Part 2 Materials and welding

Chapter 2 Metallic materials
FOREWORD

DNV GL rules for classification contain procedural and technical requirements related to obtaining and retaining a class certificate. The rules represent all requirements adopted by the Society as basis for classification.
CHANGES – CURRENT

This is a new document.

The rules enter into force 1 January 2016.
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SECTION 1 GENERAL

1 Introduction

1.1 Scope

1.1.1 The chapter specifies requirements for metallic materials used for construction of vessels and their equipment with respect to:
— manufacture
— inspection and tolerances
— repair
— identification and certification
— condition of supply and heat treatment
— test units, test material and test specimens
— grading systems
— chemical composition
— mechanical properties
— other test requirements, e.g. corrosion test, drop weight test, etc.

1.1.2 The requirements apply for assignment of class.

1.1.3 Upon agreement, the scope may be extended to other applications.

1.2 Application

1.2.1 The following materials/products are covered:
— rolled steels including rolled stainless steels
— clad steel and steel-aluminium transition joints
— pipes of steel, stainless steels, aluminium alloys, copper alloys and titanium alloys
— forgings and castings of steel, iron, stainless steels, copper alloys and aluminium alloys

1.3 Relation to other Society documents

1.3.1 General requirements for manufacture and fabrication of materials and components are given in Ch.1, and specific requirements related to welding and fabrication are given in Ch.4. Additional requirements may also be provided in each section of this chapter, and in Ch.4, as well as in other parts of the rules, Pt.3 to Pt.7. In case of conflicting requirements, the specific or additional requirements in Pt.3 to Pt.7 are prevailing.
2 References

2.1 External references

2.1.1 The external references referred in this chapter are listed in Sec.13. Unless otherwise agreed, the latest version of the referred standards valid at the date of release for the current rules is applicable.

2.2 Abbreviations, symbols and terminology

2.2.1 General abbreviations and symbols are given in Ch.1 Sec.4.

2.2.2 General terminology is given in Ch.1 Sec.1 [2.2]. Special terminology is given in Table 1:

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aligned indication</td>
<td>Three or more MT or PT indications in a line, separated by 2 mm or less edge-to-edge</td>
</tr>
<tr>
<td>Killed steel</td>
<td>Steel fully deoxidized before casting by the addition of typically silicon, manganese and aluminium, giving virtually no gas evolution during solidification. A typically Si-killed steel would contain more than 0.1% Si (usually 0.15% - 0.35% Si).</td>
</tr>
<tr>
<td>Linear indication</td>
<td>An MT or PT indication in which the length is at least three times the width</td>
</tr>
<tr>
<td>Non-linear indication</td>
<td>An MT or PT indication of circular or elliptical shape with a length less than three times the width</td>
</tr>
<tr>
<td>Non-open indication</td>
<td>An MT or PT indication that is not visually detectable after removal of the magnetic particles or that cannot be detected by the use of contrast dye penetrant</td>
</tr>
<tr>
<td>Open indication</td>
<td>An MT or PT indication visible after removal of the magnetic particles or that can be detected by the use of contrast dye penetrant</td>
</tr>
<tr>
<td>Piece</td>
<td>For testing of individual pieces of rolled products, 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.</td>
</tr>
<tr>
<td>Relevant indication</td>
<td>An MT or PT indication that is caused by a condition or type of discontinuity that requires evaluation. Indications which have any dimension greater than 1.5 mm shall be considered relevant.</td>
</tr>
<tr>
<td>Semi-killed steel</td>
<td>Steel partly deoxidized before casting, giving some gas evolution in the melt during solidification. A typical semi-killed steel would contain 0.03% to 0.1% Si</td>
</tr>
<tr>
<td>Solution heat treatment</td>
<td>A process in which an alloy or metal is heated to a suitable temperature, is held at that temperature long enough to allow a certain constituent to enter into solid solution, and is then cooled rapidly to hold that constituent in solution.</td>
</tr>
</tbody>
</table>

3 Procedural requirements

3.1 Certification requirements

3.1.1 General certification requirements are given in Ch.1.
Certification requirements for materials relevant to application are given in Pt.3 to Pt.7, see also [1.3]. Where applicable, additional specific certification requirements are given within each of the following sections.

### 3.2 Documentation requirements

#### 3.2.1

General documentation requirements are given in Ch.1. Additional product specific documentation requirements are given in Table 2, and additional manufacturer specific documentation requirements are given in Table 3. Further specific documentation requirements are given in each section as relevant.

**Table 2 Documentation requirements – products required to be certified**

<table>
<thead>
<tr>
<th>Object</th>
<th>Documentation type</th>
<th>Additional description</th>
<th>Info¹⁄²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Materials for structure and components</td>
<td>C051 - Non-destructive testing (NDT) report</td>
<td>Including testing after repair</td>
<td>FI</td>
</tr>
<tr>
<td></td>
<td>Z250 - Procedure</td>
<td>For repair by welding, when applicable. For content of procedure, M062 may be used as guidance</td>
<td>AP, L</td>
</tr>
<tr>
<td></td>
<td>M060 – Welding procedure (WPS)</td>
<td>For materials and products joined or repaired by welding</td>
<td>AP, L</td>
</tr>
<tr>
<td></td>
<td>M062 – Report from repair by welding</td>
<td>Each repair weld</td>
<td>FI</td>
</tr>
</tbody>
</table>

¹) FI = For Information, AP = For Approval, L = by Local station. For full definition of abbreviations, see Pt.1 Ch.3 Sec.2 [1.2.4]

**Table 3 Qualification documentation for manufacturer**

<table>
<thead>
<tr>
<th>Item</th>
<th>Documentation type</th>
<th>Additional description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Materials and components</td>
<td>M010 - Material specification, metals</td>
<td>For VL material certification: Shall be provided to the surveyor prior to testing and inspection, including any conditions additional to the rule requirements</td>
</tr>
<tr>
<td></td>
<td>Z252 - Test procedures at manufacturer</td>
<td>Manufacturer shall establish detailed procedures for testing, retesting and non-destructive testing.</td>
</tr>
<tr>
<td>Investigation report</td>
<td></td>
<td>Where deviations from approved process occurs and this could produce products of inferior quality</td>
</tr>
</tbody>
</table>
| | Z270 - Records | Surface inspection and dimensions including shape and straightness:  
  — the manufacturer shall maintain records of inspections and dimensional measurements  
  — the records shall be presented to the surveyor on request |
### Heat treatment:
- the manufacturer shall maintain records/logs of heat treatment identifying the furnace used, furnace charge, date, temperatures and time at temperatures
- the records shall be presented to the surveyor on request

<table>
<thead>
<tr>
<th>Welders</th>
<th>Z270 - Records</th>
<th>Of welders certificates, all welders performing welding shall be certified. See also Ch.4 Sec.3. Applicable for welding on materials and products for VL or W certification</th>
</tr>
</thead>
<tbody>
<tr>
<td>NDT personnel</td>
<td>Z270 - Record</td>
<td>Of NDT operators certificates, all NDT shall be carried out by personnel qualified and certified to level II by a recognized body for the applicable NDT method. See further requirement in Ch.4 Sec.7 [3]</td>
</tr>
<tr>
<td>Furnace</td>
<td>Z262 - Report from test at manufacturer</td>
<td>For calibration. For products subject to heat treatment, the furnace temperature uniformity shall be calibrated according to a recognized standard (e.g. ASTM A991) at regular intervals and the calibration report shall be provided to the surveyor on request. Note that approval as heat treatment workshop may be required, see Ch.1 Sec.2 [2]</td>
</tr>
</tbody>
</table>

#### 3.2.2 For general requirements to documentation including definitions, see Pt.1 Ch.3.

#### 3.3 Survey, inspection and testing requirements

**3.3.1** General survey, inspection and testing requirements are given in Ch.1 Sec.1 [3.3] and Ch.1 Sec.2 [3.1]. Specific requirements are given in the relevant sections of this chapter.
SECTION 2 ROLLED STEEL FOR STRUCTURAL APPLICATION

1 General

1.1 Scope

1.1.1 This subsection specifies the general requirements for hot rolled steel products, i.e. plates/sheets, wide flats, strips, structural sections, structural hollow sections including structural pipes, and bars, see Figure 1, for use in the construction of hulls and other marine structures.

For limitations to fabrication of welded hollow sections by hot or cold forming, see also Ch.4 Sec.6 [5.2].

Requirements for hot rolled round steel bars for non-structural application, e.g. intended for shafts, tie rods and bolts are given in Sec.6.

Figure 1 Overview of typical hot rolled steel products

1.1.2 The requirements apply to plates and wide flats not exceeding 150 mm in thickness and sections and bars not exceeding 50 mm in thickness, unless otherwise approved.

For greater thicknesses, variations in the requirements may be permitted for particular applications, i.e. based on case by case approval.

1.1.3 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 Sec.1 and the appropriate specific requirements of this section. If the specific requirements differ from these general requirements, the specific requirements shall prevail.
1.1.4 Steels differing from the specific requirements given in this section e.g. with respect to chemical composition, deoxidation practice, conditions of supply or mechanical properties may be accepted, subject to special approval. Such steels shall have the letter “S” appended to the corresponding VL grade, e.g. ES, D27SS, A36S.

1.1.5 Subject to approval and as an alternative to [1.1.3] and [1.1.4], materials which comply with other standards or proprietary specifications may be considered for acceptance provided such specifications give reasonable equivalence to the requirements of this section, or are approved case by case for a specific application, see Ch.1 Sec.1 [3.4].

2 Documentation and certification requirements

2.1 Certification requirements

2.1.1 General certification requirements are given in Sec.1 [3.1].

2.1.2 The manufacturer shall provide the type of 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 [6], the results of through thickness tensile tests and ultrasonic tests
   i) results of any supplementary and additional test requirements specified.

2.1.3 The manufacturer shall in writing confirm compliance with the rule requirements before the certificate is endorsed by the surveyor. Pending final certification, this applies for the shipping statement. 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 the Society's rules and standards for classification."

2.1.4 When products for certification are made from semi-finished products delivered by a sub-supplier, see Ch.1 Sec.2 [4.2.7].
2.2 Documentation requirements

2.2.1 General documentation requirements are given in Sec.1 [3.2]. Additional manufacturer specific documentation requirements are given in Table 1.

Table 1 Qualification documentation for manufacturer

<table>
<thead>
<tr>
<th>Item</th>
<th>Documentation type</th>
<th>Additional description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NR, TM and BCA steels</td>
<td>Z270 - Records</td>
<td>For rolling schedule:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- records providing start rolling temperature,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>start and stop finishing rolling temperatures,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>deformation ratios, and where applicable,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>accelerated cooling start and stop temperatures.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- The records shall be presented to the surveyor on request.</td>
</tr>
</tbody>
</table>

2.3 Survey, inspection and testing requirements

2.3.1 General survey, inspection and testing requirements are given in Sec.1 [3.3]. Additional specific requirements are given in Table 2, as further detailed in this section.

Table 2 Additional survey and testing requirements

<table>
<thead>
<tr>
<th>Survey, inspection and testing item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical composition</td>
<td>- required for all materials</td>
</tr>
<tr>
<td></td>
<td>- the surveyor may require the content of impurity elements</td>
</tr>
<tr>
<td></td>
<td>such as tin (Sn), antimony (Sb) and arsenic (As) to be determined when</td>
</tr>
<tr>
<td></td>
<td>recycled scrap or contaminated ore is used</td>
</tr>
<tr>
<td>Tensile test and impact toughness test</td>
<td>Required for all grades covered by this chapter unless otherwise specified</td>
</tr>
<tr>
<td>Through thickness tensile test</td>
<td>Required for materials with specified through thickness properties, and</td>
</tr>
<tr>
<td></td>
<td>all materials of grade VL D47COD and E47COD</td>
</tr>
<tr>
<td>Fracture mechanics test</td>
<td>Fracture mechanics testing (CTOD test) is required for the base material</td>
</tr>
<tr>
<td></td>
<td>of VL D47COD and E47COD grades</td>
</tr>
<tr>
<td>Non-destructive testing</td>
<td>- seams of welded hollow sections; see specific requirements in [2.11.8]</td>
</tr>
<tr>
<td></td>
<td>- steels with through thickness properties, see specific requirements in</td>
</tr>
<tr>
<td></td>
<td>[6]</td>
</tr>
<tr>
<td>Manufacturing parameters</td>
<td>It is in general the manufacturer’s responsibility to ensure</td>
</tr>
<tr>
<td></td>
<td>that the process and production controls qualified through the manufacturer</td>
</tr>
<tr>
<td></td>
<td>approval testing, are adhered to in production. This is in particular</td>
</tr>
<tr>
<td></td>
<td>emphasized for steels with delivery conditions NR and TM, as well as</td>
</tr>
<tr>
<td></td>
<td>steels manufactured as BCA, COD, RCU, RCB and RCW grades, see [7] to [9]</td>
</tr>
</tbody>
</table>
2.4 Grading system

2.4.1 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 [3] to [9].

2.4.2 Supplementary requirements for steel grades with specified through thickness properties, 'Z' grade steels, are given in [6].
Supplementary requirements for brittle crack arrest (BCA) steels are given in [7].
Supplementary requirements for CTOD (COD) steels are given in [8].
Supplementary requirements for corrosion resistant steels for cargo oil tanks (RCU, RCB, RCW) are given in [9].
Steels intended for high heat input welding ≥ 5 kJ/mm shall be specially approved. Approval is given on the approval of manufacturer certificate using a high heat input welding notation, e.g. D32-W20, indicating approval of steel grade D32 for welding by heat input ≤ 20 kJ/mm.

2.5 Manufacture

2.5.1 All materials delivered with VL or works (W) certificate shall be made at works approved by the Society for the type, grade and dimensions of steel being supplied and for the relevant steelmaking and processing route, e.g. delivery condition. Rolling mills without own steelmaking shall only use starting material supplied by works approved by the Society.

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

2.5.3 Steel shall be cast in metal ingot moulds or by continuous casting. Sufficient discard shall be made to ensure soundness in the finished product. Unless otherwise approved, the reduction ratio shall be at least 3 to 1. For slab to plate, reduction ratio applies for the thickness reduction. For other products, the reduction ratio requirement applies for the cross section reduction.

2.5.4 Conditions of supply shall be in accordance with [2.7].

2.5.5 It is the manufacturer’s responsibility to ensure that effective manufacture and process controls, and where relevant, approved or approved processes are implemented and adhered to 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 along with additional information as the Society may require shall be made available to the surveyor on request. The frequency and extent of testing for subsequent products is at the discretion of the Society.

2.6 Chemical composition

2.6.1 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 [3] to [9]. 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.

2.6.2 The composition shall be determined after all alloying additions have been made and sufficient time allowed for such an addition to homogenize.
2.6.3 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.

2.6.4 The manufacturer shall adopt adequate control in order to prevent accumulation of harmful elements in the product, e.g. tin, antimony and arsenic. This is particularly relevant for steelmaking where recycled scrap is used as raw material, and where the ore may contain high levels of harmful elements.

2.6.5 When required, the carbon equivalent value \((C_{eq})\) or the cold cracking susceptibility parameter \((P_{cm})\) shall be calculated. For further details and formulas, see Ch.1 Sec.2 [3.2].

Guidance note:
Where requirements for \(C_{eq}\) or \(P_{cm}\) are not specified, maximum values given in EN 10225 may be used as guidance.

2.6.6 The requirements for elements designated as fine grain elements (Al, Nb, V and Ti) are given in each sub-section [3] to [9]. When fine grain elements are used in combination, the minimum limits are given as follows: Al; 0.015\%, Nb: 0.010\%, V: 0.030\%, Ti: 0.007\%. Each combination of fine grain elements is subject to approval through the approval of manufacturer process, and is listed on the approval of manufacturer certificates. The applicable combination of fine grain elements shall, unless otherwise approved, follow the minimum and maximum limits given here and in subsections [3] to [9].

2.6.7 The manufacturer's declared analysis will be accepted subject to random checks on request by the Society.

2.7 Condition of supply and heat treatment

2.7.1 Conditions of supply shall be in accordance with requirements given in [3] to [9] and as defined in [2.7.2] to [2.7.6]. Where alternative conditions are permitted, the manufacturer shall supply materials only in those conditions for which he has been approved.

2.7.2 As-rolled (AR) refers to rolling at high temperature followed by air cooling. The rolling finishing temperature and reduction are typically in the austenite recrystallization region and above the normalising temperature, but may not be accurately controlled resulting in variable grain sizes and, hence, variable mechanical properties.

2.7.3 Normalising rolling (NR) is a controlled rolling procedure where the final rolling temperature is controlled within the same temperature range as for conventional furnace normalizing. Normalizing rolling is typically followed by air cooling. The primary grain control and refining mechanism is the recrystallization of austenite following each rolling pass in the normalizing temperature range. The microstructure, grain size and mechanical properties are similar to those obtained by furnace normalizing.

2.7.4 Thermo-mechanical rolling (TM) is a rolling procedure in which both rolling temperatures and reduction ratios and, when used, accelerated cooling conditions (AcC) are controlled. It is characterized by high deformation ratios per rolling pass in the austenite non-recrystallization range close to the Ar3 temperature. It may also involve rolling in the austenite-ferrite dual phase temperature region below Ar3. After the final pass, either air cooling or accelerated cooling, excluding quenching, is used.

The primary grain size and microstructural control is the fine grained structure obtained when the highly deformed austenite is transformed into typically ferrite, pearlite, bainite etc. during cooling.

Unlike steel produced by NR, the steel properties conferred by TM cannot be reproduced by subsequent furnace normalising.

Guidance note:
Where an NR process is followed by accelerated cooling (NR+AcC) the process will usually be considered to be TM. However, where it is proven that the steel properties are reproduced by a subsequent furnace normalizing, it may be considered to be an NR process. This consideration will typically be done during the approval of manufacturer process.
2.7.5 Normalising (N) is a separate heat treatment after rolling involving austenitising and air cooling to produce a fine grained ferrite-pearlite microstructure.

2.7.6 Quenching and tempering (QT). Quenching (Q) is a heat treatment process in which the steel is heated to an appropriate temperature above Ac3, followed by cooling at a rate sufficient for the formation of typically a martensite or bainite microstructure. Quenched steels are typically hard and brittle. Tempering (T) is reheating of the steel to a temperature below Ac1. Tempering improves the ductility and toughness of quenched materials through microstructural changes, but reduces the hardness and strength. Furthermore, the quenching process results in material internal stress which is to some extent released/reduced by the subsequent tempering. The result of quenching followed by tempering is typically steels combining high strength with good toughness.

2.7.7 It is the manufacturer’s responsibility to ensure that the rolling schedules for NR and TM specified and qualified through the manufacturer approval testing are adhered to during production. 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 [2.5.5].

2.7.8 For normalizing and for quenching and tempering, the furnace temperature uniformity shall be calibrated at regular intervals and provided to the surveyor on request.

2.7.9 Other delivery conditions than those listed above may be accepted based on special evaluation and approval. Extended qualification through the approval of manufacturer process will be considered for each relevant case. The approved delivery conditions are listed on the approval of manufacturer certificates.

2.8 Test material and test specimens for mechanical testing

2.8.1 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 specimens shall not be separately heat-treated in any way.

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

2.8.3 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 of the piece approximately one-quarter width from a long edge and unless otherwise agreed, equal to or less than one-quarter width from a short edge, see Table 3 Figure 2

— flats with a width < 600 mm, channels, beams, bulb flats and other sections:

  The test material shall be taken at approximately 1/3 of the width from an edge, see Table 3 Figure 2. Where indicated, the test samples may alternatively be taken from a position approximately 1/4 of the width from the web centre line or axis

— 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 Table 3 Figure 2.
### Table 3 Position of test material (Figure 2)

<table>
<thead>
<tr>
<th>Plates and flats</th>
<th>Angles</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Diagram of plates and flats" /></td>
<td><img src="image2" alt="Diagram of angles" /></td>
</tr>
<tr>
<td>Unequal angles</td>
<td>Channels and beams</td>
</tr>
</tbody>
</table>

- **Width, w**
- **$\frac{w}{4}$**
- **$\frac{w}{4}$**
- **$\frac{1}{3}$**

| ![Diagram of unequal angles](image3) | ![Diagram of channels and beams](image4) |

- **$\frac{1}{3}$**
- **$\frac{1}{4}$**
- **$\frac{1}{2}$**

---


Metallic materials
### Figure 2 Position of test material

#### 2.8.4 The following definitions relevant to orientation of test specimens apply:
- *longitudinal*: Longitudinal axis of test specimen parallel to the principal direction of rolling
- *transverse*: Longitudinal axis of test specimen perpendicular to the principal direction of rolling.

#### 2.8.5 Unless otherwise agreed, the test specimens shall be oriented as follows:
1) plates and wide flats with a width ≥ 600 mm:
   - tensile test specimens shall be transverse
— impact test specimens shall be longitudinal, except that for extra high strength steel, transverse tests are required
2) flats with a width < 600 mm, bulb flats, sections, seamless hollow sections, bars and other similar products:
   — tensile and impact test specimens shall be longitudinal
3) welded hollow sections:
   — rectangular and square sections with circumference ≥ 600 mm;
   — tensile test specimen shall be transverse
   — impact test specimens shall be longitudinal, except that for extra high strength steel, transverse tests are required
   — circular sections, and rectangular/square sections with circumference < 600 mm;
   — tensile test and impact test shall be longitudinal.

