
| NV-5383 | 0 | $t \leq 50$ | 145 | 290 | 17 | 17 |
| | H111 | $t \leq 50$ | 145 | 290 | 17 | 17 |
| | H112 | $t \leq 50$ | 190 | 310 | 13 | 13 |
| NV-6005A | T4 | $t \leq 50$ | 90 | 180 | 15 | 13 |
| | T5 | $t \leq 50$ | 215 | 260 | 9 | 8 |
| | T6 | $t \leq 10$ | 215 | 260 | 8 | 6 |
| | | $10 < t \leq 50$ | 200 | 250 | 8 | 6 |
| NV-6060 | T4 | $t \leq 50$ | 60 | 120 | 16 | 14 |
| | T5 | $t \leq 50$ | 100 | 140 | 8 | 6 |
| | T6 | $t \leq 50$ | 140 | 170 | 8 | 6 |
| NV-6061 | T4 | $t \leq 50$ | 110 | 180 | 15 | 13 |
| | T5 | $t \leq 50$ | 205 | 240 | 6 | 7 |
| | T6 | $t \leq 50$ | 240 | 260 | 10 | 8 |
| NV-6063 | T4 | $t \leq 50$ | 65 | 130 | 14 | 12 |
| | T5 | $t \leq 50$ | 110 | 150 | 8 | 7 |
| | T6 | $t \leq 50$ | 170 | 205 | 10 | 9 |
| NV-6082 | T4 | $t \leq 0$ | 110 | 205 | 14 | 12 |
| | T5 | $t \leq 50$ | 230 | 270 | 8 | 6 |
| | T6 | $t \leq 5$ | 250 | 290 | 6 | |
| | | $5 < t \leq 50$ | 260 | 310 | 10 | 8 |

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

Table A4 Underthickness tolerances for rolled products (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 |

Table A5 Underthickness tolerances for extrusions (mm)

| 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 ASNT. 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:

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

- Manufacturer's and purchaser's name, order number and vessel identification, where known.
- Description of castings and alloy type.
- Identification marking of castings.
- Heat number and chemical composition.
- Details of heat treatment, including temperatures and holding times.
- Results of mechanical tests.
- Results of non-destructive tests, where applicable.
- Test pressure, where applicable.
- 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 and where appropriate, with the limits for the principal elements of the preferred alloys listed in Table B1. The copper alloys shall have a satisfactory resistance to sea water corrosion, where applicable.

| Table B1 Chemical composition limits for principal elements in copper alloy castings | | | | | | | | |
|--|----------------|----------------------|--------------|--------------|--------------|------------|------------|-------------------------------------|
| Alloy type | Designation | Chemical composition | | | | | | Typical applications |
| | | Cu | Sn | Zn | Pb | Ni | P | |
| Phosphor bronze | Cu Sn11P | 87.9 to 89.5 | 10.0 to 11.5 | 0.05 max | 0.25 max | 0.10 max | 0.5 to 1.0 | Liners, bushes, valves and fittings |
| | Cu Sn12 | 85.9 to 88.5 | 11.0 to 13.0 | 0.50 max | 0.7 max | 2.0 max | 0.60 max | |
| Gunmetal | Cu Sn10 Zn2 | Remainder | 9.5 to 10.5 | 1.75 to 2.75 | 1.5 max | 1.0 max | - | Liners, valves and fittings |
| Leaded gunmetal | Cu Sn5 Zn5 Pb5 | 83.0 to 87.0 | 4.0 to 6.0 | 4.0 to 6.0 | 4.0 to 6.0 | 2.0 max | 0.10 max | Bushes, valves and fittings |
| | Cu Sn7 Zn2 Pb3 | 85.0 to 89.0 | 6.0 to 8.0 | 1.5 to 3.0 | 2.5 to 3.5 | 2.0 max | 0.10 max | |
| | Cu Sn7 Zn4 Pb7 | 81.0 to 85.0 | 6.0 to 8.0 | 2.0 to 5.0 | 5.0 to 8.0 | 2.0 max | 0.10 max | |
| | Cu Sn6 Zn4 Pb2 | 86.0 to 90.0 | 5.5 to 6.5 | 3.0 to 5.0 | 1.0 to 2.0 | 1.0 max | 0.05 max | |
| Leaded bronze | Cu Sn10 Pb10 | 78.0 to 82.0 | 9.0 to 11.0 | 2.0 max | 8.0 to 11.0 | 2.0 max | 0.10 max | Bushes |
| | Cu Sn5 Pb9 | 80.0 to 87.0 | 4.0 to 6.0 | 2.0 max | 8.0 to 10.0 | 2.0 max | 0.10 max | |
| | Cu Sn7 Pb15 | 74.0 to 80.0 | 6.0 to 8.0 | 2.0 max | 13.0 to 17.0 | 0.5 to 2.0 | 0.10 max | |
| | Cu Sn5 Pb20 | 70.0 to 78.0 | 4.0 to 6.0 | 2.0 max | 18.0 to 23.0 | 0.5 to 2.5 | 0.10 max | |