2.8.6 The size, thickness location and preparation of test specimens, and the procedures used for mechanical testing shall comply with the relevant requirements of Ch.1 Sec.3. See also [2.8.7].

2.8.7 Impact test specimens 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 specimens shall be at one quarter of the thickness from a rolled surface.

2.9 Test units and number of tests

2.9.1 Depending on product and grade, provision is made in [3] to [9] 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 [3] to [9].

2.9.2 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.

2.9.3 Except as required in [2.9.4], 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 [6] for testing of through thickness properties.

2.9.4 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.

2.10 Mechanical properties

2.10.1 The material shall meet the mechanical properties specified in [3] to [9].

2.10.2 If the results do not meet the specified requirements, the re-test procedures in Ch.1 Sec.2 [3.7] 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.
For re-heat treatment, the products shall not be re-austenitized more than two times, unless otherwise approved.
2.11 Inspections, dimensions and tolerances

2.11.1 Surface inspection and verification of dimensions including shape and straightness 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.

2.11.2 Products shall have a workmanlike finish consistent with the method of manufacture and shall be free from internal and surface defects prejudicial to the use of the material for the intended application. Cracks, shells, scabs, blisters and seams are not accepted. Acceptance criteria for other imperfections such as rolled-in scale, indentations and roll marks, which may occur under normal manufacturing conditions, shall be EN 10163-2 Class A for plates/wide flats, and minimum EN10163-3 Class C for sections, or equivalent standard. For repair of defects, see [2.12]

Guidance note:
Cosmetic appearance is not considered. Purchaser should specify additional requirements to the surface quality where this is critical for the intended application.

Internal defects, e.g. inclusions/sand patches (ref. EN10163-1) making the steel prone to lamination, may to some extent be considered consistent with method of manufacture, unless Z-grade steels is specified, see subsection [6]. Purchasers should specify additional requirements to the internal quality (non-destructive test, e.g. ultrasonic testing) where this is critical for the intended application.

---end---of---guidance---note---

2.11.3 For plates and wide flats, the minus tolerance on 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.

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

2.11.5 The thickness of plates and wide flats shall be measured at locations whose distance from a longitudinal or transverse edge of the piece (see [2.9.2]) 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 based on sound statistical analysis requirements.

2.11.6 The average thickness of plate and wide flat product or products shall be equal to or greater than nominal thickness.

Guidance note:
This requirement does not necessarily imply that the average thickness of each single plate have to be equal to or greater than nominal thickness. It may also be complied with when the average thickness of products produced e.g. within a certain time period, or for a given order or similar, meet this requirement.

---end---of---guidance---note---

2.11.7 The manufacturer shall maintain records of inspections and dimensional measurements, and document compliance with the requirements. The records shall be presented to the surveyor on request.

2.11.8 The seams of welded hollow sections shall be subjected to automated non-destructive testing over their entire length, unless otherwise agreed.

1) the seams of electrical welded hollow sections shall be examined according to one of the following standards:
   — EN ISO 10893-2, acceptance category E4, except that the technique of rotating pipes or with rotating saddle coils is not permitted
2.11.9 the seams of submerged-arc welded hollow sections shall be examined according to acceptance category U4 in accordance with EN ISO 10893-6, image quality Class B

2.11.10 butt welds serving to connect strip or plate lengths by spiral submerged-arc welding shall be examined over their entire length according to the same test procedure and shall satisfy the same acceptance criteria as the main weld seam.

2.12 Repair

2.12.1 Surface defects may be removed by grinding provided that the remaining thickness is within the under thickness tolerances of the plates in question. Where necessary, the entire surface may be ground to a depth as given by the under thickness tolerances of the product.

2.12.2 Local grinding repairs where the remaining thickness of the repaired area is less than that given by the under thickness tolerance, are accepted 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.

2.12.3 Surface defects which cannot be dealt with as in [2.12.1] or [2.12.2] may be repaired by chipping or grinding followed by welding, subject to the surveyor’s consent and under his supervision, provided that all of the following is complied with:

— 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 an approved procedure with low hydrogen welding consumable for the appropriate steel grade
— the welding procedure is qualified using the requirements for butt welds according to Ch.4 Sec.5
— 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 normalized or otherwise suitably post-weld heat-treated
— the weld repairs are subjected to suitable non-destructive testing.
— wherever possible, products which will be supplied in the normalized or quenched and tempered condition shall be repair welded prior to the heat treatment.

2.12.4 Products with delivery condition NR or TM shall, where appropriate further processing cannot be ensured; receive a stress-relieve heat treatment after welding according to the manufacturer’s recommendation.

2.12.5 For every repair weld, the manufacturer shall prepare a report containing details of the size and location of the defects, the welding method used and any heat treatment applied. The manufacturer shall be present this report to the surveyor. The surveyor may require the repaired product to be presented for survey.
2.13 Identification

2.13.1 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. VL E36. When products comply with the requirements of [6], the grade shall include the suffix Z25 or Z35, e.g. VL 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.

Durable marking for unique identification and traceability of the product is required.

Guidance note:
Hard stamping is normally to be used except where this may be detrimental to the material, in which case stencilling, painting or electric etching may be used. Other marking systems giving durable identification and traceability may as well be accepted. Thin plates, stainless steel and non-ferrous plates are normally not marked by hard stamping but rather by paint or similar systems.

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

2.13.2 The particulars in [2.13.1], but excluding the manufacturer's name or trade mark where this is embossed on finished products, shall be encircled with paint or otherwise marked to be easily recognisable.

2.13.3 For marking of bundles of products, see Ch.1 Sec.2 [4.1.3]

2.13.4 Where individually tested rolled lengths of plates (test piece/parent plate) are cut to more than one plate, each plate shall be marked in a manner identifying its relationship to the original length.

3 Normal strength steel

3.1 Scope

3.1.1 These requirements are supplementary to [1] and apply to normal strength steel. Provision is made for four grades with specified minimum yield strength of 235 MPa and based on the specified impact toughness.

3.2 Chemical composition

3.2.1 The chemical composition and deoxidation practice shall comply with the limits given in Table 4. When fine grain practice is applied, the requirements of Table 8 for Al, Nb, V and Ti shall apply.

Table 4 Chemical composition limits and deoxidation practice for normal strength steel

<table>
<thead>
<tr>
<th>Grade</th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Al</th>
<th>Deoxidation practice</th>
</tr>
</thead>
</table>
| VL A  | 0.21 | 0.50 | Min. 2.5 x C | 0.035 | 0.035 | - | For t ≤ 50 mm: Any method except rimmed steel  
                     |     |     |                |      |      | For t > 50 mm: Killed steel |
| VL B  | 0.21 | 0.35 | Min. 0.80  | 0.035 | 0.035 | - | For t ≤ 50 mm: Any method except rimmed steel  
                     |     |     |                |      |      | For t > 50 mm: Killed steel |
### Metallic materials

1) given value is maximum content (by weight) unless shown as a range or as a minimum
2) unless otherwise approved, the following additional limits apply:
   - Cu Max. 0.35%
   - Cr Max. 0.20%
   - Ni Max. 0.40%
   - Mo Max. 0.08%
3) C + 1/6 Mn shall not exceed 0.40%
4) maximum 0.23% for sections
5) rimmed steel may be accepted for sections up to 12.5 mm thickness subject to special approval
6) minimum 0.60% when the steel is impact tested
7) total content. Acid soluble content, if determined instead, shall be minimum 0.015%.

### 3.3 Condition of supply

#### 3.3.1 The condition of supply shall comply with the requirements given in Table 5.

#### Table 5 Conditions of supply for normal strength steel

<table>
<thead>
<tr>
<th>Grade</th>
<th>Thickness, t (mm)</th>
<th>Plates</th>
<th>Sections</th>
</tr>
</thead>
<tbody>
<tr>
<td>VL A, VL B</td>
<td>( t \leq 50 )</td>
<td>AR, NR, N, TM</td>
<td>AR, NR, N, TM</td>
</tr>
<tr>
<td></td>
<td>( 50 &lt; t \leq 150 )</td>
<td>AR(^1), NR, N, TM</td>
<td>AR(^1), NR, N, TM</td>
</tr>
<tr>
<td>VL D</td>
<td>( t \leq 35 )</td>
<td>AR, NR, N, TM</td>
<td>AR, NR, N, TM</td>
</tr>
<tr>
<td></td>
<td>( 35 &lt; t \leq 150 )</td>
<td>NR, N, TM</td>
<td>AR(^1), NR, N, TM</td>
</tr>
<tr>
<td>VL E</td>
<td>( t \leq 150 )</td>
<td>N, TM</td>
<td>AR(^1), NR(^1), N, TM</td>
</tr>
</tbody>
</table>

1) products may be supplied in this condition when especially approved, e.g. through the manufacturer approval

### 3.4 Mechanical properties

#### 3.4.1 The mechanical properties shall comply with the values given in Table 6.

#### 3.4.2 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 7.
Table 6 Mechanical properties for normal strength steel

<table>
<thead>
<tr>
<th>Grade</th>
<th>Yield strength ReH minimum (MPa)</th>
<th>Tensile strength Rm (MPa)</th>
<th>Elongation A5 minimum (%)</th>
<th>Impact energy, average minimum (J) 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Test temperature (°C)</td>
<td>t ≤ 50 (mm)</td>
<td>50 &lt; t ≤ 70 (mm)</td>
<td>70 &lt; t ≤ 150 (mm)</td>
</tr>
<tr>
<td></td>
<td>L</td>
<td>T</td>
<td>L</td>
<td>T</td>
</tr>
<tr>
<td>VL A</td>
<td>235</td>
<td>400 to 520</td>
<td>22 1)</td>
<td>+20</td>
</tr>
<tr>
<td>VL B</td>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>VL D</td>
<td></td>
<td></td>
<td></td>
<td>-20</td>
</tr>
<tr>
<td>VL E</td>
<td></td>
<td></td>
<td></td>
<td>-40</td>
</tr>
</tbody>
</table>

1) test direction shall follow [2.8.5]
2) impact tests are not required for grade B steel with t ≤ 25 mm
3) impact tests for grade A over 50 mm thickness are not required when the material is produced using fine grain practice and supplied in N condition
4) for full thickness flat test specimens with width 25 mm and gauge length 200 mm, the minimum elongation (%) is required as follows:

<table>
<thead>
<tr>
<th>Thickness, mm</th>
<th>t ≤ 5</th>
<th>5 &lt; t ≤ 10</th>
<th>10 &lt; t ≤ 15</th>
<th>15 &lt; t ≤ 20</th>
<th>20 &lt; t ≤ 25</th>
<th>25 &lt; t ≤ 30</th>
<th>30 &lt; t ≤ 40</th>
<th>40 &lt; t ≤ 50</th>
</tr>
</thead>
<tbody>
<tr>
<td>All grades</td>
<td>14</td>
<td>16</td>
<td>17</td>
<td>18</td>
<td>19</td>
<td>20</td>
<td>21</td>
<td>22</td>
</tr>
</tbody>
</table>

Table 7 Test units for impact testing of normal strength steel

<table>
<thead>
<tr>
<th>Grade</th>
<th>Thickness, t (mm)</th>
<th>Plates</th>
<th>Sections</th>
</tr>
</thead>
<tbody>
<tr>
<td>VL A</td>
<td>50 &lt; t ≤ 150</td>
<td>50 tonnes</td>
<td>Not required</td>
</tr>
<tr>
<td>VL B</td>
<td>25 &lt; t ≤ 150</td>
<td>50 tonnes 1)2)</td>
<td>50 tonnes 2)</td>
</tr>
<tr>
<td>VL D</td>
<td>t ≤ 150</td>
<td>50 tonnes 1)2)</td>
<td>50 tonnes 2)</td>
</tr>
<tr>
<td>VL E</td>
<td>t ≤ 150</td>
<td>Each piece</td>
<td>25 tonnes 3)</td>
</tr>
</tbody>
</table>

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

4 High strength steel

4.1 Scope

4.1.1 These requirements are supplementary to [1] and apply to high strength steel. Provision is made for four strength levels with specified minimum yield strength 265 MPa, 315 MPa, 355 MPa and 390 MPa. Each strength level is further subdivided into four grades based on the specified impact toughness.
4.2 Chemical composition

4.2.1 The chemical composition shall comply with the limits given in Table 8. Except for VL A27S with thickness less than 25 mm, the steel grades shall be killed and fine grain treated. VL A27S in thicknesses up to and including 25 mm may be semi-killed or killed and without fine grain treatment.

4.2.2 For TM steels, the carbon equivalent value shall comply with the limits given in Table 9.

Table 8 Chemical composition limits 1) for high strength steel

<table>
<thead>
<tr>
<th>Grade</th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Cr</th>
<th>Mo</th>
<th>Ni</th>
<th>Cu</th>
<th>Al</th>
<th>Nb</th>
<th>V</th>
<th>Ti</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>VL A27S, VL D27S, VL E27S</td>
<td>0.18</td>
<td>0.50</td>
<td>0.70 to 1.60</td>
<td>0.035</td>
<td>0.035</td>
<td>0.20</td>
<td>0.08</td>
<td>0.40</td>
<td>0.35</td>
<td>Min. 0.020</td>
<td>0.02 to 0.05</td>
<td>0.05 to 0.10</td>
<td>0.007 to 0.02</td>
<td>-</td>
</tr>
<tr>
<td>VL A32, VL D32, VL E32, VL A36, VL D36, VL E36, VL A40, VL D40, VL E40</td>
<td>0.18</td>
<td>0.50</td>
<td>0.90 to 1.60 2)</td>
<td>0.035</td>
<td>0.035</td>
<td>0.20</td>
<td>0.08</td>
<td>0.40</td>
<td>0.35</td>
<td>Min. 0.020</td>
<td>0.02 to 0.05</td>
<td>0.05 to 0.10</td>
<td>0.007 to 0.02</td>
<td>-</td>
</tr>
<tr>
<td>VL F27S, VL F32, VL F36, VL F40</td>
<td>0.16</td>
<td>0.50</td>
<td>0.90 to 1.60 2)</td>
<td>0.025</td>
<td>0.025</td>
<td>0.20</td>
<td>0.08</td>
<td>0.80</td>
<td>0.35</td>
<td>Min. 0.020</td>
<td>0.02 to 0.05</td>
<td>0.05 to 0.10</td>
<td>0.007 to 0.02</td>
<td>0.009 6)</td>
</tr>
</tbody>
</table>

1) given value is maximum content (by weight) 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 grain refining elements 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) maximum 0.05% Ti for TM steels subjected to approval
6) 0.012% if Al is present

Table 9 Maximum carbon equivalent values (C_{eq}) for high strength steel supplied in TM condition

<table>
<thead>
<tr>
<th>Grade</th>
<th>t ≤ 50 mm</th>
<th>50 mm &lt; t ≤ 100 mm</th>
<th>100 mm &lt; t ≤ 150 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>VL A27S, VL D27S, VL E27S, VL F27S</td>
<td>0.34</td>
<td>0.36</td>
<td>0.38</td>
</tr>
<tr>
<td>VL A32, VL D32, VL E32, VL F32</td>
<td>0.36</td>
<td>0.38</td>
<td>0.40</td>
</tr>
<tr>
<td>VL A36, VL D36, VL E36, VL F36</td>
<td>0.38</td>
<td>0.40</td>
<td>0.42</td>
</tr>
<tr>
<td>VL A40, VL D40, VL E40, VL F40</td>
<td>0.40</td>
<td>0.42</td>
<td>0.45</td>
</tr>
</tbody>
</table>
### 4.3 Condition of supply

#### 4.3.1 The condition of supply shall comply with the requirements given in Table 10.

**Table 10 Conditions of supply for high strength steel**

<table>
<thead>
<tr>
<th>Grade</th>
<th>Grain refining element</th>
<th>Thickness, ( t ) (mm)</th>
<th>Plates</th>
<th>Sections</th>
</tr>
</thead>
<tbody>
<tr>
<td>VL A27S, VL A32, VL A36</td>
<td>Al or any combinations with Al</td>
<td>( t \leq 20 )</td>
<td>AR, NR, N, TM</td>
<td>AR, NR, N, TM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( 20 &lt; t \leq 35 )</td>
<td>AR(^1), NR, N, TM</td>
<td>AR, NR, N, TM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( 35 &lt; t \leq 150 )</td>
<td>NR, N, TM, QT</td>
<td>AR(^1), NR, N, TM, QT</td>
</tr>
<tr>
<td></td>
<td>Any combination without Al</td>
<td>( t \leq 12.5 )</td>
<td>AR, NR, N, TM</td>
<td>AR, NR, N, TM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( 12.5 &lt; t \leq 150 )</td>
<td>NR, N, TM, QT</td>
<td>AR(^1), NR, N, TM, QT</td>
</tr>
<tr>
<td>VL A40</td>
<td>Any</td>
<td>( t \leq 12.5 )</td>
<td>AR, NR, N, TM</td>
<td>AR, NR, N, TM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( 12.5 &lt; t \leq 150 )</td>
<td>NR, N, TM, QT</td>
<td>NR, N, TM</td>
</tr>
<tr>
<td>VL D27S, VL D32, VL D36</td>
<td>Al or any combinations with Al</td>
<td>( t \leq 20 )</td>
<td>AR, NR, N, TM</td>
<td>AR, NR, N, TM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( 20 &lt; t \leq 25 )</td>
<td>AR(^1), NR, N, TM</td>
<td>AR, NR, N, TM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( 25 &lt; t \leq 150 )</td>
<td>NR, N, TM, QT</td>
<td>AR(^1), NR, N, TM, QT</td>
</tr>
<tr>
<td></td>
<td>Any combination without Al</td>
<td>( t \leq 12.5 )</td>
<td>AR, NR, N, TM</td>
<td>AR, NR, N, TM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( 12.5 &lt; t \leq 150 )</td>
<td>NR, N, TM, QT</td>
<td>AR(^1), NR, N, TM, QT</td>
</tr>
<tr>
<td>VL D40</td>
<td>Any</td>
<td>( t \leq 150 )</td>
<td>NR, N, TM, QT</td>
<td>NR, N, TM</td>
</tr>
<tr>
<td>VL E27S, VL E32, VL E36</td>
<td>Any</td>
<td>( t \leq 50 )</td>
<td>N, TM, QT</td>
<td>AR(^1), NR(^1), N, TM, QT</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( 50 &lt; t \leq 150 )</td>
<td>N, TM, QT</td>
<td>NR(^1), N, TM, QT</td>
</tr>
<tr>
<td>VL F27S, VL F32, VL F36</td>
<td>Any</td>
<td>( t \leq 150 )</td>
<td>N, TM, QT</td>
<td>NR(^1), N, TM, QT</td>
</tr>
<tr>
<td>VL E40, VL F40</td>
<td>Any</td>
<td>( t \leq 150 )</td>
<td>N, TM, QT</td>
<td>N, TM, QT</td>
</tr>
</tbody>
</table>

1) products may be supplied in this condition when approved

### 4.4 Mechanical properties

#### 4.4.1 The mechanical properties shall comply with the values given in Table 11.

#### 4.4.2 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 12.
Table 11 Mechanical properties for high strength steel

<table>
<thead>
<tr>
<th>Grade</th>
<th>Yield strength $R_{eH}$ minimum (MPa)</th>
<th>Tensile strength $R_{m}$ minimum (MPa)</th>
<th>Elongation $A_{5}$ minimum (%)</th>
<th>Impact energy, average minimum (J)(^1)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Test temperature (°C)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>L</td>
</tr>
<tr>
<td>VL A27S</td>
<td>265</td>
<td>400 to 530</td>
<td>22 (^2)</td>
<td>0</td>
</tr>
<tr>
<td>VL D27S</td>
<td></td>
<td></td>
<td></td>
<td>31</td>
</tr>
<tr>
<td>VL E27S</td>
<td></td>
<td></td>
<td></td>
<td>34</td>
</tr>
<tr>
<td>VL F27S</td>
<td></td>
<td></td>
<td></td>
<td>39</td>
</tr>
<tr>
<td>VL A32</td>
<td>315</td>
<td>440 to 570</td>
<td>22 (^2)</td>
<td>0</td>
</tr>
<tr>
<td>VL D32</td>
<td></td>
<td></td>
<td></td>
<td>34</td>
</tr>
<tr>
<td>VL E32</td>
<td></td>
<td></td>
<td></td>
<td>39</td>
</tr>
<tr>
<td>VL F32</td>
<td></td>
<td></td>
<td></td>
<td>41</td>
</tr>
<tr>
<td>VL A36</td>
<td>355</td>
<td>490 to 630</td>
<td>21 (^2)</td>
<td>0</td>
</tr>
<tr>
<td>VL D36</td>
<td></td>
<td></td>
<td></td>
<td>39</td>
</tr>
<tr>
<td>VL E36</td>
<td></td>
<td></td>
<td></td>
<td>41</td>
</tr>
<tr>
<td>VL F36</td>
<td></td>
<td></td>
<td></td>
<td>44</td>
</tr>
<tr>
<td>VL A40</td>
<td>390</td>
<td>510 to 660</td>
<td>20 (^2)</td>
<td>0</td>
</tr>
<tr>
<td>VL D40</td>
<td></td>
<td></td>
<td></td>
<td>41</td>
</tr>
<tr>
<td>VL E40</td>
<td></td>
<td></td>
<td></td>
<td>44</td>
</tr>
<tr>
<td>VL F40</td>
<td></td>
<td></td>
<td></td>
<td>47</td>
</tr>
</tbody>
</table>

1) Test direction shall follow [2.8.5]
2) For full thickness flat test specimens with width 25 mm and gauge length 200 mm, the minimum elongation (%) is required as follows:

<table>
<thead>
<tr>
<th>Thickness (mm)</th>
<th>t ≤ 5</th>
<th>5 &lt; t ≤ 10</th>
<th>10 &lt; t ≤ 15</th>
<th>15 &lt; t ≤ 20</th>
<th>20 &lt; t ≤ 25</th>
<th>25 &lt; t ≤ 30</th>
<th>30 &lt; t ≤ 40</th>
<th>40 &lt; t ≤ 50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strength levels 27S and 32</td>
<td>14</td>
<td>16</td>
<td>17</td>
<td>18</td>
<td>19</td>
<td>20</td>
<td>21</td>
<td>22</td>
</tr>
<tr>
<td>Strength level 36</td>
<td>13</td>
<td>15</td>
<td>16</td>
<td>17</td>
<td>18</td>
<td>19</td>
<td>20</td>
<td>21</td>
</tr>
<tr>
<td>Strength level 40</td>
<td>12</td>
<td>14</td>
<td>15</td>
<td>16</td>
<td>17</td>
<td>18</td>
<td>19</td>
<td>20</td>
</tr>
</tbody>
</table>

Table 12 Test units for impact testing of high strength steels

<table>
<thead>
<tr>
<th>Grades</th>
<th>Strength levels</th>
<th>Delivery condition</th>
<th>Thickness</th>
<th>Plates</th>
<th>Sections</th>
</tr>
</thead>
<tbody>
<tr>
<td>A and D</td>
<td>All</td>
<td>AR</td>
<td>All</td>
<td>25 tonnes</td>
<td>25 tonnes</td>
</tr>
<tr>
<td>A and D</td>
<td>All</td>
<td>NR</td>
<td>≤ 50 mm</td>
<td>50 tonnes</td>
<td>50 tonnes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>&gt; 50 mm</td>
<td>25 tonnes</td>
<td></td>
</tr>
</tbody>
</table>
5 Extra high strength steel

5.1 Scope

5.1.1 These requirements are supplementary to [1] and apply to extra high strength steel. Provision is made for six strength levels with specified minimum yield strength 420 MPa, 460 MPa, 500 MPa, 550 MPa, 620 MPa and 690 MPa, see Table 13 and Table 14. Each strength level is further subdivided into four grades based on the specified impact toughness.

Guidance note:
The extra high strength steel grades VL D/E47COD, BCA and BCACOD are specially designed for Hull Structural Application in Container Ships. Specific manufacturer approval requirements for qualification of these grades are detailed in approval of manufacturer program DNVGL-CP-0348.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

5.2 Chemical composition

5.2.1 The chemical composition and deoxidation practice shall comply with the limits given in Table 13. The steel grades shall be killed and fine grain treated.

Table 13 Chemical composition limits ¹) for extra high strength steel

| Element | Grade A of strength levels 420 to 690 | Grades D and E of strength levels 420 to 690 | Grade F of strength levels 420 to 690 | Grades VL D/E47COD, BCA and BCACOD ²)
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>0.21</td>
<td>0.20</td>
<td>0.18</td>
<td>0.12</td>
</tr>
<tr>
<td>Si</td>
<td>0.10 to 0.55</td>
<td>0.10 to 0.55</td>
<td>0.10 to 0.55</td>
<td>0.12</td>
</tr>
<tr>
<td>Mn</td>
<td>1.70</td>
<td>1.70</td>
<td>1.60</td>
<td>1.80 ³)</td>
</tr>
<tr>
<td>P</td>
<td>0.035</td>
<td>0.030</td>
<td>0.025</td>
<td>0.020</td>
</tr>
<tr>
<td>S</td>
<td>0.035</td>
<td>0.030</td>
<td>0.025</td>
<td>0.008</td>
</tr>
<tr>
<td>Cr ³)</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.25</td>
</tr>
<tr>
<td>Mo ⁴)</td>
<td>0.08</td>
<td>0.08</td>
<td>0.08</td>
<td>0.25</td>
</tr>
<tr>
<td>Ni ⁴)</td>
<td>0.40</td>
<td>0.40</td>
<td>0.80</td>
<td>1.00</td>
</tr>
<tr>
<td>Cu ⁴)</td>
<td>0.35</td>
<td>0.35</td>
<td>0.35</td>
<td>0.50</td>
</tr>
<tr>
<td>Al ⁵,⁶)</td>
<td>Min. 0.020</td>
<td>Min. 0.020</td>
<td>Min. 0.020</td>
<td>0.020 to 0.06 ⁷)</td>
</tr>
<tr>
<td>Nb ⁶)</td>
<td>0.02 to 0.05</td>
<td>0.02 to 0.05</td>
<td>0.02 to 0.05</td>
<td>0.02 to 0.04 ⁸)</td>
</tr>
</tbody>
</table>

¹) Unless otherwise noted.
²) Requirements of grade VL D/E47COD, BCA and BCACOD are given in Table 13.
³) For extra high strength steel grades VL D/E47COD, BCA and BCACOD.
⁴) For grades VL D/E47COD, BCA and BCACOD.
⁵) For grades VL D/E47COD, BCA and BCACOD.
⁶) For all grades.
⁷) For grades VL D/E47COD, BCA and BCACOD.
⁸) For grades VL D/E47COD, BCA and BCACOD.
5.3 Condition of supply

5.3.1 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 TM or QT condition.

5.4 Mechanical properties

5.4.1 The mechanical properties shall comply with the values given in Table 14. The extent of tensile and impact testing shall be each piece.

5.4.2 Fracture mechanics testing (CTOD test) is required for the base material and coarse grained HAZ (CGHAZ) for D/E47COD, BCA and BCACOD grades, and shall be carried out in accordance with the method described in Ch.1 Sec.3 [3.9]. Testing may be omitted if the CTOD properties have been qualified through the manufacturer approval test and the qualified material and manufacturing process is adhered to.

— CTOD value for the base material is to be reported for reference
— CTOD values of CGHAZ for D/E47BCA grades is to be reported for reference
— Acceptance criteria for CTOD values of CGHAZ for COD-grades are given in [8.1.2].

Guidance note:
Guidance on qualification of D/E47COD, BCA and BCACOD are given in manufacturer approval program DNVGL-CP-0348.
Table 14 Mechanical properties for extra high strength steel

<table>
<thead>
<tr>
<th>Grade</th>
<th>Yield strength ( \sigma_{e} ) minimum (MPa)</th>
<th>Tensile strength ( \sigma_{m} ) (MPa)</th>
<th>Elongation AS minimum (%)</th>
<th>Impact energy, average (minimum), (J) (^{1})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( R_{eH, min} )</td>
<td>( t \leq 70 )</td>
<td>0</td>
<td>( L (T) )</td>
</tr>
<tr>
<td></td>
<td>( t &gt; 70 )</td>
<td>70 &lt; t ≤ 85</td>
<td>0</td>
<td>( L (T) )</td>
</tr>
<tr>
<td></td>
<td>( t &gt; 85 )</td>
<td>85 &lt; t ≤ 150</td>
<td>0</td>
<td>( L (T) )</td>
</tr>
<tr>
<td>VL A420</td>
<td>420</td>
<td>530 to 680</td>
<td>20</td>
<td>18</td>
</tr>
<tr>
<td>VL D420</td>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>VL E420</td>
<td></td>
<td></td>
<td></td>
<td>-20</td>
</tr>
<tr>
<td>VL F420</td>
<td></td>
<td></td>
<td></td>
<td>-40</td>
</tr>
<tr>
<td>VL A460</td>
<td>460</td>
<td>570 to 720</td>
<td>19</td>
<td>17</td>
</tr>
<tr>
<td>VL D460</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>VL E460</td>
<td></td>
<td></td>
<td></td>
<td>-20</td>
</tr>
<tr>
<td>VL F460</td>
<td></td>
<td></td>
<td></td>
<td>-40</td>
</tr>
<tr>
<td>VL D/E47Z35COD,</td>
<td>460</td>
<td>570 to 720</td>
<td>19</td>
<td>17</td>
</tr>
<tr>
<td>BCA and BCACOD</td>
<td></td>
<td></td>
<td></td>
<td>-20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-40</td>
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<tr>
<td>VL A500</td>
<td>500</td>
<td>610 to 770</td>
<td>18</td>
<td>16</td>
</tr>
<tr>
<td>VL D500</td>
<td></td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>VL E500</td>
<td></td>
<td></td>
<td></td>
<td>-20</td>
</tr>
<tr>
<td>VL F500</td>
<td></td>
<td></td>
<td></td>
<td>-40</td>
</tr>
<tr>
<td>VL A550</td>
<td>550</td>
<td>670 to 830</td>
<td>18</td>
<td>16</td>
</tr>
<tr>
<td>VL D550</td>
<td></td>
<td></td>
<td></td>
<td>0</td>
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<tr>
<td>VL E550</td>
<td></td>
<td></td>
<td></td>
<td>-20</td>
</tr>
<tr>
<td>VL F550</td>
<td></td>
<td></td>
<td></td>
<td>-40</td>
</tr>
<tr>
<td>VL A620</td>
<td>620</td>
<td>720 to 890</td>
<td>17</td>
<td>15</td>
</tr>
<tr>
<td>VL D620</td>
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<td>VL E620</td>
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<td>-20</td>
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<tr>
<td>VL F620</td>
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<td>-40</td>
</tr>
<tr>
<td>VL A690</td>
<td>690</td>
<td>770 to 940</td>
<td>16</td>
<td>14</td>
</tr>
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<td>VL D690</td>
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<tr>
<td>VL E690</td>
<td></td>
<td></td>
<td></td>
<td>-20</td>
</tr>
<tr>
<td>VL F690</td>
<td></td>
<td></td>
<td></td>
<td>-40</td>
</tr>
</tbody>
</table>

1) test direction shall follow [2.8.5]
2) \( t \leq 100 \) for grades D/E47COD, BCA and BCACOD
3) through thickness properties are required in accordance with [6], quality class Z35
4) CTOD test is required for COD and BCACOD, see [5.4.2]
5) for full thickness flat test specimens with width 25 mm and gauge length 200 mm, the minimum transverse elongation (%) is reduced to the following values:
6 Plates with through thickness properties

6.1 Scope

6.1.1 These requirements are supplementary to [1] to [9] and apply to plates and wide flats with thickness 15 mm and over with improved through thickness 'Z' direction properties, see Figure 3. The use of 'Z' grade steels is required for certain types of welded structures, as detailed in the relevant design and construction rules or on the approved drawings. Common areas for Z-grade steels are areas where plates are subjected to significant tensile stress in the through thickness direction. Z-grade steels are typically used in order to minimise the possibility of lamellar tearing, e.g. during fabrication.

6.1.2 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, 25% and 35% respectively
- specified maximum values for sulphur content, 0.005% and 0.008%
- ultrasonic testing.
Quality class Z25 is intended for normal vessel applications and Z35 for more severe applications.

Figure 3 Through thickness tensile testing

6.2 Manufacture

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

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

---e-n-d---of---g-u-i-d-a-n-c-e---n-o-t-e---
6.3 Chemical composition

6.3.1 The steel grades shall be killed and fine grain treated. The ladle analysis sulphur content shall be ≤ 0.008% unless alternative methods of improving through thickness properties have been approved. For sulphur content ≤ 0.005%, reduced test unit size is accepted, see Table 15.

6.4 Test material

6.4.1 Test material shall be taken close to the longitudinal centreline from one end of each rolled piece representing the test unit, see Figure 4 and Table 15. The longitudinal axes of the test specimens shall be perpendicular to the surface of the product.

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

6.4.3 Round test specimens shall be prepared in accordance with recognised standards, e.g. EN 10164 and ASTM A770.

![Figure 4 Plate and wide flat sampling position](image)

Table 15 Test unit (batch) maximum size dependent on product and sulphur content

<table>
<thead>
<tr>
<th>Product</th>
<th>Sulphur content</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.005% &lt; S ≤ 0.008%</td>
</tr>
<tr>
<td>Plates</td>
<td>Each piece (parent plate)</td>
</tr>
<tr>
<td>Wide flats of nominal thickness ≤25 mm</td>
<td>10 tonnes</td>
</tr>
<tr>
<td>Wide flats of nominal thickness &gt; 25 mm</td>
<td>20 tonnes</td>
</tr>
</tbody>
</table>

6.5 Mechanical testing

6.5.1 The average reduction of area value of three test specimens shall be determined and meet the specified minimum average value given in Table 16. One individual value may be below the specified minimum average value, provided that it is not less than the specified minimum individual value.

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

— the average value of six test specimens 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.
6.5.3 Where batch testing is permitted and the conditions for acceptance after retest in [6.5.2] 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.

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

**Table 16 Reduction of area acceptance values**

<table>
<thead>
<tr>
<th>Quality class</th>
<th>Z25</th>
<th>Z35</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum average</td>
<td>25%</td>
<td>35%</td>
</tr>
<tr>
<td>Minimum individual</td>
<td>15%</td>
<td>25%</td>
</tr>
</tbody>
</table>

6.6 Ultrasonic testing

6.6.1 Each product shall be subjected to ultrasonic testing in the delivery condition. Testing shall be performed in accordance with either EN 10160 and with acceptance criteria Level S1/E1, or ASTM A578 with acceptance criteria Level C. Details of the performance of testing including probe frequencies are described in the applied standard.

7 Brittle crack arrest steels (BCA steels)

7.1 Scope

7.1.1 These requirements are supplementary to [1] to [9] and apply to brittle crack arrest (BCA) steels. Provision is made for steel plates, wide flats and sections with a thickness of more than 50 mm and with specified minimum yield strength 360 MPa, 400 MPa and 460 MPa.

7.1.2 BCA steel is defined as steel plate with measured crack arrest properties, $K_{ca} \geq 6000 \text{ N/mm}^{3/2}$ at -10°C determined by ESSO test (ref. Ch.1 Sec.3 [3.10]), or other methods based on the determination of crack arrest temperature (CAT).

To verify the brittle crack arrest-ability, either ESSO test to determine the crack arrest toughness $K_{ca}$ shall be carried out, see Ch.1 Sec.3 [3.10], or double tension wide plate test to determine the crack arrest temperature CAT. The obtained brittle crack arrest toughness $K_{ca}$, or the crack arrest temperature CAT, respectively, shall be reported.

**Guidance note:**
Subject to approval, alternative test methods may be accepted for testing during production of BCA steels. The use of small scale tests, e.g. drop weight tests in order to determine the nil ductility test temperature (NDTT), or other relevant tests, may be considered for acceptance provided that mathematical relationships of NDTT to $K_{ca}$ or CAT can be shown to be valid. The $K_{ca}$ or CAT property, and its relationship with small scale tests are typically established during the manufacturer approval testing of this particular grade, whereas small scale testing is subsequently carried out during production.

Where the thickness of the steel exceeds 80 mm the required $K_{ca}$ value or alternative crack arrest parameter for the brittle crack arrest steel plate shall be specifically agreed with the Society.

7.2 Chemical composition

7.2.1 As specified in [7.3.1] the manufacturer shall establish a specification for the chemical composition, with particular focus on elements which affect the BCA properties. The specified chemical composition shall
in general follow the requirements of the corresponding grade of non-BCA steel as given in [4] and [5]. The chemical composition of samples taken from each ladle of each cast shall be determined by the manufacturer and shall be in accordance with the qualified specification. The manufacturer shall verify compliance.

Guidance note:
The specification may typically give ranges of each element as indicated in EN 10225 Option 18, under the provision that the chemical composition range is also within the requirements given for the corresponding grade of non-BCA steels.

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

7.3 Manufacture and testing

7.3.1 Qualification of BCA steels: All materials shall be manufactured at works approved by the Society for the grade of BCA steel being supplied.

The manufacturer shall establish a specification for the chemical composition, manufacturing process and production control for the BCA steels, with particular focus on parameters which affect the BCA properties. The specification for strength grades 36BCA and 40BCA may follow the chemical composition requirements for steel grades VL D/E47COD, BCA and BCACOD, ref. Table 13.

The BCA steel grades corresponding to the manufacturer specification shall be qualified during the approval of manufacturer process in accordance with the relevant approval program DNVGL-CP-0348.

Guidance note:
CTOD test of base material and CGHAZ is required as part of the qualification, see DNVGL-CP-0348. The CTOD test results are reported for information and acceptance criteria for BCA grades without COD designation are not specified.

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

7.3.2 Testing during production: The frequency of testing is each test unit, see [2.9]. The size of a test unit shall be as defined for the corresponding steel grade without BCA properties, see [3] to [6]. In addition testing for BCA property is required as follows (see also [7.1.2]):

— for grades with specified minimum yield strength 360 MPa and 400 MPa: Test frequency as per tensile test (i.e. each heat and each thickness, max. test unit may be 50 tons)
— for grades with specified minimum yield strength 460 MPa: Test frequency is each piece.

Guidance note:
Approval for reduced extent of testing may be given based on statistics showing consistent good BCA properties combined with the manufacturers’ strict process and production control.

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

7.3.3 Production control: For steels manufactured as BCA steels, it is the manufacturer’s responsibility to ensure that the qualified specification including process and production controls in operation are adhered to, see [7.3.1].

7.3.4 Changes to the process or failure to meet the specification: If the composition, process or production controls are changed in any way, or any product fails to meet specifications, the manufacturer shall issue a report explaining the reasons, and, in the instance of product which fails to meet specifications, the measures to prevent recurrence. The complete report shall be submitted to the Society along with such additional information as the Society may require. The frequency of testing for subsequent products is at the discretion of the Society.

7.3.5 Declaration of conformance: By naming the steel as BCA grade on the certificate, the manufacturer declares conformance with the qualified specification.
7.4 Identification

7.4.1 Identification shall be in accordance with [2.13]. Additionally, the grade shall include the brittle crack arrest steel designation suffix BCA, e.g. VL E40Z35BCA.

8 Steels with crack initiation resistance (COD steels)

8.1 Scope

8.1.1 These requirements are supplementary to [1] to [9] and apply to steels with certain resistance to crack initiation (COD steels), i.e. which exhibit a certain fracture toughness in terms of crack tip opening displacement (CTOD). Provision is made for steel plates, wide flats and sections with a thickness of more than 50 mm.

8.1.2 COD steel is defined as steels with measured minimum single CTOD value of 0.18 mm and minimum average CTOD value of 0.20 mm for notch position in CGHAZ. The average CTOD value is calculated based on at least three valid CTOD test results.

8.2 Chemical composition

8.2.1 As specified in [8.3.1] the manufacturer shall establish a specification for the chemical composition, with particular focus on elements which affect the CTOD properties. Unless otherwise approved, the specified chemical composition shall follow the requirements of the corresponding grade of non-COD steel as given in [4] and [5], although narrower ranges will apply, see guidance note. The chemical composition of samples taken from each ladle of each cast shall be determined by the manufacturer and shall be in accordance with the qualified specification. The manufacturer shall verify compliance.

Guidance note:
The specification may typically give ranges of each element as indicated in EN 10225 Option 18, under the provision that the chemical composition range is also within the rule requirements given for the corresponding grade of non-COD steels.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

8.3 Manufacture

8.3.1 Qualification of COD steels: All materials shall be manufactured at works approved by the Society for the grade of COD steel being supplied.

The manufacturer shall establish a specification for the chemical composition, manufacturing process and production control for the COD steels, with particular focus on parameters which affect the CTOD properties. The COD steel grade corresponding to the manufacturer specification shall be qualified during the approval of manufacturer process in accordance with the relevant Approval Program CP-0348.

8.3.2 Production control: For steels manufactured as COD steels, it is the manufacturer's responsibility to ensure that the qualified specification including process and production controls in operation are adhered to, see [8.3.1].

8.3.3 Changes to the process or failure to meet the specification: If the composition, process or production controls are changed in any way, or any product fails to meet specifications, the manufacturer shall issue a report explaining the reasons, and, in the instance of product which fails to meet specifications, the measures to prevent recurrence. The complete report shall be submitted to the Society along with such additional
information as the Society may require. The frequency of testing for subsequent products is at the discretion of the Society.

**8.3.4 Declaration of conformance:** By naming the steel as COD grade on the certificate, the manufacturer declares conformance with the qualified specification.

**8.4 Identification**

**8.4.1 Identification** shall be in accordance with [2.13]. Additionally, the grade shall include the designated suffix COD, e.g. VL E40Z35COD or VL E40Z35BCACOD.

**9 Corrosion resistant steels for cargo oil tanks**

**9.1 Scope**

**9.1.1** These requirements are supplementary to [1] to [6] and apply to corrosion resistant steels when such steel is used as the alternative means of corrosion protection for cargo oil tanks as specified in the performance standard MSC.289 (87) of Regulation 3-11, Part A-1, Chapter II-1 of the SOLAS Convention (Corrosion protection of cargo oil tanks of crude oil tankers).

**9.1.2 Provision** is made for steel plates, wide flats and sections with a thickness up to 50 mm.

**9.1.3 Corrosion resistant steels as defined within this chapter are steels whose corrosion resistance performance in the bottom or top of the internal cargo oil tank is tested and approved to satisfy the requirements in MSC.289 (87) in addition to other relevant requirements for vessel material, structural strength and construction. It is not intended that such steels shall be used for corrosion resistant applications in other areas of a vessel that are outside of those specified in the performance standard MSC.289 (87) of Regulation 3-11, Part A-1, Chapter II-1 of the SOLAS Convention.