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 and where appropriate, with the values given in Table B2.

| Table B2 Mechanical properties for copper alloy castings | | | | | | | |
|---|--------------------|--|--------------------|---|--------------------|---|--------------------|
| <i>Alloy type</i> | <i>Designation</i> | <i>Proof stress $R_{p0.2}$ minimum (N/mm²)</i> | | <i>Tensile strength R_m minimum (N/mm²)</i> | | <i>Elongation on 5.65 $\sqrt{S_0}$ % minimum</i> | |
| | | <i>Sand</i> | <i>Centrifugal</i> | <i>Sand</i> | <i>Centrifugal</i> | <i>Sand</i> | <i>Centrifugal</i> |
| Phosphor bronze | Cu Sn11 P | 130 | 170 | 250 | 330 | 5 | 4 |
| | Cu Sn12 | 140 | 150 | 260 | 280 | 7 | 5 |
| Gunmetal | Cu Sn10 Zn2 | 130 | 130 | 270 | 250 | 13 | 5 |
| Leaded gunmetal | Cu Sn5 Zn5 Pb5 | 90 | 110 | 200 | 250 | 13 | 13 |
| | Cu Sn7 Zn2 Pb3 | 130 | 130 | 230 | 260 | 14 | 12 |
| | Cu Sn7 Zn4 Pb7 | 120 | 120 | 230 | 260 | 15 | 12 |
| | Cu Sn6 Zn4 Pb2 | 110 | 110 | 220 | 240 | 15 | 12 |
| Leaded bronze | Cu Sn10 Pb10 | 80 | 110 | 180 | 220 | 8 | 6 |
| | Cu Sn5 Pb9 | 60 | 90 | 160 | 200 | 7 | 6 |
| | Cu Sn7 Pb15 | 80 | 90 | 170 | 200 | 8 | 7 |
| | Cu Sn5 Pb20 | 70 | 80 | 150 | 170 | 5 | 6 |

B 500 Inspection

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

B 600 Repair

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

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

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

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

All other weld repairs are considered minor

604 Major weld repairs require the approval of the Society before the repair is commenced. Proposals for major weld repairs shall be accompanied by sketches or photographs showing the extent and positions of the repairs.

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

C. Castings for Propellers

C 100 Scope

101 These requirements are supplementary to subsection A and apply to copper alloy castings for propellers and separately cast blades and hubs.

102 These requirements may also be used for the repair of propellers damaged in service, subject to prior agreement with the Society.

C 200 Chemical composition

201 The chemical composition shall comply with the limits given in Table C1.

C 300 Heat treatment

301 Propeller castings need generally not to be heat treated except as specified in 600.

C 400 Mechanical testing

401 The mechanical properties shall meet the requirements in Table C2.

C 500 Inspection

501 The castings are subject to inspection in accordance with A900 and as given in 502 to 504.

502 For all propellers, separately cast blades and hubs, the surfaces covered by severity zones A, B and C are subject to PT. For definition of skew and description of severity zones, see the relevant parts of Sec.7. Testing of zone A shall be undertaken in the presence of the surveyor whilst testing of zones B and C may be witnessed by the surveyor upon his request.

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

504 The indications detected may, with respect to their size and number, not exceed the values given in Table C4. Weld repairs are, independent of their location, always to be assessed according to zone A.

C 600 Repair

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

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

603 Weld repairs require the approval of the Society before the repair is commenced. Proposals for weld repairs shall be accompanied by sketches or photographs showing the extent and positions of the repairs.

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

605 Defects in severity zone B that are not deeper than $t/40$ mm (t is the minimum local thickness according to the rules) or 2 mm, whichever is greatest, may be removed by grinding. Those defects that are deeper may be repaired by welding.

606 Repair welding is generally permitted in severity zone C.

607 Repair welding of propellers with skew angle equal to 0° is generally permitted on the blade faces, and may also be repaired at the root area if so agreed with the Surveyor.