**9.2 Chemical composition**

**9.2.1** The chemical composition of samples taken from each ladle of each cast shall be determined by the manufacturer, and shall be in accordance with the qualified specification, see [7.2.1]. The manufacturer shall verify compliance.

**9.3 Manufacture**

**9.3.1** All materials shall be manufactured at works approved by the Society for the grade of corrosion resistant steel being supplied, and according to the process specification and chemical composition specification qualified through the manufacturer approval process.

**9.3.2** The corrosion resistant steel grades shall be qualified during the approval process in accordance with the relevant Society approval program. Approval can be given for application in one of the following areas of a cargo oil tank:

a) lower surface of strength deck and surrounding structures (RCU)

b) upper surface of inner bottom plating and surrounding structures (RCB)

c) for both strength deck and inner bottom plating (RCW).

**9.3.3 By naming the steel as RCU, RCB or RCW grade on the certificate, the manufacturer declares conformance with the qualified specification.”
9.4 Identification

9.4.1 Identification shall be in accordance with [2.13]. Additionally, the grade shall include the corrosion designation suffix RCU, RCB or RCW, e.g. VL E36RCU Z35.
SECTION 3 ROLLED STEEL FOR BOILERS, PRESSURE VESSELS AND SPECIAL APPLICATIONS

1 General

1.1 Scope

1.1.1 This section specifies the requirements for hot rolled steel products intended for use in the construction of boilers and pressure vessels, tanks and process equipment for low temperature service, and rolled austenitic and ferritic-austenitic (duplex) stainless steels. Application is ambient, elevated and low temperature service.

Requirements for the manufacture of rolled bars for shafts, shanks, studs, bolts and other rotating parts are covered by Sec.8.

1.1.2 Where required by the relevant design and construction parts of the rules, rolled steel shall comply with the general requirements of Sec.1 and [1], and the appropriate specific requirements of [2] to [5]. Where the specific requirements differ from these general requirements, the specific requirements shall prevail.

1.1.3 Subject to approval and as an alternative to [1.1.2], materials which comply with other standards or proprietary specifications may be considered for acceptance provided such specifications give reasonable equivalence to the requirements of this section or are approved for a specific application, see Ch.1 Sec.1 [3.4].

1.2 Certification requirements

1.2.1 General certification requirements are given in Sec.1 [3.1].

1.2.2 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. For pressed parts where renewed full heat treatment has not been carried out, the information concerning the forming process and the modified heat treatment as per [5.2.5] to [5.2.10] shall be added, e.g. cold formed and stress-relieved
g) results of mechanical tests; and specimen no., where applicable
h) when products comply with the requirements of Sec.2 [6], the results of through thickness tensile tests and ultrasonic tests
i) for pressed parts; deformation ratio calculated according to Ch.4 Sec.6 [5.2].
j) results of any supplementary and additional test requirements specified.

1.3 Documentation requirements

1.3.1 General documentation requirements are given in Sec.1 [3.2]. Additional manufacturer specific documentation requirements are given in Table 1.
### Table 1 Qualification documentation for manufacturer

<table>
<thead>
<tr>
<th>Item</th>
<th>Documentation type</th>
<th>Additional description</th>
</tr>
</thead>
</table>
| NR and TM steels                                          | Z260 - Records     | For rolling schedule:  
|                                                           |                    | — records providing start rolling temperature, start and stop finishing rolling temperatures, deformation ratios, and where applicable, accelerated cooling start and stop temperatures  
|                                                           |                    | — the records shall be presented to the surveyor on request                                                                                           |
| All pressed parts                                         | Z250 - Procedures  | Describing each operational and controlling step for the forming and heat treatment                                                                   |
| Pressed parts supplied in the hot pressed condition       | Z260 - Records     | Documenting:  
|                                                           |                    | — that the whole forming operation was carried out within the specified normalizing temperature range  
|                                                           |                    | — the method of cooling  
|                                                           |                    | — the delivery condition of the starting material  
|                                                           |                    | — the records shall be presented to the surveyor on request                                                                                           |

### 1.4 Survey, inspection and testing requirements

**1.4.1** General survey, inspection and testing requirements are given in [Sec.1](3.3). Additional specific requirements are given in Table 2, as further detailed in this section.

### Table 2 Additional survey and testing requirements

<table>
<thead>
<tr>
<th>Survey, inspection and testing item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical composition</td>
<td>Required for all materials</td>
</tr>
<tr>
<td>Tensile test and impact toughness test</td>
<td>Required for all grades covered by this chapter unless otherwise specified</td>
</tr>
<tr>
<td>Mechanical properties at elevated temperature</td>
<td>When determination of yield strength at high temperature is required</td>
</tr>
<tr>
<td>Through thickness tensile test</td>
<td>Required for materials with specified through thickness properties</td>
</tr>
<tr>
<td>Drop weight test</td>
<td>Drop weight test is required for Nickel alloy steels for low temperature service depending on design temperature, see [3.5.3]</td>
</tr>
<tr>
<td>Non-destructive test (NDT)</td>
<td>Ultrasonic test is required for steels specified with through thickness properties, see Sec.2 [6.6]</td>
</tr>
<tr>
<td>Intercrystalline corrosion test</td>
<td>Intercrystalline corrosion test is required for stainless steels, see [4.6.1]</td>
</tr>
</tbody>
</table>
1.5 Manufacture

1.5.1 All materials delivered with VL or works (W) certificate shall be made at works approved by the Society for the type, grade and dimension of steel being supplied and for the relevant steelmaking and processing route, e.g. delivery condition. Rolling mills without own steelmaking shall use starting material supplied by works approved by the Society.

1.5.2 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.

1.5.3 The steels shall be fully killed.

1.5.4 The reduction ratio of thickness from ingot or continuously cast slab to plate shall be at least 5 to 1 unless otherwise approved by the Society.

1.5.5 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.

1.6 General for testing

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

1.6.2 Test samples shall be taken from positions as required according to Sec.2 [2.8], unless specified otherwise.

1.7 Test unit

1.7.1 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. Where plates cut from pieces are heat-treated separately, the testing shall additionally cover each heat treatment batch.

1.8 Chemical composition

1.8.1 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 [2] to [5]. When multiple heats are tapped into a common ladle, the ladle analysis shall apply and be within the specified limits.

1.8.2 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.

1.9 Tensile testing at ambient temperature

1.9.1 For plates, one tensile test specimen shall be taken from each piece. Where the piece is divided and heat treated in different batches, each piece in each heat treatment batch shall be tested. Where ingot casting is used, the material for testing shall represent the top of the ingot.
1.9.2 For sections, one tensile test specimen 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.

1.9.3 For thermo-mechanically rolled steels processed by accelerated cooling, additional testing in the simulated stress relieved condition may be required.

1.9.4 Test specimens 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 specimens shall be taken transverse or parallel to the final direction of rolling at the option of the steelmaker.

1.10 Tensile testing at elevated temperatures

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

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

1.10.3 When determination of lower yield strength or proof stress at high temperatures is required according to [2.4.4], 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.

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

1.11 Impact testing

1) At least one set (i.e. 3 specimens) of impact tests shall be made for each tensile test, see [1.9].

2) Additional requirements when the test temperature is -50°C or lower:
   — for plates one set of impact tests shall be taken for at least every 10 tonnes
   — for sections one set of impact tests shall be made for every 2 tonnes or part thereof, representing each type from the same heat and with thickness variation less than 5 mm

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

4) The average value from each set of three impact test specimens shall comply with the appropriate requirements in [2] to [5].

1.12 Drop weight testing

1.12.1 When drop weight test is required according to [3.5.3], one set of tests (2 test specimens) 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.

1.13 Testing of through thickness properties

1.13.1 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.2 [6].
1.14 Corrosion testing

1.14.1 When intercrystalline corrosion testing is required, the test shall be carried out according to ASTM A 262, Practice E, Copper - Copper Sulphate - Sulphuric Acid Test or another recognised standard.

Guidance note:
In case requirements for pitting or crevice corrosion resistance are specified, appropriate corrosion tests should be carried out in accordance with an agreed standard, e.g. ASTM G48.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

1.15 Inspections, dimensions and tolerances

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

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

1.15.2 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. The surveyor may require further non-destructive testing, e.g. magnetic particle test, in order to verify the soundness of the material in areas he suspects' that defects could be present.

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

1.15.3 For thickness measurement the procedure shall follow the requirements given in Sec.2 [2.11].

1.15.4 No minus tolerance is permitted in the thickness of plates according to [2], [3], and [4] with pressure rating.

For plates, strips and wide flats not forming part of the shell and without pressure rating, and for stainless steels according to [4] 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.

1.16 Surface condition and rectification of defects

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

1.16.2 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.

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

1.16.4 Depressions caused by grinding shall show a smooth transition to the surface.
1.17 Identification and marking

1.17.1 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,
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,
e) specimen number (where necessary)

2 Steel for boilers and pressure vessels

2.1 Steel grades

2.1.1 This section specifies the requirements for rolled steel intended for use in the construction of boilers, pressure vessels, heat exchangers and other process equipment.

2.1.2 Requirements regarding carbon and carbon-manganese steels are specified for the as rolled condition in thicknesses up to 25 mm and for the normalized, normalized rolled and thermo mechanically rolled condition in thicknesses up to 100 mm. Requirements are also given for alloy steels in thicknesses up to 100 mm.

Guidance note:
Several DNV GL grades fulfil requirements for grades according to EN 10028 (edition 2009) as follows:
VL 360S-1FN — correspond to — P235GH
VL 410S-1FN — correspond to — P265GH
VL 460S-1FN — correspond to — P295GH
VL 510S-1FN — correspond to — P355GH
VL 0.3MoS — correspond to — 16Mo3
VL 1Cr0.5MoS — correspond to — 13CrMo4-5
VL 2.25Cr1MoS — correspond to — 10CrMo9-10

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

2.1.3 The designations for carbon and carbon-manganese steel grades are built up as follows:
— The letters VL are followed by three figures which stand for the specified minimum tensile strength in N/mm².
— Further, there is a single digit referring to the impact test temperature:
  — the digits 0, 1 and 2 mean impact testing at +20°, 0° and – 20°C respectively.
— The suffix letters are symbolizing the heat treatment and fine grain treatment:
  — A means As rolled
  — N means normalized
  — NR means normalized Rolled
  — TM means thermo mechanically rolled
  — QT means quenched and tempered
  — F means fine grain treated.

Guidance note:
Example: VL 360−1FN means a steel grade with specified minimum tensile strength 360 N/mm² impact tested at 0°C (1), fine grain treated (F) and normalized (N).

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

The tables of requirements list the normalized (N) grades. For steels having another delivery condition, the requirements given for delivery condition N apply.

2.2 Chemical composition

2.2.1 The chemical composition shall satisfy the requirements specified in Table 3 for carbon and carbon-manganese steels and in Table 4 for alloy steels.

2.2.2 The content of all elements given in the specification including grain refining elements shall be determined and entered on the certificate. The content shall be in accordance with the composition qualified through manufacturer approval. The content of residual elements shall be checked by random tests as agreed upon with the surveyor.

2.2.3 Where Al is replaced by other grain refining elements and unless otherwise approved, the contents of such elements shall be:
   — Nb, minimum 0.02%, maximum 0.05%
   — V, minimum 0.05%, maximum 0.10%.

See also [2.2.2].

2.2.4 For carbon and carbon-manganese steels, the carbon equivalent shall be calculated as per Ch.1 Sec.2 [3.2].

2.3 Heat treatment

2.3.1 The materials shall be supplied in the heat treatment conditions stated in Table 10, except for applications where as rolled condition is explicitly permitted, and 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 and in compliance with the Society Rules. In such cases heat treatment and subsequent mechanical testing shall be carried out after forming, and the results shall fulfil the requirements for the appropriate heat treatment condition. Nevertheless, the starting material in the as rolled condition shall be subjected to testing in accordance with the certification requirements, e.g. at the steel mill, before forming, and the results shall fulfil the requirements for as rolled condition. Further information about hot and cold forming is given in subsection [5] for pressed parts.

2.4 Mechanical properties

2.4.1 Sampling: General requirements for sampling are given in [1.6] to [1.13].

For sheets made from hot rolled wide strip coils, at least one specimen shall be sampled from the outer end of each coil.

2.4.2 Acceptance criteria: The mechanical properties of the material shall comply with the requirements specified in the following tables:
   — Table 5
     — carbon and carbon-manganese steels, as rolled
   — Table 6
     — carbon and carbon-manganese steels, normalized, normalized rolled or thermo mechanically rolled
   — Table 7
— alloy steels.
The values for tensile strength, yield strength and elongation specified in the tables refer to testing at room temperature.

2.4.3 Formability of fire tubes: Plates to be manufactured into fire tubes shall exhibit adequate formability, i.e. elongation A ≥ 20% at 20°C.

2.4.4 Tensile properties at elevated temperature: Values for lower yield strength or 0.2% proof stress at elevated temperatures are given in Table 8. 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 strength or 0.2% proof stress at high temperatures is higher than stated in Table 8, these higher values will be accepted, provided that tensile tests at high temperatures, in compliance with [1.10], 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.

2.4.5 Stress to rupture: Estimated average values for stress to rupture in 10 000, 100 000 and 200 000 hours are given in Table 9 for design purposes.

**Table 3 Carbon and carbon-manganese steels for boilers and pressure vessels. Chemical composition**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>VL 360-0A, -0N</td>
<td>0.17</td>
<td>≤0.35</td>
<td>0.40 to 1.00</td>
<td>0.035</td>
<td>0.30</td>
<td>≥ 0.015</td>
<td>0.009 5)</td>
<td></td>
</tr>
<tr>
<td>VL 360-1FN</td>
<td>0.17</td>
<td>≤0.35</td>
<td>0.40 to 1.00</td>
<td>0.035</td>
<td>0.30</td>
<td>0.020 to 0.085 6)</td>
<td>0.012</td>
<td></td>
</tr>
<tr>
<td>VL 360S-1FN</td>
<td>0.16</td>
<td>≤0.35</td>
<td>0.60 to 1.20</td>
<td>0.025</td>
<td>0.010</td>
<td>&gt; 0.020</td>
<td>0.012 7)</td>
<td></td>
</tr>
<tr>
<td>VL 410-0A, -0N</td>
<td>0.20</td>
<td>≤0.35</td>
<td>0.50 to 1.30</td>
<td>0.035</td>
<td>0.30</td>
<td>≥ 0.015</td>
<td>0.009 5)</td>
<td></td>
</tr>
<tr>
<td>VL 410-1FN</td>
<td>0.20</td>
<td>≤0.35</td>
<td>0.50 to 1.30</td>
<td>0.035</td>
<td>0.30</td>
<td>0.020 to 0.085 6)</td>
<td>0.012</td>
<td></td>
</tr>
<tr>
<td>VL 410S-1FN</td>
<td>0.20</td>
<td>≤0.40</td>
<td>0.80 to 1.40</td>
<td>0.025</td>
<td>0.010</td>
<td>≥ 0.020</td>
<td>0.012 7)</td>
<td></td>
</tr>
<tr>
<td>VL 460-0A, -0N</td>
<td>0.20</td>
<td>≤0.40</td>
<td>0.60 to 1.40</td>
<td>0.035</td>
<td>0.30</td>
<td>≥ 0.015</td>
<td>0.009 5)</td>
<td></td>
</tr>
<tr>
<td>VL 460-1FN</td>
<td>0.20 9)</td>
<td>≤0.40</td>
<td>0.60 to 1.40</td>
<td>0.035</td>
<td>0.30</td>
<td>0.020 to 0.085 6)</td>
<td>0.012</td>
<td></td>
</tr>
<tr>
<td>VL 460S-1FN</td>
<td>0.08 to 0.20</td>
<td>≤0.40</td>
<td>0.90 to 1.50</td>
<td>0.025</td>
<td>0.010</td>
<td>≥ 0.020</td>
<td>0.012 7)</td>
<td></td>
</tr>
<tr>
<td>VL 490-0N</td>
<td>0.20 9)</td>
<td>0.10 to 0.50</td>
<td>0.90 to 1.60</td>
<td>0.035</td>
<td>0.30</td>
<td>≥ 0.015</td>
<td>0.009 1)</td>
<td></td>
</tr>
<tr>
<td>VL 490-1FN</td>
<td>0.20 9)</td>
<td>0.10 to 0.50</td>
<td>0.90 to 1.60</td>
<td>0.035</td>
<td>0.30</td>
<td>0.020 to 0.085 5)</td>
<td>0.012</td>
<td></td>
</tr>
<tr>
<td>VL 510-1FN</td>
<td>0.22</td>
<td>0.10 to 0.60</td>
<td>1.00 to 1.60</td>
<td>0.035</td>
<td>0.30</td>
<td>0.020 to 0.085 5)</td>
<td>0.012</td>
<td></td>
</tr>
<tr>
<td>VL 510S-1FN</td>
<td>0.10 to 0.22</td>
<td>≤0.60</td>
<td>1.10 to 1.70</td>
<td>0.025</td>
<td>0.010</td>
<td>≥ 0.020</td>
<td>0.012 7)</td>
<td></td>
</tr>
</tbody>
</table>
1) all grades shall be killed
2) limits for residual elements (%):
   - Cr ≤ 0.30
   - Cu ≤ 0.30
   - Ni ≤ 0.30
   - Mo ≤ 0.08
   - Total ≤ 0.70
3) total content. The requirement for acid soluble content is 0.005% lower than total content
4) for thicknesses exceeding 40 mm, Mn = 0.40 to 1.20%
5) for electric furnace steel, maximum 0.012%
6) aluminium may be replaced by other grain refining elements
7) a ratio of Al/N > 2 shall apply
8) if high temperature properties of Table 8 are specified, Mn content shall be 0.80 to 1.40%
9) for thickness 30 < t ≤ 100 mm, C ≤ 0.22%

Table 4 Alloy steels for boilers and pressure vessels. Chemical composition

<table>
<thead>
<tr>
<th>Grade</th>
<th>Chemical composition 1), (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VL 0.3Mo</td>
<td>0.12 to 0.20</td>
</tr>
<tr>
<td>VL 0.3MoS</td>
<td>0.12 to 0.20</td>
</tr>
<tr>
<td>VL 1Cr0.5Mo</td>
<td>0.10 to 0.18</td>
</tr>
<tr>
<td>VL 1Cr0.5MoS</td>
<td>0.08 to 0.18</td>
</tr>
<tr>
<td>VL 2.25Cr1Mo</td>
<td>0.08 to 0.18</td>
</tr>
<tr>
<td>VL 2.25Cr1MoS</td>
<td>0.08 to 0.14</td>
</tr>
</tbody>
</table>

1) all grades shall be killed
2) the Al content of the cast shall be determined and given in the inspection document
3) if resistance to pressurized hydrogen is of importance, a minimum content of 0.80% Cr may be agreed upon at the time of enquiry and order
Table 5 Carbon and carbon-manganese steels for boilers and pressure vessels, as rolled condition. Mechanical properties

<table>
<thead>
<tr>
<th>Grade</th>
<th>Tensile strength ( R_m ) (N/mm(^2))</th>
<th>Yield strength, ( R_{el} ) or ( R_{p0.2} ) (N/mm(^2)) minimum for thickness, (mm)</th>
<th>Elongation ( A5 ) (%) minimum</th>
<th>KV, average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>( t &lt; 16 ) ( 16 \leq t \leq 25 )</td>
<td></td>
<td>Test temperature (°C)</td>
</tr>
<tr>
<td>VL 360-0A</td>
<td>360 to 480</td>
<td>205</td>
<td>195</td>
<td>26</td>
</tr>
<tr>
<td>VL 410-0A</td>
<td>410 to 530</td>
<td>235</td>
<td>225</td>
<td>24</td>
</tr>
<tr>
<td>VL 460-0A</td>
<td>460 to 580</td>
<td>285</td>
<td>255</td>
<td>22</td>
</tr>
</tbody>
</table>

Table 6 Carbon and carbon-manganese steels for boilers and pressure vessels, normalized or normalized rolled condition. Mechanical properties

<table>
<thead>
<tr>
<th>Grade</th>
<th>Tensile strength ( R_m ) (N/mm(^2))</th>
<th>Yield strength, ( R_{el} ) or ( R_{p0.2} ) (N/mm(^2)) minimum for thickness, (mm)</th>
<th>Elongation ( A5 ) (%) minimum</th>
<th>KV, average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>( t \leq 16 ) ( 16 &lt; t \leq 40 ) ( 40 &lt; t \leq 63 ) ( 63 &lt; t \leq 100 )</td>
<td></td>
<td>Test temperature (°C)</td>
</tr>
<tr>
<td>VL 360-0N</td>
<td>360 to 480</td>
<td>205</td>
<td>195</td>
<td>185</td>
</tr>
<tr>
<td>VL 360-1FN</td>
<td>360 to 480</td>
<td>235</td>
<td>215</td>
<td>195 (^2)</td>
</tr>
<tr>
<td>VL 360S-1FN</td>
<td>360 to 480</td>
<td>235</td>
<td>225</td>
<td>215 (^4)</td>
</tr>
<tr>
<td>VL 410-0N</td>
<td>410 to 530</td>
<td>235</td>
<td>225</td>
<td>215</td>
</tr>
<tr>
<td>VL 410-1FN</td>
<td>410 to 530</td>
<td>265</td>
<td>245</td>
<td>235</td>
</tr>
<tr>
<td>VL 410S-1FN</td>
<td>410 to 530</td>
<td>265</td>
<td>255</td>
<td>245 (^4)</td>
</tr>
<tr>
<td>VL 460-0N</td>
<td>460 to 580</td>
<td>285</td>
<td>255</td>
<td>245</td>
</tr>
<tr>
<td>VL 460-1FN</td>
<td>460 to 580</td>
<td>295</td>
<td>285</td>
<td>275</td>
</tr>
<tr>
<td>VL 460S-1FN</td>
<td>460 to 580</td>
<td>295</td>
<td>290</td>
<td>285 (^4)</td>
</tr>
<tr>
<td>VL 490-0N</td>
<td>490 to 610</td>
<td>305</td>
<td>275</td>
<td>265</td>
</tr>
<tr>
<td>VL 490-1FN</td>
<td>490 to 610</td>
<td>315</td>
<td>315</td>
<td>305</td>
</tr>
<tr>
<td>VL 510-1FN</td>
<td>510 to 650 (^3)</td>
<td>355</td>
<td>345</td>
<td>335</td>
</tr>
<tr>
<td>VL 510S-1FN</td>
<td>510 to 650</td>
<td>355</td>
<td>345</td>
<td>335 (^4)</td>
</tr>
</tbody>
</table>


Metallic materials
1) for thicknesses 40 < t ≤ 63 mm, the minimum value is 1 unit lower and for thicknesses 63 < t ≤ 100 mm, 2 units lower
2) for thicknesses in the range 63 < t ≤ 100 mm, the value specified for the thickness range 40 < t ≤ 63 mm is to be lowered by 1% for each 5 mm of thickness over 63 mm
3) for thicknesses 63 < t ≤ 100 mm: $R_m = 490$ to 630 N/mm$^2$
4) for thickness 40 < t ≤ 60 mm
5) for thickness 60 < t ≤ 100 mm

Table 7 Alloy steels for boilers and pressure vessels. Mechanical properties

<table>
<thead>
<tr>
<th>Grade</th>
<th>Tensile strength $R_m$ (N/mm$^2$)</th>
<th>Yield strength $R_{el}$ or $R_{p0.2}$ (N/mm$^2$) minimum for thickness, (mm)</th>
<th>Elongation A5 (%) min.</th>
<th>KV, average</th>
</tr>
</thead>
<tbody>
<tr>
<td>VL 0.3Mo</td>
<td>440 to 590</td>
<td>$\begin{array}{c</td>
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<td>c</td>
</tr>
<tr>
<td>VL 0.3MoS</td>
<td>440 to 590</td>
<td>$\begin{array}{c</td>
<td>c</td>
<td>c</td>
</tr>
<tr>
<td>VL 1Cr0.5Mo</td>
<td>470 to 620</td>
<td>$\begin{array}{c</td>
<td>c</td>
<td>c</td>
</tr>
<tr>
<td>VL 1Cr0.5MoS</td>
<td>450 to 600</td>
<td>$\begin{array}{c</td>
<td>c</td>
<td>c</td>
</tr>
<tr>
<td>VL 2.25Cr1Mo</td>
<td>480 to 630</td>
<td>$\begin{array}{c</td>
<td>c</td>
<td>c</td>
</tr>
<tr>
<td>VL 2.25Cr1MoS</td>
<td>480 to 630</td>
<td>$\begin{array}{c</td>
<td>c</td>
<td>c</td>
</tr>
</tbody>
</table>

1) for thicknesses 40 < t ≤ 63 mm, the minimum value is 1 unit lower and for thicknesses 63 < t ≤ 100 mm, 2 units lower
2) for thicknesses in the range 63 < t ≤ 100 mm, the value specified for the thickness range 40 < t ≤ 63 mm is to be lowered by 1% for each 5 mm of thickness over 63 mm
3) for thicknesses 63 < t ≤ 100 mm: $R_m = 490$ to 630 N/mm$^2$
4) for thickness 40 < t ≤ 60 mm
5) for thickness 60 < t ≤ 100 mm

Table 8 Steels for boiler and pressure vessels. Minimum lower yield stress ($R_{el}$) or 0.2% proof stress ($R_{p0.2}$) values at high temperature for design purposes

<table>
<thead>
<tr>
<th>Grade</th>
<th>Thickness (mm)</th>
<th>Minimum $R_{el}$ or $R_{p0.2}$ (N/mm$^2$)</th>
<th>Temperature, (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>100</td>
<td>150</td>
</tr>
<tr>
<td>C- and C/ Mn-steels, normalized</td>
<td>t ≤ 16</td>
<td>175</td>
<td>172</td>
</tr>
<tr>
<td></td>
<td>16 &lt; t ≤ 40</td>
<td>171</td>
<td>169</td>
</tr>
<tr>
<td></td>
<td>40 &lt; t ≤ 63</td>
<td>162</td>
<td>158</td>
</tr>
<tr>
<td>VL 360-0N</td>
<td>t ≤ 16</td>
<td>204</td>
<td>185</td>
</tr>
<tr>
<td>VL 360-1FN</td>
<td>t ≤ 16</td>
<td>175</td>
<td>172</td>
</tr>
</tbody>
</table>

1) for thicknesses 40 < t ≤ 63 mm, the minimum value is 1 unit lower and for thicknesses 63 < t ≤ 100 mm, 2 units lower
2) for thicknesses in the range 63 < t ≤ 100 mm, the value specified for the thickness range 40 < t ≤ 63 mm is to be lowered by 1% for each 5 mm of thickness over 63 mm
3) for thicknesses 63 < t ≤ 100 mm: $R_m = 490$ to 630 N/mm$^2$
4) for thickness 40 < t ≤ 60 mm
5) for thickness 60 < t ≤ 100 mm
<table>
<thead>
<tr>
<th>Part 2 Chapter 2 Section 3</th>
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<tbody>
<tr>
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<tr>
<td>16 &lt; t ≤ 40</td>
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<tr>
<td>40 &lt; t ≤ 63</td>
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<tr>
<td>VL 360S-1FN</td>
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<td></td>
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<tr>
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<td>VL 510-1FN</td>
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<tr>
<td>VL 510S-1FN</td>
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<td></td>
</tr>
</tbody>
</table>

Metallic materials

DNV GL AS
<table>
<thead>
<tr>
<th>C- and C/ Mn-steels as rolled</th>
<th>VL 360-0A</th>
<th>VL 410-0A</th>
<th>VL 460-0A</th>
<th>VL 0.3Mo</th>
<th>VL 0.3MoS</th>
<th>VL 1Cr0.5Mo</th>
<th>VL 1Cr0.5MoS</th>
<th>VL 2.25Cr1Mo</th>
<th>VL 2.25Cr1MoS</th>
</tr>
</thead>
<tbody>
<tr>
<td>t ≤ 25</td>
<td>150</td>
<td>180</td>
<td>210</td>
<td>237</td>
<td>264</td>
<td>285</td>
<td>249</td>
<td>266</td>
<td>257</td>
</tr>
<tr>
<td>16 &lt; t ≤ 40</td>
<td>150</td>
<td>170</td>
<td>200</td>
<td>232</td>
<td>245</td>
<td>260</td>
<td>242</td>
<td>254</td>
<td>246</td>
</tr>
<tr>
<td>40 &lt; t ≤ 60</td>
<td>150</td>
<td>150</td>
<td>180</td>
<td>218</td>
<td>226</td>
<td>243</td>
<td>227</td>
<td>248</td>
<td>240</td>
</tr>
<tr>
<td>60 &lt; t ≤ 100</td>
<td>150</td>
<td>150</td>
<td>180</td>
<td>200</td>
<td>203</td>
<td>216</td>
<td>210</td>
<td>224</td>
<td>222</td>
</tr>
</tbody>
</table>

1) unless values for thickness range 63 < t ≤ 100 mm are specified, the values specified for thickness range 40 < t ≤ 63 mm are lowered by 1% for each 5 mm of thickness over 63 mm

Table 9: Estimated average stress to rupture values in 10 000, 100 000 and 200 000 hours for design purposes

<table>
<thead>
<tr>
<th>Test temperature (°C)</th>
<th>100k hours</th>
<th>200k hours</th>
<th>100k hours</th>
<th>200k hours</th>
<th>100k hours</th>
<th>200k hours</th>
<th>100k hours</th>
<th>200k hours</th>
<th>100k hours</th>
<th>200k hours</th>
<th>100k hours</th>
<th>200k hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>380</td>
<td>165</td>
<td>145</td>
<td>227</td>
<td>206</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>390</td>
<td>148</td>
<td>129</td>
<td>203</td>
<td>181</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>400</td>
<td>132</td>
<td>115</td>
<td>179</td>
<td>157</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>410</td>
<td>118</td>
<td>101</td>
<td>157</td>
<td>135</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Table 10 Heat treatment of steel for boilers and pressure vessels

<table>
<thead>
<tr>
<th>Grade</th>
<th>Heat treatment or condition of supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>VL 360-0A</td>
<td>As rolled&lt;sup&gt;1)&lt;/sup&gt;</td>
</tr>
<tr>
<td>VL 410-0A</td>
<td></td>
</tr>
<tr>
<td>VL 460-0A</td>
<td></td>
</tr>
<tr>
<td>VL 360-0N, -1FN</td>
<td>Normalized / normalized rolled / thermo-mechanically rolled</td>
</tr>
<tr>
<td>VL 410-0N, -1FN</td>
<td></td>
</tr>
<tr>
<td>VL 460-0N, -1FN</td>
<td></td>
</tr>
<tr>
<td>VL 490-0N, -1FN</td>
<td></td>
</tr>
<tr>
<td>VL 510-1FN</td>
<td></td>
</tr>
<tr>
<td>VL P360-1FN or 360S-1FN</td>
<td>Normalized / normalized and tempered</td>
</tr>
<tr>
<td>VL P410-1FN or 410S-1FN</td>
<td></td>
</tr>
<tr>
<td>VL P490-1FN or 490S-1FN</td>
<td></td>
</tr>
<tr>
<td>VL P510-1FN or 510S-1FN</td>
<td></td>
</tr>
<tr>
<td>VL 0.3Mo</td>
<td>Normalized</td>
</tr>
<tr>
<td>VL 0.3MoS</td>
<td>Normalised / normalised and tempered</td>
</tr>
</tbody>
</table>
### 3 Steel for low temperature service

#### 3.1 Scope

3.1.1 This section specifies the requirements for rolled steel intended for use at low temperatures, e.g. for the fabrication of cargo tanks and process pressure vessels for carrying liquefied gases.

#### 3.2 Steel grades

3.2.1 Steel grades covered by this section: Requirements are specified for the following steels with specified low temperature properties, for thickness up to 40 mm:
- fine grained carbon-manganese structural steels,
- Nickel alloy steels.

3.2.2 Other steel grades: For acceptance and approval of steel grades based on other standards, see Ch.1 Sec.1 [3.4].

**Guidance note:**
As an example, steel grades based on EN 10028-3/4/5/6 needs additional requirements to chemical composition and impact toughness in order to comply with the requirements for liquefied gas carriers in Pt.5 Ch.7 Sec.6.

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

3.2.3 High strength carbon manganese steels: Carbon manganese steels with specified minimum yield strength SMYS > 335 MPa complying with a recognized standard, e.g. EN 10028, may be considered for acceptance and approval. Note that for steels for liquefied gas carriers, a SMYS ≤ 410 MPa is required unless otherwise approved.

3.2.4 Austenitic stainless steels: Requirements for austenitic stainless steels applied for low temperature service are given in [4].

3.2.5 Steels for liquefied gas carriers: In addition to the requirements given in this section, steels for liquefied gas carriers shall satisfy the requirements given in Pt.5 Ch.7 Sec.6 (e.g. with respect to delivery condition, deoxidation practice, fine grain treatment, testing extent, specified minimum yield strength and impact toughness, chemical composition, etc.)

3.2.6 Minimum design temperatures: The minimum design temperatures for the specified grades are given in Table 13 and Table 14.

<table>
<thead>
<tr>
<th>Steel Grade</th>
<th>Heat Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>VL 1Cr0.5Mo</td>
<td>Normalized and tempered</td>
</tr>
<tr>
<td>VL 2.25Cr1Mo</td>
<td>Normalised and tempered 2) / quenched and tempered 3)</td>
</tr>
<tr>
<td>VL 2.25Cr1MoS</td>
<td>Normalised and tempered</td>
</tr>
</tbody>
</table>

1) see [2.3.1]; as rolled condition permitted for starting material only, or where explicitly permitted by the rules for specific applications
2) applicable for thickness t ≤ 100 mm
3) applicable for thickness 60 mm < t ≤ 100 mm
### 3.3 Chemical composition

#### 3.3.1 The chemical composition shall satisfy the requirements specified in Table 11 for carbon manganese steels and in Table 12 for nickel alloy steels.

For materials complying with recognized standards, see [3.2.2], the chemical composition shall satisfy the requirements of the relevant standard and grade.

#### 3.3.2 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.

#### 3.3.3 The steels shall be aluminium and fine grain treated.

#### 3.3.4 For carbon and carbon-manganese steels, the carbon equivalent \( C_{eq} \) shall be calculated from the ladle analysis using the formula given in Ch.1 Sec.2 [3.2], when applicable.

For evaluation of the weldability of high-strength steels see [3.2.3], sensitivity to cold-cracking \( P_{cm} \) shall be determined as per Ch.1 Sec.2 [3.2].

#### Table 11 Carbon-manganese steels for low temperature service. Chemical composition

<table>
<thead>
<tr>
<th>Grade</th>
<th>Chemical composition,%</th>
<th>( C ) maximum</th>
<th>( Si )</th>
<th>( Mn )</th>
<th>( S ) maximum</th>
<th>( P ) maximum</th>
<th>( Al ) total</th>
<th>( N ) maximum</th>
<th>Requirements for other elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>VL 360-2FN</td>
<td></td>
<td>0.16</td>
<td>0.10 to 0.35</td>
<td>0.40 to 1.00</td>
<td>0.025</td>
<td>0.025</td>
<td>≥ 0.020</td>
<td>0.015</td>
<td></td>
</tr>
<tr>
<td>VL 2-2</td>
<td></td>
<td>0.16</td>
<td>0.10 to 0.40</td>
<td>0.40 to 1.60</td>
<td>0.025</td>
<td>0.025</td>
<td>≥ 0.020</td>
<td>0.015</td>
<td></td>
</tr>
<tr>
<td>VL 2-3</td>
<td></td>
<td>0.14</td>
<td>0.10 to 0.40</td>
<td>0.70 to 1.60</td>
<td>0.025</td>
<td>0.025</td>
<td>≥ 0.020</td>
<td>0.015</td>
<td></td>
</tr>
<tr>
<td>VL 2-4</td>
<td></td>
<td>0.14</td>
<td>0.10 to 0.40</td>
<td>0.70 to 1.60</td>
<td>0.025</td>
<td>0.025</td>
<td>≥ 0.020</td>
<td>0.015</td>
<td></td>
</tr>
<tr>
<td>VL 2-4L</td>
<td></td>
<td>0.14</td>
<td>0.10 to 0.40</td>
<td>0.70 to 1.60</td>
<td>0.025</td>
<td>0.025</td>
<td>≥ 0.020</td>
<td>0.015</td>
<td>Cr ≤ 0.25, Cu ≤ 0.35, Ni ≤ 0.40</td>
</tr>
<tr>
<td>VL 4-2</td>
<td></td>
<td>0.16</td>
<td>0.10 to 0.40</td>
<td>0.70 to 1.60</td>
<td>0.025</td>
<td>0.025</td>
<td>≥ 0.020</td>
<td>0.015</td>
<td>Mo ≤ 0.08, Cr+Mo+Cu ≤ 0.45</td>
</tr>
<tr>
<td>VL 4-3</td>
<td></td>
<td>0.16</td>
<td>0.10 to 0.40</td>
<td>0.70 to 1.60</td>
<td>0.025</td>
<td>0.025</td>
<td>≥ 0.020</td>
<td>0.015</td>
<td>Nb ≤ 0.05, V ≤ 0.1</td>
</tr>
<tr>
<td>VL 4-4</td>
<td></td>
<td>0.16</td>
<td>0.10 to 0.40</td>
<td>0.70 to 1.60</td>
<td>0.025</td>
<td>0.025</td>
<td>≥ 0.020</td>
<td>0.015</td>
<td></td>
</tr>
<tr>
<td>VL 4-4L</td>
<td></td>
<td>0.16</td>
<td>0.10 to 0.40</td>
<td>0.70 to 1.60</td>
<td>0.025</td>
<td>0.025</td>
<td>≥ 0.020</td>
<td>0.015</td>
<td></td>
</tr>
</tbody>
</table>
1) by special agreement with the Society, the carbon content may be increased to 0.18% maximum, provided the design temperature is not lower than -40°C
2) acid soluble 0.015% minimum
3) for thicknesses exceeding 40 mm, Mn = 0.40 to 1.20%
4) for the steel grades VL 2-3, VL 2-4, VL 2-4L, VL 4-3, VL 4-4 and VL 4-4L a Ni-content up to 0.80% may be approved

### Table 12 Nickel alloy steels for low temperature service. Chemical composition

<table>
<thead>
<tr>
<th>Grade</th>
<th>C maximum (%)</th>
<th>Si (%)</th>
<th>Mn maximum (%)</th>
<th>S maximum (%)</th>
<th>P maximum (%)</th>
<th>Ni (%)</th>
<th>Al tot (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VL 0.5Ni/a 1)</td>
<td>0.14</td>
<td>0.10-0.50</td>
<td>0.70-1.50</td>
<td>0.010</td>
<td>0.025</td>
<td>0.15 2)</td>
<td>0.80</td>
</tr>
<tr>
<td>VL 0.5Ni/b 1)</td>
<td>0.16</td>
<td>0.10-0.50</td>
<td>0.85-1.70</td>
<td>0.010</td>
<td>0.025</td>
<td>0.15 2)</td>
<td>0.85</td>
</tr>
<tr>
<td>VL 1.5Ni</td>
<td>0.14</td>
<td>0.10 to 0.35</td>
<td>0.30 to 1.50</td>
<td>0.025</td>
<td>0.025</td>
<td>1.30</td>
<td>1.70</td>
</tr>
<tr>
<td>VL 2.25Ni</td>
<td>0.13</td>
<td>0.10 to 0.35</td>
<td>0.30 to 1.50</td>
<td>0.025</td>
<td>0.025</td>
<td>2.00</td>
<td>2.50</td>
</tr>
<tr>
<td>VL 3.5Ni</td>
<td>0.12</td>
<td>0.10 to 0.35</td>
<td>0.30 to 0.70</td>
<td>0.025</td>
<td>0.025</td>
<td>3.25</td>
<td>3.75</td>
</tr>
<tr>
<td>VL 5Ni</td>
<td>0.12</td>
<td>0.10 to 0.35</td>
<td>0.30 to 0.80</td>
<td>0.025</td>
<td>0.025</td>
<td>4.70</td>
<td>5.30</td>
</tr>
<tr>
<td>VL 9Ni</td>
<td>0.10</td>
<td>0.10 to 0.35</td>
<td>0.30 to 0.90</td>
<td>0.025</td>
<td>0.025</td>
<td>8.50</td>
<td>10.0</td>
</tr>
</tbody>
</table>

1) further compositional requirements:
   - Cr ≤ 0.25%
   - Mo ≤ 0.08%
   - Cu ≤ 0.35%
   - Nb ≤ 0.05%
   - V ≤ 0.05%
   - Cr+Cu+Mo ≤ 0.50%
2) for thicknesses ≥ 40 mm; Ni ≥ 0.30%

### 3.4 Condition of supply

#### 3.4.1 The steels shall be supplied in the heat treatment conditions stated in Table 13.

#### 3.4.2 Quenched and tempered, normalized rolled and thermo-mechanically treated steel grades shall be given the suffix QT, NR, and TM respectively.

#### 3.4.3 Steels with delivery condition TM shall not be used where hot forming or normalizing will be carried out.

**Guidance note:**
Hot forming or normalising of thermo-mechanically treated steels may result in considerable reduction of tensile strength and yield strength.