608 Before welding is started, a detailed welding procedure specification shall be submitted covering the weld preparation, welding parameters, filler metals, preheating, post weld heat treatment and inspection procedures. Recommendations for welding are given in Table C3.

609 The scope of the welding procedure qualification test is given in 900.

610 With the exception of NiAl-Bronze all weld repairs shall be stress relief heat treated, in order to avoid stress corrosion cracking. The temperatures for the heat treatment is given in Table C3. The cooling rate shall not exceed 50°C/h until a temperature of 200°C is reached.

C 700 Identification

701 Castings shall be identified in accordance with A1100 and with the following additional particulars:

- 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.

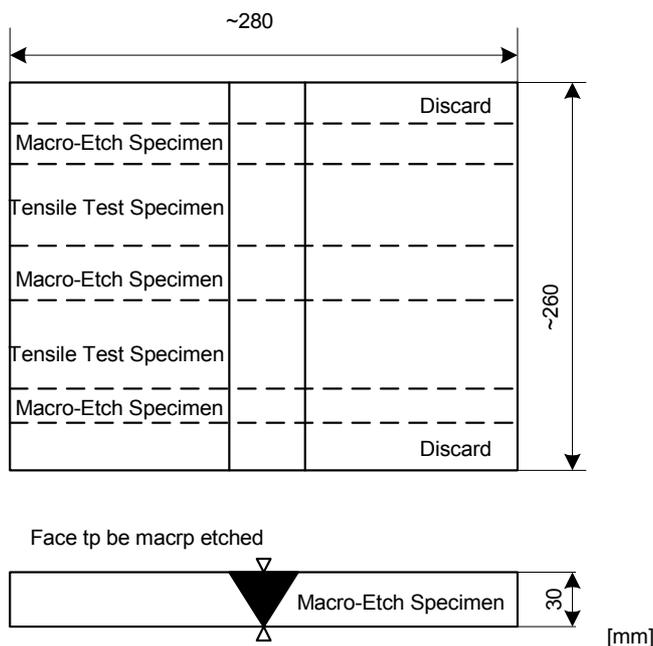


Fig. 1
Weld test assembly

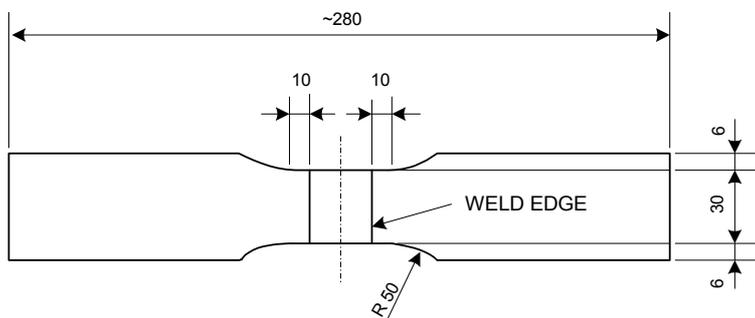


Fig. 2
Tensile test specimen for weld test assembly

| Table C1 Chemical composition limits ¹⁾ for copper alloy propeller castings | | | | | | | | | | | |
|---|-----------|-------------|-------------|------------|------------|-----------|------------|-----------|-----------|-----------|-----------|
| <i>Alloy type</i> | <i>Cu</i> | <i>Al</i> | <i>Mn</i> | <i>Fe</i> | <i>Ni</i> | <i>Zn</i> | <i>Sn</i> | <i>Pb</i> | <i>Cr</i> | <i>Mg</i> | <i>Si</i> |
| Mn-bronze ²⁾ , Cu1 | 52 to 62 | 0.5 to 3.0 | 0.5 to 4.0 | 0.5 to 2.5 | 1.0 | 35 to 40 | 0.1 to 1.5 | 0.5 | - | - | - |
| Mn-Ni-bronze ²⁾ , Cu2 | 50 to 57 | 0.5 to 2.0 | 1.0 to 4.0 | 0.5 to 2.5 | 3.0 to 8.0 | 33 to 38 | 0.15 | 0.5 | - | - | - |
| Ni-Al-bronze, Cu3 | 77 to 82 | 7.0 to 11.0 | 0.5 to 4.0 | 2.0 to 6.0 | 3.0 to 6.0 | 1.0 | 0.1 | 0.03 | - | - | - |
| Mn-Al-Bronze, Cu4 | 70 to 80 | 6.5 to 9 | 8.0 to 20.0 | 2.0 to 5.0 | 1.5 to 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:

$$\text{Zinc equivalent (\%)} = 100 - (100 \text{ Cu}/100 + A) \text{ where } A = \text{Sn} + 5 \text{ Al} - 0.5 \text{ Mn} - 0.1 \text{ Fe} - 2.3 \text{ Ni}$$

| Table C2 Mechanical properties for copper alloy propeller castings | | | |
|---|---|--|---|
| <i>Alloy type</i> | <i>Yield strength</i> <i>R_{p0.2} minimum</i> <i>(N/mm²)</i> | <i>Tensile strength</i> <i>R_m minimum</i> <i>(N/mm²)</i> | <i>Elongation</i> <i>A₅ minimum</i> <i>(%)</i> |
| | | | |

| | | | |
|-------------------|-----|-----|----|
| Mn-bronze, Cu1 | 175 | 440 | 20 |
| Mn-Ni-bronze, Cu2 | 175 | 520 | 18 |
| Ni-Al-bronze, Cu3 | 245 | 590 | 16 |
| Mn-Al-Bronze, Cu4 | 275 | 630 | 18 |

| Table C3 Recommendations for welding of copper alloy propeller castings | |
|--|--|
| <i>Alloy type</i> | <i>Description</i> |
| Mn-bronze, Cu1 | Use Al-bronze ¹⁾ or Mn-bronze filler metal. Preheat 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. Preheat to 150°C and interpass temperature not to exceed 300°C. Stress relief at 350°C to 550°C. |
| Ni-Al-bronze, Cu3 | Use Al-bronze, Ni-Al-bronze ²⁾ or Mn-Al-bronze filler metal. Preheat to 100°C and interpass temperature not to exceed 250°C. Stress relief at 450°C to 500°C. |
| Mn-Al-Bronze, Cu4 | Use Mn-Al-bronze filler metal. Preheat to 100°C and interpass temperature not to exceed 300°C. Stress relief at 450°C to 600°C. |

1) Ni-Al-Bronze and Mn-Al-Bronze acceptable
2) If Ni-Al-Bronze is used, stress relief is not required

| Table C4 Allowable number and size of indications depending on severity zones | | | | |
|--|--|------------------------|--|---|
| <i>Severity zone</i> | <i>Maximum total number of indications</i> | <i>Indication type</i> | <i>Maximum number for each type ^{1) 2)}</i> | <i>Maximum dimension of indication (mm)</i> |
| A | 7 | Non-linear | 5 | 4 |
| | | Linear or aligned | 2 | 3 |
| B | 14 | Non-linear | 10 | 6 |
| | | Linear or aligned | 4 | 6 |
| C | 20 | Non-linear | 14 | 8 |
| | | Linear or aligned | 6 | 6 |

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

| Table C5 Tensile strength requirements for weld qualification test | |
|---|--|
| <i>Alloy type</i> | <i>Tensile strength (N/mm²)</i> |
| Mn-Bronze (brass) | 370 |
| MnNi-Bronze (brass) | 410 |
| NiAl-Bronze (bronze) | 500 |
| MnAl-Bronze (bronze) | 550 |

SECTION 11 NON-FERROUS TUBES

A. Copper and Copper Alloy Tubes

A 100 Scope

101 This subsection specifies requirements for copper and copper alloy tubes to be used in shipboard systems. Provision is made for phosphorus-deoxidised copper, aluminium brass and copper-nickel alloys.

102 Tubes shall be in accordance with recognised standards, e.g. ASTM B 111, ASTM B 543, EN 12499, EN 12451, EN 12452, 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 ²⁾ | - | 0.015 to 0.040 | - | - | - | - | - | - |
| Aluminium brass | 76.0 to 79.0 | 0.02 to 0.06 | - | 0.07 | 0.06 | Remainder | - | 1.8 to 2.5 | - |
| Copper-Nickel 90-10 ³⁾ | Remainder | - | - | - | 1.0 to 2.0 | - | 9.0 to 11.0 | - | 0.5 to 1.0 |
| Copper-Nickel 70-30 ³⁾ | Remainder | - | - | - | 0.40 to 1.0 | - | 29.0 to 33.0 | - | 0.5 to 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</i> <i>R_{p0.2} minimum</i> <i>(N/mm²)</i> | <i>Tensile strength</i> <i>R_m minimum</i> <i>(N/mm²)</i> | <i>Elongation</i> <i>A₅ minimum</i> <i>(%)</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.