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

#### 3.4.4 For materials complying with recognized standards, see [3.2.2], the condition of supply shall satisfy the requirements of the relevant standard and grade, unless otherwise approved.
### Table 13 Heat treatment of steels for low temperature service

<table>
<thead>
<tr>
<th>Grade</th>
<th>Heat treatment/condition of supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>VL 360-2FN</td>
<td>Plates: normalized 1)</td>
</tr>
<tr>
<td>VL 2-2</td>
<td>Sections: normalized, thermo-mechanically treated or normalized rolled 2)</td>
</tr>
<tr>
<td>VL 2-3</td>
<td></td>
</tr>
<tr>
<td>VL 2-4</td>
<td></td>
</tr>
<tr>
<td>VL 2-4L</td>
<td></td>
</tr>
<tr>
<td>VL 4-2</td>
<td></td>
</tr>
<tr>
<td>VL 4-3</td>
<td></td>
</tr>
<tr>
<td>VL 4-4</td>
<td></td>
</tr>
<tr>
<td>VL 4-4L</td>
<td></td>
</tr>
<tr>
<td>VL 0.5Ni/a</td>
<td>Normalized, normalized and tempered or quenched and tempered.</td>
</tr>
<tr>
<td>VL 0.5Ni/b</td>
<td>Thermo-mechanically treated or other heat treatments upon special approval</td>
</tr>
<tr>
<td>VL 1.5Ni</td>
<td></td>
</tr>
<tr>
<td>VL 2.25Ni</td>
<td></td>
</tr>
<tr>
<td>VL 3.5Ni</td>
<td></td>
</tr>
<tr>
<td>VL 5Ni</td>
<td></td>
</tr>
<tr>
<td>VL 9Ni</td>
<td>Double normalized and tempered or quenched and tempered 3)</td>
</tr>
</tbody>
</table>

1) other heat treating processes, e.g. quenching and tempering or thermo-mechanical controlled processing may be approved. See [3.4.3]
2) see [3.4.3]
3) quenching and tempering will normally be required for thicknesses above 30 mm

### 3.5 Mechanical properties

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

- Table 14 — carbon-manganese steels
- Table 15 — nickel alloy steels.

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

For materials complying with recognized standards, see [3.2.2], the mechanical properties shall satisfy the requirements of the relevant standard and grade.

#### 3.5.3 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:

- VL 2.25Ni when intended for design temperature below −65°C
- VL 3.5Ni when intended for design temperature below −80°C
- VL 5Ni 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. See also [1.12].
### Table 14 Carbon-manganese steels for low temperature service. Mechanical properties

<table>
<thead>
<tr>
<th>Grade</th>
<th>Tensile strength (N/mm²)</th>
<th>Yield strength (N/mm²) minimum for thickness, (mm)</th>
<th>Elongation A5 (%) minimum</th>
<th>Impact energy KV, average</th>
<th>Thickness (mm)</th>
<th>Test temperature (°C)</th>
<th>Min design temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>≤ 16 &lt; 16 ≤ 40</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VL 360-2FN</td>
<td>360 to 480</td>
<td>235 215 26</td>
<td></td>
<td></td>
<td>27</td>
<td>41</td>
<td>-15°C</td>
</tr>
<tr>
<td>VL 2-2</td>
<td>400 to 490</td>
<td>265 255 24</td>
<td></td>
<td></td>
<td>27</td>
<td>41</td>
<td>-15°C</td>
</tr>
<tr>
<td>VL 2-3</td>
<td>400 to 490</td>
<td>265 255 24</td>
<td></td>
<td></td>
<td>27</td>
<td>41</td>
<td>-35°C</td>
</tr>
<tr>
<td>VL 2-4</td>
<td>400 to 490</td>
<td>265 255 24</td>
<td></td>
<td></td>
<td>27</td>
<td>41</td>
<td>-50°C</td>
</tr>
<tr>
<td>VL 2-4L</td>
<td>400 to 490</td>
<td>265 255 24</td>
<td></td>
<td></td>
<td>27</td>
<td>41</td>
<td>-55°C</td>
</tr>
<tr>
<td>VL 4-2</td>
<td>490 to 610</td>
<td>335 325 21</td>
<td></td>
<td></td>
<td>27</td>
<td>41</td>
<td>-15°C</td>
</tr>
<tr>
<td>VL 4-3</td>
<td>490 to 610</td>
<td>335 325 21</td>
<td></td>
<td></td>
<td>27</td>
<td>41</td>
<td>-35°C</td>
</tr>
</tbody>
</table>
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 \( t \leq 40 \) mm be tested at a temperature \( 5^\circ C \) below the minimum design temperature
4) materials for liquefied gas carriers see Pt.5 Ch.7 Sec.6
5) for thickness \( 25 < t \leq 40 \) mm the impact test temperature shall be stamped on the products and stated in the certificate

**Table 15 Nickel alloy steels for low temperature service. Mechanical properties**

<table>
<thead>
<tr>
<th>Grade</th>
<th>Tensile strength (N/mm²)</th>
<th>Yield strength (N/mm²) min. for thickness, (mm)</th>
<th>Elongation A5 (%)</th>
<th>Impact energy KV, average 2)</th>
<th>Transverse (J) min.</th>
<th>Min design temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>t ≤ 30</td>
<td>30 &lt; t ≤ 40</td>
<td></td>
<td></td>
<td>27</td>
<td>41</td>
</tr>
<tr>
<td>VL 0.5Ni/a</td>
<td>420 to 530</td>
<td>285</td>
<td>275</td>
<td>24</td>
<td>t ≤ 25</td>
<td>25 &lt; t ≤ 30</td>
</tr>
<tr>
<td>VL 0.5Ni/b</td>
<td>490 to 610</td>
<td>355</td>
<td>345</td>
<td>22</td>
<td>t ≤ 25</td>
<td>25 &lt; t ≤ 30</td>
</tr>
<tr>
<td>VL 1.5Ni/a</td>
<td>470 to 640</td>
<td>275</td>
<td>265</td>
<td>22</td>
<td>t ≤ 25</td>
<td>25 &lt; t ≤ 30</td>
</tr>
<tr>
<td>VL 1.5Ni/b</td>
<td>490 to 640</td>
<td>355</td>
<td>345</td>
<td>22</td>
<td>t ≤ 25</td>
<td>25 &lt; t ≤ 30</td>
</tr>
</tbody>
</table>
### 4 Stainless steel

#### 4.2 Steel grades

**4.2.1** Requirements are specified for seven grades of austenitic and two grades of duplex (ferritic/austenitic) stainless steels, for thickness up to 150 mm.

### 3.6 Non-destructive testing

**3.6.1** For materials with SMYS > 335 MPa, see [3.2.3], ultrasonic testing as described in Sec.2 [6.6] is required.
4.2.2 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.

4.2.3 The austenitic steels may be used for applications where the design temperature is not lower than -165°C. Limitation to upper temperature for austenitic steels shall be assessed based on high temperature properties, also considering corrosion in the applicable environment of exposure. Austenitic-ferritic (duplex) steels may be used for applications where the design temperature is not lower than -46°C, and not higher than 100°C/110°C if exposed to saliferous atmosphere for UNS S31803/UNS S32750, respectively. Design temperatures outside these ranges are subject to approval.

4.3 Chemical composition

4.3.1 The chemical composition shall comply with the requirements given in Table 16, or the approved specification.

Table 16 Chemical composition, austenitic and duplex stainless steels

<table>
<thead>
<tr>
<th>Grade</th>
<th>C maximum</th>
<th>Si maximum</th>
<th>Mn maximum</th>
<th>P maximum</th>
<th>S maximum</th>
<th>Cr</th>
<th>Ni</th>
<th>Mo&lt;sup&gt;1)&lt;/sup&gt;</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Austenitic</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VL 304 L</td>
<td>0.03</td>
<td>1.0</td>
<td>2.0</td>
<td>0.045</td>
<td>0.030</td>
<td>18.0 to 20.0</td>
<td>8.0 to 12.0</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>VL 316 L</td>
<td>0.03</td>
<td>1.0</td>
<td>2.0</td>
<td>0.045</td>
<td>0.030</td>
<td>16.5 to 18.5</td>
<td>10.0 to 15.0</td>
<td>2.0 to 3.0</td>
<td></td>
</tr>
<tr>
<td>VL 316 L N</td>
<td>0.03</td>
<td>1.0</td>
<td>2.0</td>
<td>0.045</td>
<td>0.030</td>
<td>16.5 to 18.5</td>
<td>10.0 to 14.5</td>
<td>2.0 to 3.0</td>
<td>N.014 - 0.22</td>
</tr>
<tr>
<td>VL 317 L</td>
<td>0.03</td>
<td>1.0</td>
<td>2.0</td>
<td>0.045</td>
<td>0.030</td>
<td>18.0 to 20.0</td>
<td>11.0 to 15.0</td>
<td>3.0 to 4.0</td>
<td></td>
</tr>
<tr>
<td>VL 317 L N</td>
<td>0.03</td>
<td>1.0</td>
<td>2.0</td>
<td>0.045</td>
<td>0.030</td>
<td>18.0 to 20.0</td>
<td>12.5 to 15.0</td>
<td>3.0 to 4.0</td>
<td>N.014 - 0.22</td>
</tr>
<tr>
<td>VL 321</td>
<td>0.08</td>
<td>1.0</td>
<td>2.0</td>
<td>0.045</td>
<td>0.030</td>
<td>17.0 to 19.0</td>
<td>9.0 to 12.0</td>
<td>-</td>
<td>Ti.5xΣ&lt;sub&gt;C&lt;/sub&gt;&lt;sup&gt;≤&lt;/sup&gt;Ti=0.70</td>
</tr>
<tr>
<td>VL 347</td>
<td>0.08</td>
<td>1.0</td>
<td>2.0</td>
<td>0.045</td>
<td>0.030</td>
<td>17.0 to 19.0</td>
<td>9.0 to 13.0</td>
<td>-</td>
<td>Nb.10xΣ&lt;sub&gt;C&lt;/sub&gt;&lt;sup&gt;≤&lt;/sup&gt;Nb=1.0</td>
</tr>
<tr>
<td><strong>Duplex</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UNS S31803</td>
<td>0.03</td>
<td>1.0</td>
<td>2.0</td>
<td>0.030</td>
<td>0.020</td>
<td>21.0 to 23.0</td>
<td>4.5 to 6.5</td>
<td>2.5 to 3.5</td>
<td>N.014 - 0.20</td>
</tr>
<tr>
<td>UNS S32750</td>
<td>0.03</td>
<td>0.8</td>
<td>1.2</td>
<td>0.035</td>
<td>0.020</td>
<td>24.0 to 26.0</td>
<td>6.0 - 8.0</td>
<td>3.0 to 5.0</td>
<td>N.024 - 0.32</td>
</tr>
</tbody>
</table>

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%, see Pt.5 Ch.6 Sec.2 [2]
4.4 Condition of supply

4.4.1 All materials specified in this subsection shall be supplied in the solution heat treated condition.

4.5 Mechanical properties

4.5.1 The mechanical properties of the material shall comply with the requirements specified in Table 17. For austenitic steels both the 0.2% and the 1.0% yield strength shall be reported.

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

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

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

Table 17: Austenitic and duplex stainless steel. Mechanical properties

<table>
<thead>
<tr>
<th>Grade</th>
<th>Tensile strength $R_m$ (N/mm²)</th>
<th>Minimum Yield strength $R_{p0.2}$ and $R_{p1.0}$ (N/mm²)</th>
<th>Elongation $A_5$ (%)</th>
<th>Impact energy, Charpy V-notch $2^)$ (°C)</th>
<th>Test temperature $3^)$ (°C)</th>
<th>Minimum average (J)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$R_{p0.2}$</td>
<td>$R_{p1.0}$</td>
<td>$A_5$</td>
<td>transverse: 27</td>
<td>longitudinal: 41</td>
</tr>
<tr>
<td>Austenitic</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VL 304 L</td>
<td>450 to 700</td>
<td>175</td>
<td>215</td>
<td>40</td>
<td>- 196</td>
<td></td>
</tr>
<tr>
<td>VL 316 L</td>
<td>450 to 700</td>
<td>195</td>
<td>235</td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VL 316 L N</td>
<td>600 to 800</td>
<td>300</td>
<td>340</td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VL 317 L</td>
<td>500 to 700</td>
<td>195</td>
<td>235</td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VL 317 L N</td>
<td>600 to 800</td>
<td>300</td>
<td>340</td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VL 321</td>
<td>500 to 750</td>
<td>205</td>
<td>245</td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VL 347</td>
<td>500 to 750</td>
<td>205</td>
<td>245</td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duplex (austenitic-ferritic)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UNS S31803</td>
<td>minimum 620</td>
<td>450</td>
<td>25</td>
<td>max. -20$^3$)</td>
<td>transverse: 27</td>
<td>longitudinal: 41</td>
</tr>
<tr>
<td>UNS S32750</td>
<td>minimum 690</td>
<td>550</td>
<td>25</td>
<td>max. -20$^3$)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1) the specified yield strength 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.

3) to be tested at minimum design temperature if this is lower than -20°C.

4.6 Corrosion tests

4.6.1 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. See also [1.14].

5 Pressed parts

5.1 Scope

5.1.1 This sub-section specifies the requirements for pressed parts made by hot forming or by cold forming to be used in the construction of pressure vessels, e.g.:
— pressed heads
— shell components
— cylinders for gas bottles.
This sub-section is also applicable to the method of heat treatment where heat treatment is required after forming.
Provision is made for carbon and carbon-manganese, alloy, and austenitic steels.

5.1.2 Where required by the relevant design and construction parts of the rules, pressed parts shall comply with the requirements of Ch.1, of Sec.1 and this sub-section.
Further requirements for pressed parts are given in the relevant design and construction rules, e.g. Pt.4 Ch.7.

5.2 Manufacture

5.2.1 General: All pressed parts delivered with VL or works (W) certificate shall be made at works approved by the Society for the type, grade and thickness of pressed parts being supplied and for the relevant processing route as per [1] to [4] and Sec.4. The forming and heat treatment shall be carried out in accordance with the manufacturer’s established procedures describing each operational and controlling step.

5.2.2 Requirements applicable to the starting plates or pipes:
1) where the pressed parts are to be delivered with VL or W certificate, the starting materials applied for the pressed parts shall also be delivered with VL or works (W) certificate from an approved manufacturer
2) the grades of steel from which the starting plates or pipes are made shall be specified in the order. In selecting them, care shall be taken to ensure that they fulfil the requirements to be met by the base material concerned after forming and, where applicable, heat treatment
3) the plates or pipes may be supplied in the stipulated final heat-treated condition or in another condition which facilitates the subsequent forming. In the latter case, testing of the starting plates or pipes shall be performed using test specimens which have undergone the heat treatment intended for the finished part. The condition of supply of the plates or pipes and the method of heat treatment of the test specimens shall be indicated in the test certificate.

5.2.3 General principles for forming: Requirements for calculation of the deformation rate are given in Ch.4 Sec.6 [5.2].

5.2.4 Preheating for the hot forming operation: As far as possible, all parts shall be uniformly heated for the forming operation in their entirety.
1) when approved by the Society, local heating may be accepted. In these cases the area heated to the forming temperature shall, however, embrace the whole area of deformation
2) the temperatures, holding times and heating and cooling rates shall be determined by reference to the data contained in the standards or manufacturer's specifications, in accordance with the material and the component concerned.

3) where the testing of finished parts is allowed to be carried out on separate test samples, provision shall be made to ensure that these receive the same heat treatment as the finished part. For this purpose, the test samples shall be laid on top of the corresponding finished parts for the preheating.

4) hot forming of plates or pipes with delivery condition QT or TM requires special consideration and approval.

5.2.5 Heat treatment after hot forming of ferritic steels:

1) **General:**
   Hot forming shall normally be followed by renewed heat treatment as prescribed for the base material. However, some exceptions are given as follows.

2) **heat treatment exceptions after hot forming:**
   Provided that the full cycle of pre-heating and hot forming operation has been carried out at a temperature within the normalising temperature range, some exceptions from the required full heat treatment apply as follows:
   - for normalized steels, subsequent normalizing may be omitted.
   - for normalized, or air quenched and tempered steels, subsequent tempering may be sufficient.
   - in the case of 5% and 9% Ni steels calling for triple normalizing heat treatment, two normalizing heat treatments after hot forming may be sufficient. Proved the material was normalized before hot forming, one normalizing heat treatment after hot forming may be sufficient.

3) the manufacturer's material specification or the applicable standard shall specify the normalizing temperature range.

4) the exceptional provisions set out in [5.2.5] 2) may also be applied where localized heating and hot forming is performed, provided that, prior to forming, the plates or pipes were in a heat-treated condition appropriate to the material.

5.2.6 Heat treatment after hot forming of austenitic steels: After hot forming, parts made of austenitic steels shall be subjected to renewed heat treatment, i.e. typically solution annealing and rapid cooling. This may be waived where the hot forming operation begins in the temperature range from 1150°C to 1000°C and:
   - for stabilized steels and steels with C ≤ 0.03%; forming is ended above 750°C followed by rapid cooling to ambient temperature.
   - for non-stabilized steels with C ≤ 0.08%; forming is ended above 875°C followed by rapid cooling to ambient temperature.

   **Guidance note:**
   For hot forming of austenitic steels, guidance may be found in e.g. EN 10088 or AD 2000 Merkblatt (AD Data Sheet) HP/7.3.

5.2.7 Heat treatment after hot forming of clad steel plates: For pressed parts made of clad steel plates, the heat treatment is governed by the applied base material. However, where the cladding material requires a heat treatment different from that of the base material, the heat treatment shall be done as per manufacturer's specification and as per approved drawing where applicable. The details shall be recorded and reported by the manufacturer.

5.2.8 Heat treatment after cold forming of ferritic steels: The starting material shall be in the prescribed condition of supply before cold forming is carried out.

1) **Cold formed pressure vessel components**
Due to the possible changes in material properties caused by cold forming and ageing, the material shall be heat treated after cold forming. However, heat treatment may be waived for the applications and conditions given in Table 18. For acceptance of waived heat treatment, the material manufacturer shall be approved by the Society for the steel grade in question.

### Table 18 Conditions where heat treatment after cold forming may be waived

<table>
<thead>
<tr>
<th>Intended application</th>
<th>Steel type/grade</th>
<th>Deformation degree for which heat treatment may be waived</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure vessels operated at ambient temperatures or feedstock temperatures down to minus (-) 10°C</td>
<td>All</td>
<td>≤ 5%</td>
</tr>
<tr>
<td>Pressure vessels operated at charging media temperatures below minus (-) 10°C, as well as gas tanks with design temperatures below 0°C</td>
<td>VL 3.5Ni, VL 5Ni, VL 9Ni</td>
<td>≤ 5%</td>
</tr>
<tr>
<td></td>
<td>C and C-Mn Alloy (other than above)</td>
<td>≤ 3%</td>
</tr>
</tbody>
</table>

Where the deformation degree above is exceeded and the product will be subject to subsequent welding, a suitable heat treatment shall be performed before welding is carried out.

If the acceptable degree of cold deformation is exceeded, renewed heat treatment of the final product is required in order to restore the delivery condition specified for the material in question.

Subject to case by case approval and for special cases, stress relieving heat treatment may be accepted in lieu of full heat treatment. For such cases, the impact toughness shall be qualified for (a) the artificially aged condition and (b) for the stress relieved condition, both for the applicable maximum strain. Artificial ageing shall be carried out on the strained material at 250°C for one hour.

2) **Cold formed heads**

Cold-formed heads, including those fabricated from welded round blanks, shall be heat treated (normalized or quenched and tempered) in accordance with the relevant standards or material specifications.

3) **Cold formed dished heads**

For cold-formed dished heads made of steel grades with nominal yield strengths not exceeding 275 MPa, heat treatment is not required if all of the following conditions are fulfilled:

- the temperature of the charging media is −10 °C or above,
- the design temperature $T_D \leq 120^\circ C$ and
- the nominal wall thickness $t \leq 8$ mm.

4) **Heat treatment after cold forming of materials with delivery condition QT or TM**

For cold forming exceeding the limits given in **Table 18**, heat treatment of QT and TM steels requires special consideration and acceptance by the Society.

#### 5.2.9 Heat treatment after cold forming of austenitic steels: Solution annealing or stabilization annealing followed by quenching is required, depending on the austenitic steel grade.

**Guidance note:**

For heat treatment of austenitic steels, guidance may be found in e.g. EN 10088 or AD 2000 Merkblatt (AD Data Sheet) HP/7.3.

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

Heat treatment after cold forming of solution annealed or stabilization annealed material may be dispensed with for:
Part 2 Chapter 2 Section 3

Metallic materials

a) steels with specified minimum elongation $A_5 \geq 30\%$ for the starting material
b) materials where the specified minimum elongation $A_5 < 30\%$, and proof is furnished that:
   — the degree of cold deformation is $\leq 15\%$ and the starting material certificate shows elongation $A_5 \geq 30\%$, or
   — the residual elongation $A_5 \geq 15\%$ after cold forming
c) for cold deformation $> 15\%$, proof is furnished that the residual elongation $A_5 \geq 15\%$ after cold forming
d) in the case of dished, ellipsoidal and hemispherical heads, the following elongations are achieved for the starting material:
   — $A_5 \geq 40\%$ for nominal wall thicknesses $t \leq 15 \text{ mm}$ at design temperatures $T_D \geq -196 \, ^\circ\text{C}$
   — $A_5 \geq 45\%$ for nominal wall thicknesses $t > 15 \text{ mm}$ at design temperatures $T_D \geq -196 \, ^\circ\text{C}$
   — $A_5 \geq 50\%$ for design temperatures $T_D < -196 \, ^\circ\text{C}$.

5.2.10 Heat treatment after cold forming of clad plates: For pressed parts made of clad steel plates, the heat treatment is governed by the applied base material. Where the cladding material requires a heat treatment different from that of the base material, the heat treatment shall be done as per manufacturer's specification and as per approved drawing where applicable. The details shall be recorded and reported by the manufacturer.

5.3 Mechanical properties

5.3.1 Scope of testing is given in Table 19.
The testing of pressed parts shall comprise tensile and notched bar impact tests performed on specimens taken from the finished parts after the final forming and heat treatment. Test specimens orientation shall be transverse to the original rolling direction of the plate or pipe. A deviation up to $20^\circ$ from the required specimen orientation is accepted. Test specimen orientation for small diameter pipes or small bending radiiuses may be specially considered.

5.3.2 For hot formed pressed parts, the test samples shall be taken from surplus material at the edges of the pressed parts or from cut-outs.
For cold formed pressed parts, the following requirements apply:
   — test samples shall be taken either from the finished parts in the area with the maximum plastic deformation, or
   — from surplus material at the edges of the finished parts, which are subsequently subjected to the relevant maximum plastic deformation in the cold condition.

Where stress relief heat treatment would suffice after forming, the test samples may be removed from the product before heat treatment but shall be subjected to the same deformation rate and heat treatment. Where batch testing is applicable for pressed parts, a test batch may only comprise items made from plates or pipes originating from the same heat which have been deformed and heat treated in the same way. The wall thicknesses of items within a test batch may vary by $20\%$ from the mean wall thickness. The number of sets of specimens shall be determined as follows:
   — up to 10 items: 1 set of specimens
   — up to 25 items: 2 sets of specimens
   — over 25 items: 3 sets of specimens.

Where the material is tested after final forming and heat treatment, the requirements for mechanical testing of the starting material will be dispensed with as specified in Table 19. It is a precondition that the material manufacturer is approved by the Society.

5.3.3 Alternative sampling for cold formed parts: For cold formed products not subject to subsequent heat treatment, but complying with the requirements/exceptions of [5.2.8] to [5.2.10], the following alternative to testing of finished pressed parts may be agreed with the Society:
— testing of the starting plate or pipe with one set of test specimens per piece, see definition in Sec.1 Table 1.

For this alternative, there are two pre-conditions:

a) representative material has been qualified for the applicable deformation rate during the manufacturer approval process, i.e. with test scope as defined in the relevant approval program. For ferritic steels, testing in the strained and strain-aged condition shall always be included. For austenitic steel, testing in the strained condition shall be added.

b) manufacturer has shown to the Society and qualified, e.g. through an audit for this purpose, that he is able to consistently manufacture the pressed parts in accordance with the qualified process.

5.3.4 Acceptance criteria: The test results shall satisfy all the corresponding requirements of the plate or pipe material for its prescribed final heat treatment condition. Excerpted from this is the elongation A5 for cold formed materials where heat treatment have been waived, see [5.2.8] and [5.2.9]. The new requirements are given as follows:

— for ferritic steels, an elongation of minimum specified A5 (as required for the finally heat treated plate or pipe), minus the corresponding deformation degree value in Table 18, will be required as a new minimum

Guidance note:
Example; for VL 3.5Ni, minimum specified A5 = 22%. Value in Table 18 is 5% which gives 22-5 = 17; new requirement after cold forming A5 ≥ 17%.

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

— for austenitic steels, A5 ≥ 15% is required.

5.4 Inspection

5.4.1 The surface finish, dimensions and compliance with tolerances shall be verified by the manufacturer.

5.4.2 Magnetic particle or liquid penetrant testing of deformed areas for finished pressed parts shall be carried out according to recognized standards, see Ch.4, Pressure vessels.

Table 19 Scope of tests on pressed parts made from plate or pipe

<table>
<thead>
<tr>
<th>Type/grade of steel</th>
<th>Starting material according to:</th>
<th>Test performed on:</th>
<th>Extent of tests on pressed parts</th>
</tr>
</thead>
<tbody>
<tr>
<td>All unalloyed steels with a minimum tensile strength ≤ 410 N/mm²</td>
<td>[2] and [3]</td>
<td>Starting plate or pipe</td>
<td>Not required</td>
</tr>
<tr>
<td>Unalloyed and fine-grained structural steels with a minimum tensile strength 410 &lt; Rm ≤ 510 N/mm², and Rm ≤ 355 N/mm², and 0.3% Mo alloy steels</td>
<td>[2] and [3]</td>
<td>Starting plate or pipe Pressed part</td>
<td>Testing by batches</td>
</tr>
<tr>
<td>High-temperature CrMo alloy steels</td>
<td>[2]</td>
<td>Starting plate or pipe², 3) Pressed part ²)</td>
<td>1 set of specimens from each individual pressed part ²)</td>
</tr>
<tr>
<td>Steels for low temperature service</td>
<td>[3]</td>
<td>Starting plate or pipe², 3) Pressed part ²)</td>
<td>1 set of specimens from each individual pressed part ²)</td>
</tr>
</tbody>
</table>
### Metallic materials

<table>
<thead>
<tr>
<th>Austenitic stainless steels with thickness:</th>
<th>≤ 20 mm</th>
<th>[4]</th>
<th>Not required</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&gt; 20 mm</td>
<td></td>
<td>Starting plate or pipe</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pressed part</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Clad plates</th>
<th>Sec.4</th>
<th>The extent of testing depends on the base material</th>
</tr>
</thead>
</table>

1) for pressed parts which are designed for the manufacture of tanks carrying pressure-liquefied ammonia, see respective design rules
2) testing of starting plate or pipe may be agreed with the Society under the condition that the test material have been subjected to deformation and heat treatment corresponding to that of the final product
3) for testing of pressed parts, mechanical testing of starting plate or pipe may be dispensed with, see [5.3.2]
SECTION 4 CLAD PRODUCTS

1 General requirements

1.1 Scope

1.1.1 This section specifies the requirements for clad steel plates consisting of a base material and a thinner layer of cladding metal on one or both sides, continuously and integrally bonded. The clad metals covered are stainless steels, aluminium and copper-nickel alloys. Furthermore, explosion bonded steel-aluminium joints for the connection of steel structure with aluminium structure are covered.

1.1.2 Where required by the relevant design and construction parts of the rules, clad products shall comply with the requirements of Sec.1, the general requirements of [1] and the appropriate specific requirements of [2] and [3]. If the specific requirements differ from the general requirements, the specific requirements shall prevail.

1.2 Certification requirements

1.2.1 General certification requirements are given in Sec.1 [3.1]. Additional certification requirements for materials covered by this section are given in Table 1 and [1.2.2]

Table 1 Additional certification requirements

<table>
<thead>
<tr>
<th>Object</th>
<th>Additional description</th>
<th>Certificate type</th>
<th>Validated by</th>
<th>Certification standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base materials and clad materials</td>
<td>Starting material for clad products</td>
<td>VL or W</td>
<td>Manufacturer</td>
<td>*)</td>
</tr>
</tbody>
</table>

*) unless otherwise specified the certification standard is the rules

1.2.2 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 grades
d) identification marking of products
e) for the starting materials (base material, clad metal), VL or works (W) certificate with the particulars as stipulated in Sec.2 and Sec.3
f) condition of supply
g) results of mechanical tests
h) results of ultrasonic tests
i) results of any supplementary and additional test requirements specified.

1.3 Documentation requirements

1.3.1 General documentation requirements are given in Sec.1 [3.2]. Additional manufacturer specific documentation requirements are given in Table 2.
### Table 2 Qualification documentation for manufacturer

<table>
<thead>
<tr>
<th>Item</th>
<th>Documentation type</th>
<th>Additional description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clad products</td>
<td>Z100 - Specification</td>
<td>The thickness of the cladding metal is subject to approval by the Society in each case</td>
</tr>
</tbody>
</table>
|               | Z266 - Measurement report | — the thickness of the cladding materials be measured at the edges and in the middle of the plate  
|               |                     | — the records shall be presented to the surveyor on request                               |

### 1.4 Survey, inspection and testing requirements

1.4.1 General survey, inspection and testing requirements are given in Ch.1 Sec.1 [3.3]. Additional specific requirements are given in Table 3, as further detailed in this section.

### Table 3 Additional survey and testing requirements

<table>
<thead>
<tr>
<th>Survey, inspection and testing item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical composition</td>
<td>— Required for all materials</td>
</tr>
<tr>
<td>Tensile test and impact toughness test</td>
<td>— Required for all grades covered by this chapter unless otherwise specified</td>
</tr>
<tr>
<td>Bend test</td>
<td>— Requires for all clad products, and when specified for steel-aluminium transition joints</td>
</tr>
<tr>
<td>Shear test</td>
<td>— Required for all steel-transition joints, and when specified for clad steel products.</td>
</tr>
<tr>
<td>Through thickness tensile test</td>
<td>— At least three specimens shall be prepared from each end of the steel-aluminium transition joint (plate, rod or circular blank)</td>
</tr>
</tbody>
</table>
| Testing of bond quality by UT                        | — Unless otherwise specified in each subsection, UT shall be performed to check the bonding quality,  
|                                                       | — If bonding defects are found, their extent shall be clearly marked and reported to the surveyor |
| Intergranular corrosion test                          | — In the case of austenitic and austenitic-ferritic cladding materials If it is required to determine the resistance of the cladding metal against intergranular corrosion for each test batch |
| Repair by welding                                    | — Before welding, the dimensions and location of the defects shall be reported to the surveyor for acceptance of the repair |
1.5 Manufacture

1.5.1 All clad products delivered with VL or works (W) certificate shall be made at works approved by the Society for the type, grade and thickness of clad product being supplied and for the relevant processing route as per Sec.2 and Sec.3, respectively.

1.5.2 Base material and cladding materials applied for the clad products shall be delivered with VL or works (W) certificate from an approved manufacturer.

1.5.3 If the plates are intended for participation in the vessel's strength, the base material is at least to satisfy the requirements for the corresponding hull material as per Sec.2. If the plates are intended for boilers or pressure vessels, the base material shall at least satisfy the requirements for materials for such components as per Sec.3.

1.5.4 The cladding metal may be metallurgically bonded to the base metal by any method that will produce a clad material which will conform to the requirements of this section.

1.6 Chemical composition

1.6.1 Base metals suitable for joining with the clad metal will be accepted, provided that the process has no adverse effects on the finished plates.

1.7 Condition of supply

1.7.1 The clad products 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.

1.8 Mechanical testing

1.8.1 For plate thickness equal to or less than 50 mm, and unless otherwise agreed, tensile and bend test specimens shall be of the flat type and the test specimens shall 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 specimen may be reduced by machining.

On single clad plates, both sides of the test specimen shall be machined to maintain the same ratio of cladding materials to base steel materials as in the product, but the cladding materials need not be reduced to less than 3 mm.

Test specimens of double clad plates may be reduced by dividing according to a recognized standard. In this case, both halves shall be tested.

1.8.2 If the results do not meet the specified requirements, the test unit is rejected, or the re-test procedures in Ch.1 [3.7] may be adopted.

1.9 Inspections, dimensions and tolerances

1.9.1 The surface finish and dimensions of all products shall be checked by the manufacturer. 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.

1.9.2 Each clad product shall be inspected by the manufacturer before delivery.
The clad products shall be free from injurious defects and shall have a workmanlike appearance. The surface finish of the base material shall comply with the respective requirements specified in Sec.2 [2.11], Sec.3 [1.15] and Sec.3 [1.16]. The clad materials shall have a smooth surface consistent with their purpose. The surface shall be free from scale, impurities, annealing colour and other defects which may impair the manufacturing processes, the application of the product, or its chemical stability.

1.9.3 The base materials shall satisfy the requirements for minus tolerances on thickness according to Sec.2 [2.11] and Sec.3 [1.15]. The thickness control shall be carried out by the manufacturer.

1.9.4 The thickness of the cladding metal is subject to approval by the Society in each case. The thickness of the cladding materials shall be measured at the edges and in the middle of the plate complying with the requirements of [2] and [3]. The results shall be recorded. The records shall be presented to the surveyor on request.

1.9.5 Bond quality: The cladding metal shall be integrally and continuously bonded to the base metal. Unless otherwise specified in each subsection, UT shall be performed to check the bonding quality in accordance with the general practice of recognized standards, e.g. ASTM A578. If bonding defects are found, their extent shall be clearly marked and reported to the surveyor.

For different clad products, acceptance criteria of bond quality by UT are given in [2.5.1] and [3.5.1], respectively.

1.10 Repair

1.10.1 Repair of defects shall comply with the requirements of [2.6] and [3.5.1].

1.11 Identification

1.11.1 In addition to marking as required in Ch.1 Sec.2 [4] the following shall be marked on the product:

— material grade for both base and cladding material
— thickness of base and cladding material.

On single clad plates, the marking shall be stamped on the surface of the base plate. On double clad plates, all marking shall be done with a colour seal rather than by stamping.

2 Clad steel plates

2.1 Scope

2.1.1 These requirements are supplementary to [1] and apply to clad steel plates with cladding materials made of stainless steels and intended for the manufacture of e.g. containers and tanks, for chemical tankers, etc.

 Guidance note: It may be agreed to apply these rules to plate clad with other materials, e.g. aluminium or copper-nickel alloys.

---end---of---g-u-i-d-a-n-c-e---n-o-t-e---

2.2 Manufacture

2.2.1 Cladding may be performed by rolling or explosive cladding or by a combination of the two methods.
2.3 Chemical composition

2.3.1 Cladding materials of austenitic stainless steel shall be delivered with carbon content limitations strictly following Sec.3 Table 16. Other stainless steels, nickel and nickel-base alloys will be accepted, when they are suited for the intended service.

2.4 Mechanical and corrosion testing

2.4.1 Tensile test: For steels for construction of hull structure, one set of tensile tests shall be taken from every fifth plate, and at least one set from each heat and each thickness interval. For steel for construction of pressure vessels, one set of tensile tests shall be taken from each plate. The tensile tests shall be performed on transverse specimens. The gauge marks shall be applied to the base material side. One set of tensile tests consists of one or two tests:

1) one test of the base metal after removal of the cladding metal. The test shall satisfy the requirements for the base material
2) provided the cladding will be considered for the strength calculation; One test from the full clad plate which shall have a tensile strength $R_m$ not less than derived from the following formula:

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

$R_{m1}$ = 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

Elongation: In the case of clad steels where the elongation of the cladding material is less than that of the base material, the cladding material shall attain an elongation $A_5$ of at least 12% in a tensile test after the base metal has been removed by machining.

2.4.2 Impact test: Where impact test is required for the respective materials, see Sec.2 and Sec.3, it shall comply with the requirements specified for the base material in each case.

2.4.3 Bend test: As an alternative or in addition to the shear test provided in [2.4.4], bend test shall be carried out with the following conditions:

a) two bend test specimens shall be taken from each plate
b) on single clad plates, one test specimen shall be bent with the cladding in tension and the other with the cladding in compression. On double clad plates, the test specimens shall be bent, so that both cladding metals are tested both ways
c) the diameter of the mandrel 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
d) the bend test specimens shall be bent 180° around a mandrel without showing signs of cracking or loosening of the cladding metal from the base material.

2.4.4 Shear test: The shear strength between the base and the cladding metal shall be determined in order to ensure proper bonding. 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 or
other recognized standards. In the case of clad materials with a tensile strength of < 280 N/mm², the shear strength shall be at least 50% of the minimum tensile strength of the clad material and for all other clad materials it shall not be less than 140 N/mm², irrespective of the direction of testing, unless otherwise agreed in the order.

2.4.5 Corrosion test: In the case of austenitic cladding materials the resistance of the cladding metal against intergranular corrosion shall be determined. For this purpose, the plates may be grouped together in test batches which have been clad in the same manufacturing cycle with cladding materials originating from the same heat. Testing shall be carried out according to ASTM A 262, Practice E (Copper — Copper Sulphate — Sulphuric Acid Test) or another recognised standard. Extent of testing is each batch.

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

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

2.5 Inspection

2.5.1 Ultrasonic test: 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 [2.6]. 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.

2.5.2 Bond quality: Unless more stringent requirements have been specified, the proportion of bonded surface shall be at least 95%, and the area of isolated points where bonding has not occurred shall not exceed 50 cm².

   **Guidance note:**
   The bond quality to be supplied should preferably be listed on the purchase order. For clad steels which are severely stressed during processing, e.g. in the manufacture of dished ends, or while in use, e.g. in tube-sheets, it may be necessary for the purchaser to impose more stringent requirements.

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

2.5.3 Dimensions and tolerances: The nominal thickness of the cladding material shall be at least 2 mm, unless otherwise approved.

   Where no closer thickness tolerances are specified in the order, the minus tolerances for the thickness shall be as shown in Table 4.

**Table 4 Minus tolerances in relation to the thickness of the cladding material**

<table>
<thead>
<tr>
<th>Nominal thickness (mm)</th>
<th>Minus tolerance (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 2.0 and &lt; 2.5</td>
<td>-0.20</td>
</tr>
<tr>
<td>≥ 2.5 and &lt; 3.0</td>
<td>-0.25</td>
</tr>
<tr>
<td>≥ 3.0 and &lt; 3.5</td>
<td>-0.35</td>
</tr>
<tr>
<td>≥ 3.5 and &lt; 4.0</td>
<td>-0.45</td>
</tr>
<tr>
<td>≥ 4.0</td>
<td>-0.50</td>
</tr>
</tbody>
</table>

2.6 Repair

2.6.1 Shallow defects in the cladding material, e.g. impressions, grooves and scratches, shall be removed by grinding within the tolerance specified in [2.5.3].
2.6.2 Minor surface defects and bonding defects which do not exceed the limits specified in [2.6.3], may be repaired by means of welding. Bonding defects along the edges shall be repaired.

2.6.3 The plate will be rejected if:
— a repair will cause a weakening of the plate.
— a bonding defect exceeds 400 cm\(^2\) for plates up to 15 mm in thickness and 800 cm\(^2\) for plates over 15 mm or several bonding defects amounting in total to more than 5% of the surface of the plate revealed.

2.6.4 Before welding, the dimensions and location of the defects shall be reported to the surveyor for acceptance of the repair. Repair by welding shall be subject to the following requirements:
— all welds shall be made by qualified welders using an approved welding processes and welding consumables
— the welds shall be free from any defects liable to impair the characteristics of the cladding
— after welding, the repaired defect shall be ground flush with the plate. Welding shall be followed by heat treatment if this is specified by the welding procedure qualification tests or if called for in the order
— after final machining, the plates shall be subjected to a suitable non-destructive test technique, e.g. PT, in order to prove that the repairs are free from defects
— for each repair weld the manufacturer shall record the dimensions and location of the defects, the details of the welding technique used, the nature of any heat treatment applied and the results of the test. On request, the report shall be submitted to the surveyor.

3 Steel-aluminium transition joints

3.1 Scope

3.1.1 These requirements are supplementary to [1] and apply to explosion-bonded steel-aluminium joints intended for the connection of steel structures with aluminium structures.

3.2 Manufacture

3.2.1 The product is formed by explosive cladding without additional heat transfer or change of thickness.

3.2.2 The clad products shall be delivered in smoothed condition, unless otherwise agreed.

3.3 Chemical composition

3.3.1 Steels produced according to Sec.2 or Sec.3 shall be used as base materials.

3.3.2 Wrought aluminium alloys produced according to Sec.10 shall be used as cladding material.

3.4 Mechanical testing

3.4.1 Through thickness tensile test is required for product thickness \( \geq 15\)mm.
At least three specimens shall be prepared from each end of the clad product (plate, rod or circular blank). Two specimens from each end shall be tested with their longitudinal axis perpendicular to the product surface (across the cladding).
Specimen shape shall be chosen according to Sec.2 [6.4]. One specimen from each end shall be tested at 25°C ±5°C after heating to a temperature of 300°C for 15 minutes.
The tensile strength of a clad product shall be at least 60 N/mm$^2$, unless higher values have been agreed in the order.

3.4.2 Side bend test: If specially agreed in the order, one specimen of each clad product shall be taken and tested. Dimensions of the test specimen and test arrangement are shown in Figure 1.

![Figure 1 Side bend test](image)

The mandrel shall have a diameter equal to six times the thickness of the specimen. Where the product thickness exceeds 80 mm, the specimens may be reduced to 80 mm by machining the base material side. When tested, the clad product shall be capable of being bent through 90° without separation of the cladding material or formation of incipient cracks.

3.4.3 Shear testing: The shear strength between the base and the cladding metal shall be determined in order to ensure proper bonding.

From each clad product one shear test specimen shall be made with its axis transverse to the rolling direction and tested in accordance with DIN 50162 or other recognized standards. The dimensions of the test specimen and the test arrangement are shown in Figure 2.
Figure 2 Shear test

One specimen of each end shall be heated to 300°C for 15 minutes before testing at 25°C ±5°C. The shear strength shall be at least 60 N/mm$^2$ irrespective of the direction of testing, unless higher values have been agreed in the order.

3.5 Inspection

3.5.1 Bonding quality: The manufacturer shall carry out 100% ultrasonic testing of the surfaces and edges of all products.

The proportion of bonded surface shall be at least 99%. For rods and bars with width or diameter up to 300 mm, the size of individual indications shall not exceed the evaluation level given for UT of rolled steel plates, see DNV GL Classification Notes No. 7. For other products and sizes, the area of isolated points where bonding has not occurred shall not exceed 6.5 cm$^2$. If products are cut in order to remove indications, the distance to registered indications shall be at least 20 mm.

3.5.2 Dimensions and tolerances: Where no other tolerances are specified in the order, the details in Table 5 apply.

Table 5 Permissible tolerances of steel-aluminium transition joints

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Product</th>
<th>Tolerance (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Lower</td>
</tr>
<tr>
<td>Thickness</td>
<td>All</td>
<td>-2</td>
</tr>
<tr>
<td>Length</td>
<td>All</td>
<td>0</td>
</tr>
<tr>
<td>Width</td>
<td>Plates</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Rods$^{1)}$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&lt; 25 mm width</td>
<td>-1.5</td>
</tr>
<tr>
<td></td>
<td>≥ 25 mm width</td>
<td>-2</td>
</tr>
<tr>
<td>Diameter</td>
<td>Circular blanks</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&lt; 500 mm width</td>
<td>0</td>
</tr>
<tr>
<td>Rectangularity</td>
<td>Plates (difference between the diagonals)</td>
<td>≥ 500 mm width</td>
</tr>
<tr>
<td>---------------</td>
<td>------------------------------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>Evenness (aluminium side)</td>
<td></td>
<td>&lt; 1 m length</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≥ 1 m length</td>
</tr>
<tr>
<td>Straightness of longitudinal edges</td>
<td>Rods&lt;sup&gt;1)&lt;/sup&gt;</td>
<td></td>
</tr>
</tbody>
</table>

1) Contrary to plates, rods are flat products of width < 300 mm
SECTION 5 STEEL PIPES AND FITTINGS

1 General requirements for pipes

1.1 Scope

1.1.1 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.

1.1.2 Separate requirements for steel piping fittings are given in [6]. Requirements for pipes and fittings of forgings and castings are given in Sec.6 and Sec.8 respectively.

1.1.3 Requirements for pipes and hollow sections intended for structural application are given in Sec.2.

1.1.4 Requirements for individually manufactured and welded pipes for applications not covered by this section shall comply with the relevant design and construction rules.

1.2 Certification requirements

1.2.1 General certification requirements are given in Sec.1 [3.1].

1.2.2 The product shall be delivered with the type of certificate required in the relevant design and construction rules giving at least 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/fittings and material quality
— identification marking of pipes/fittings
— 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.

1.3 Documentation requirements

1.3.1 General documentation requirements are given in Sec.1 [3.2]. Additional manufacturer specific documentation requirements are given in Table 1.

Table 1 Qualification documentation for manufacturer

<table>
<thead>
<tr>
<th>Item</th>
<th>Documentation type</th>
<th>Additional description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon and carbon-manganese steel pipes</td>
<td>VL or W certificate or TR</td>
<td>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</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Carbon equivalent shall be reported</td>
</tr>
</tbody>
</table>
1.4 Survey, inspection and testing requirements

1.4.1 General survey, inspection and testing requirements are given in Ch.1 Sec.1 [3.3]. Additional specific requirements are given in Table 2, as further detailed in this section.

**Table 2 Additional survey and testing requirements**

<table>
<thead>
<tr>
<th><strong>Survey, inspection and testing item</strong></th>
<th><strong>Description</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical composition</td>
<td>Required for all materials</td>
</tr>
<tr>
<td>Carbon equivalent</td>
<td>Unless stricter requirements are specified in the standard, carbon and carbon-manganese steel shall conform to a carbon equivalent of maximum 0.50%</td>
</tr>
<tr>
<td>Mechanical testing</td>
<td>Required for all grades in accordance with the requirements of the relevant standard</td>
</tr>
<tr>
<td>Hot tensile test</td>
<td>Where pipes are designed for use at elevated temperatures on the basis of their high-temperature strength characteristics, a hot tensile test shall be performed on one test specimen per heat and per pipe size</td>
</tr>
<tr>
<td>Impact toughness test, all pipes</td>
<td>Where Charpy V-notch impact testing is required, this is applicable for wall thickness 6 mm or greater</td>
</tr>
<tr>
<td>Impact toughness test of austenitic steel pipes</td>
<td>For austenitic stainless steel pipes, Charpy V-notch impact testing is required where the design temperature is below -105°C</td>
</tr>
<tr>
<td>Hardness test on fittings</td>
<td>Hardness tests on fittings shall be carried out as specified in [6]</td>
</tr>
<tr>
<td>NDT of all pipes</td>
<td>Where required by the design principle, pipes shall be subjected to a non-destructive test over their whole length</td>
</tr>
<tr>
<td>NDT of welded pipes</td>
<td>For welded pipes, an automatic non-destructive testing of the whole length of the weld is required</td>
</tr>
<tr>
<td>Leak tightness test</td>
<td>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</td>
</tr>
<tr>
<td>Test equipment used for the continuous inspection of pipes</td>
<td>The efficiency of the equipment shall be demonstrated to the surveyor on request</td>
</tr>
<tr>
<td>Corrosion test of pipes and fittings</td>
<td>Where pipes/fittings of austenitic stainless steels shall be used in systems where corrosion testing of the pipes is required, testing shall be carried out in accordance with Sec.3 [1.14]</td>
</tr>
<tr>
<td>Corrosion test for duplex steels</td>
<td>For ferritic-austenitic (duplex) stainless steel pipes, corrosion testing in accordance with ASTM G48 Method A or an equivalent standard is required</td>
</tr>
<tr>
<td>Repair by grinding</td>
<td>— defects may be removed by grinding provided that the dimensional tolerances are not exceeded</td>
</tr>
<tr>
<td></td>
<td>— repair by welding is not permitted except for repair to the weld seam of electric fusion welded pipe</td>
</tr>
</tbody>
</table>
1.5 Materials

1.5.1 Pipes shall be in accordance with recognised standards, as given in [2] to [5], provided that supplementary requirements contained herein and in [2] to [5] also are met. Recognition of other standards is subject to submission to the Society for evaluation, see Ch.1 Sec.1 [3.4].

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

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

1.5.4 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
— non-destructive testing.

Guidance note:
In order for other materials to be considered for approval, a gap analysis report identifying the differences between the proposed material and a corresponding material grade according to one of the standards listed below should be submitted.

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1.6 Manufacture

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

1.6.2 Pipes shall be manufactured as specified in [2] to [5]. The terms “hot finished” and “cold finished” apply to the condition of the pipe before it is heat-treated.

1.7 Chemical composition

1.7.1 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.

1.7.2 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.

1.7.3 Elements designated as residual elements in the standard shall not be intentionally added to the steel. The content of such elements shall be reported.
1.7.4 Unless stricter requirements are specified in the standard, carbon and carbon-manganese steel shall conform to a carbon equivalent $C_{eq}$ of maximum 0.50% as determined by the formula given in Ch.1 Sec.2 [3.2]

1.8 Condition of supply

1.8.1 The pipes shall be supplied in a condition in accordance with the requirements of the relevant standard and the requirements in [2] to [5]. Unless otherwise required, hot finished or as-welded pipes need not be heat-treated.

1.9 Mechanical testing

1.9.1 Pipes shall be sampled and subjected to testing in accordance with the requirements of the relevant standard.

1.9.2 Unless stricter requirements are specified in the standard, the size of a test unit (batch) shall be restricted to maximum:

- 400 pipes for outside diameter < 100 mm
- 100 pipes for outside diameter ≤ 500 mm
- 50 pipes for outside diameter > 500 mm.

Further details are given in [1.9.3] and [1.9.4].

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

1.9.4 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.

1.9.5 Where pipes are designed for use at elevated temperatures on the basis of their high-temperature strength characteristics, a hot tensile test shall be performed on one test specimen per heat and per pipe size. The test is not required if the pipes are made according to a recognized standard where the high-temperature mechanical properties are regarded as proven.

1.9.6 Where Charpy V-notch impact testing is required, this is applicable for wall thickness 6 mm or greater. Unless otherwise specified by the selected recognised standard for the grade in question, transverse Charpy V-notch specimens shall be used for outside diameter of $D \geq 200$ mm. For outside diameter $D < 200$ mm, longitudinal specimens may be used.

If the dimensions of the pipe are such that transverse test specimens can be taken without straightening, an additional (transverse) set of specimens shall be taken from fusion-welded pipes so that the notch is located in the middle of the weld metal.

1.10 Leak tightness testing

1.10.1 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 [1.10.2].

1.10.2 The internal pressure test shall be performed at a standard hydraulic test pressure of 80 bars, except as specified below or unless otherwise approved. Where pipes are intended for an operating pressure of ≤ 25 bars, the test pressure may be reduced to a standard value of 50 bars. In the case of thin-walled pipes with
large outside diameters, the test pressure shall be limited so as to ensure that the yield strength or 0.2% proof stress of the pipe material at room temperature is not exceeded. Where, in exceptional cases, testing with water is not possible, another testing medium may be used in agreement with the surveyor.

1.11 Inspection

1.11.1 Pipes shall be subjected to visual inspection and measurements of dimensions by the manufacturer 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.

1.11.2 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.

1.11.3 For welded pipes, an automatic non-destructive testing of the whole length of the weld is required. Such pipes are considered equivalent to seamless pipes for design purpose.

1.11.4 Where required by the design principle, pipes shall be subjected to a non-destructive test over their whole length in accordance with a recognized standard, e.g. EN ISO 10893.

1.11.5 The test equipment used for the continuous inspection of pipes shall be regularly calibrated using pipes with artificial defects. The efficiency of the equipment shall be demonstrated to the surveyor on request.

1.12 Repair

1.12.1 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. Defects removed by grinding shall be re-inspected by NDT. For pipes/fittings repaired by welding, both leak tightness test according to [1.10] and inspection according to [1.11] shall be repeated after repair.

1.13 Identification

1.13.1 Pipes shall be legibly marked for identification in accordance with the requirements of the relevant standard with the following minimum information:
- manufacturer's name or trade mark
- material designation
- where applicable, quality level in the case of boiler tubes
- heat number or production code.

2 Pipes for pressure systems

2.1 Scope

2.1.1 These requirements are supplementary to [1] and apply to carbon and carbon-manganese and alloy steel pipes for use in pressure systems.

2.2 Materials

2.2.1 Suitable pipe grades shall be selected from the following recognised standards:
2.3 Manufacture

2.3.1 Pipes for class I and II pressure systems, as defined in Pt. 4 Ch. 7, shall be manufactured by any of the following methods:

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

2.4 Mechanical testing

2.4.1 Pipes for class I and II pressure vessels shall satisfy a Charpy V-notch impact toughness requirement of minimum 27 J, unless otherwise approved.

3 Austenitic and ferritic-austenitic steel pipes

3.1 Scope

3.1.1 These requirements are supplementary to [1] and apply to austenitic and ferritic-austenitic stainless steel pipes for corrosive service and to austenitic steel pipes for low-temperature service.

3.2 Materials

3.2.1 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
- JIS G3459.

3.3 Manufacture

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

- hot finished seamless
- cold finished seamless
- electric resistance or induction welded
- cold finished electric resistance or induction welded
- electric fusion welded.
3.4 Condition of supply

3.4.1 The pipes shall be supplied in solution treated condition. Welded austenitic pipes may be delivered in the welded state provided that a test of the procedure has demonstrated that the characteristics of the material are satisfactory and that the strips or plates used for their manufacture are solution annealed.

3.5 Mechanical testing

3.5.1 Where pipes are used at elevated temperatures, the required values for the 0.2% or 1% proof stress prescribed in the relevant standards or recognized specifications shall be met at the corresponding temperature level.

3.5.2 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 specimens shall be minimum 41 J.

3.6 Corrosion testing

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

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

4 Pipes for low-temperature service

4.1 Scope

4.1.1 These requirements are supplementary to [1] 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.

4.2 Materials

4.2.1 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
— JIS G3460.

4.3 Manufacture

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

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

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

4.4 Mechanical testing

4.4.1 Requirements for Charpy V-notch impact testing dependent of steel type and minimum design temperature are given in Table 3.

Table 3 Charpy V-notch impact properties

<table>
<thead>
<tr>
<th>Steel type</th>
<th>Min. design temperature (°C)</th>
<th>Charpy V-notch</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Test temperature (°C)</td>
<td>Minimum average energy (J)</td>
</tr>
<tr>
<td>C and C-Mn</td>
<td>-55</td>
<td>1) 27</td>
</tr>
<tr>
<td>2 ¼ Ni</td>
<td>-65</td>
<td>-70 34</td>
</tr>
<tr>
<td>3 ½ Ni</td>
<td>-90</td>
<td>-95 34</td>
</tr>
<tr>
<td>9 Ni</td>
<td>-165</td>
<td>-196 41</td>
</tr>
</tbody>
</table>

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

5 Boiler and superheater tubes

5.1 Scope

5.1.1 These requirements are supplementary to [1] and [2] and apply to carbon and carbon-manganese and alloy steel tubes for use in boilers, superheaters and heat exchangers.

5.1.2 Austenitic stainless steels may also be used for this type of service. Where such applications are proposed, see [3.5.1].

5.2 Materials

5.2.1 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
— JIS G3461, JIS G3462, JIS G3463.

5.3 Manufacture

5.3.1 Pipes shall be manufactured by any of the following methods:
Metallic materials

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

6 Piping fittings

6.1 Scope

6.1.1 This sub-section specifies the requirements for steel piping fittings such as elbows, bends, tees, reducers and caps - for the applications covered in [2] to [5], made from plates, seamless pipes or welded pipes. Detachable pipe couplings and flanges are excluded from these requirements.

Steel pipe fittings made by forging or casting are covered by Sec.6 and Sec.8, respectively.

6.2 Materials

6.2.1 Fittings shall be in accordance with recognised standards, as given in [6.2.2]. Recognition of other standards is subject to submission to the Society for evaluation, see Ch.1 Sec.1 [3.4].

6.2.2 Suitable fitting grades shall be selected from the following recognised standards:
- EN 10253
- ASTM A234, A403, A420, A744, A815, A960, A961
- JIS B2312, JIS B2313, JIS B2316.

6.2.3 Where required by the relevant design and construction parts of the rules, fittings shall comply with the requirements of [1] and this subsection.

6.2.4 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.

6.3 Manufacture

6.3.1 All fittings delivered with VL or works (W) certificate shall be made by works approved by the Society. See also guidance note.

**Guidance note:**
Exceptions may be accepted in a transition period as decided by the Society, in which fittings for VL or W certification may be accepted from non-approved manufacturers. Such manufacturers should apply for approval. Manufacturers in which approval certificate is suspended or withdrawn are not covered by this exception.

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

6.3.2 The starting materials for fabrication of fittings (covered by this section) shall consist of plates, seamless pipes or welded pipes and shall be sourced from works approved by the Society.

6.3.3 Fittings shall be manufactured by hot or cold forming operations such as pressing, bending or fusion welding according to recognized standards.
6.4 Chemical composition

6.4.1 Chemical composition of the starting materials shall fulfil [1.7].

6.5 Condition of supply

6.5.1 All fittings shall be in the heat-treated or hot worked state specified for the material in the relevant standard or material specification.

6.5.2 Heat treatment after cold bending shall be carried out as specified in Pt.4 Ch.6 Sec.10 [3].

6.6 Mechanical testing

6.6.1 Fittings shall be tested in accordance with the requirements of the relevant standard. For stainless steel fittings and fittings for low-temperature service, supplementary requirements for testing in [3] and [4] also apply.

6.6.2 Unless stricter requirements are specified in the standard, the size of a test unit shall be restricted to the maximum size given in Table 4 and as given in [6.6.3] and [6.6.4].

Table 4 Test units for fittings

<table>
<thead>
<tr>
<th>Size $d_a$ (mm)$^1$</th>
<th>No. of fittings per test unit$^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 100</td>
<td>≤ 200</td>
</tr>
<tr>
<td>≥ 100 and &lt; 225</td>
<td>≤ 100</td>
</tr>
<tr>
<td>≥ 225 and &lt; 350</td>
<td>≤ 50</td>
</tr>
<tr>
<td>≥ 350</td>
<td>≤ 25</td>
</tr>
</tbody>
</table>

1) $d_a$ = outer diameter
2) test batches apply to 90° elbows. The number of elbows per test batch is halved in the case of 180° elbows and doubled in the case of 45° elbows

6.6.3 Where heat treatment has been carried out, a test unit shall consist of fittings of the same size, made from the same grade of steel, the same heat treatment in a continuous furnace or heat-treated in the same furnace charge in a batch furnace, and in the case of alloy steel fittings with an outer diameter $d_a > 100$ mm, originating from the same heat.

6.6.4 Where no heat treatment has been carried out, a test unit shall consist of fittings of the same size, made by the same forming process, and from the same grade of steel.

Where the fittings are delivered without heat treatment, and have been subject to theoretical cold forming of less than 5% for ferritic steels and less than 10% for austenitic and ferritic-austenitic steels, testing of the starting material is sufficient. Theoretical cold forming may be calculated in accordance with Ch.4 Sec.6 [5.2.6]. See also the requirements given in Pt.4 Ch.6 Sec.10 [3].

6.6.5 Testing shall be carried out on selected fitting from the unit to be covered. Provided the length of the fitting is not sufficient for testing, fittings of excess length shall be manufactured using the same or a similar process, and shall follow the test unit as described in [6.6.3] and [6.6.4]. The test samples shall be prepared from the hardest and softest fittings determined in the hardness test, see [6.6.6]
6.6.6 Hardness tests shall be carried out on 10% of the fittings per test unit, except for austenitic and austenitic-ferritic steels subject to tensile testing on the fitting. Where the number of fittings per test unit is less than 30 fittings a minimum of three fittings shall be tested.

Hardness test shall be performed on each individual fitting for the following:

— outer diameter \( D \geq 225 \text{ mm} \) for unalloyed steel with tensile strength \( R_m \geq 500 \text{ MPa} \)
— outer diameter \( D \geq 200 \text{ mm} \) for alloyed steel, except for 0.3% Mo and Cr-Mo steel.

6.6.7 One tensile test shall be carried out for each test unit unless stricter requirements are specified. For outer diameter \( D \geq 100 \text{ mm} \), two tensile tests shall be carried out (where the test unit is less than 10 fittings, one set of specimens is acceptable). Sample product shall be selected as the hardest and the softest fitting found in hardness tests according to [6.6.6]. Fittings having an outer diameter \( D < 100 \text{ mm} \) may be tensile tested on the starting material.

6.6.8 Where Charpy V-notch impact testing is required, this is applicable for wall thickness 6 mm or greater. Two sets of specimen shall be tested for each test unit unless test unit is less than 10 fittings, where one set of specimen is acceptable.

Where the fittings are delivered without heat treatment and have been subject to theoretical cold forming of more than 5% for ferritic steels and more than 10% for austenitic and ferritic-austenitic steels, the area with the highest cold forming shall be tested. Where sampling of the representative area is not possible, testing of same material in artificially cold formed condition is accepted. For ferritic steels, the material shall additionally be tested in the strain-aged condition, see Ch.1 Sec.3 [3.8], Ch.4 Sec.6 [5.2] and Pt.4 Ch.6 Sec.10 [3].

6.7 Corrosion testing

6.7.1 Where fittings of austenitic stainless steels shall be used in systems where corrosion testing of the pipes is required, testing shall be carried out in accordance with Table 2.

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

6.7.3 Test specimen surfaces shall have a finish representative of the fitting’s delivery condition. The test temperature shall be +20°C for type 22Cr duplex and +50°C for type 25Cr duplex, respectively. No pitting on specimen surfaces is allowed when viewed at 20 times magnification. The specimen mass loss shall be less than 4.0 g/m\(^2\).

6.8 Inspection

6.8.1 Fittings shall be subject to visual inspection and measurements of dimensions by the manufacturer. Surface quality and dimensions shall be in accordance with the requirements of the relevant standard. The fittings 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.

6.8.2 Unless stricter requirements are specified in the standard, welded alloy steel fittings with nominal bores > 75 mm shall be subject to random radiographic inspection of the welds. These shall be selected in such a way that every size of fittings is included.

6.9 Identification

6.9.1 Fitting with outer diameter \( D \geq 225 \text{ mm} \) shall be marked in accordance with [1.13]. Smaller fittings may alternatively be marked with the manufacturer’s symbol and a unique identification number ensuring traceability to the test unit and certificate.
The level of documentation shall be in accordance with [1.3].
SECTION 6 STEEL FORGINGS

1 General requirements

1.1 Scope

1.1.1 This section gives the requirements for:
— steel forgings to be used in the construction of hulls, equipment, machinery, boilers, pressure vessels and piping systems, and forgings for low temperature service
— semi-finished rolled or forged products for forging stock and to forgings from which blanks for various components may be cut out
— rolled bars intended for machining into components of simple shape, e.g. shafts, bolts, studs and other components
— bolts and nuts.

1.1.2 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 Sec.1 and [1] and the appropriate specific requirements of [2] to [9]. If the specific requirements differ from these general requirements, the specific requirements shall prevail.

1.1.3 As an alternative to [1.1.2], materials which comply with national or proprietary specifications may be accepted provided such specifications give reasonable equivalence to the requirements of [1] 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.1 Sec.1.

Guidance note:
In order for other materials to be considered for approval, a gap analysis report, identifying the differences between the proposed material and the corresponding Society material grade should be submitted, see Ch.1 Sec.1 [3.4].

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

1.1.4 This section contains requirements applicable to general certification of materials. However, for components that shall be certified according to other parts of the rules, the requirements in these parts prevail.

1.2 Certification requirements

1.2.1 The general certification requirements are given in Sec.1 [3.1].

1.2.2 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 soaking time
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.

1.3 Documentation requirements

1.3.1 General documentation requirements are given in Sec.1 [3.2]. Additional manufacturer specific documentation requirements are given in Table 1.

Table 1 Qualification documentation for manufacturer

<table>
<thead>
<tr>
<th>Item</th>
<th>Documentation type</th>
<th>Additional description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CGF Crankshaft</td>
<td>AoM certificate</td>
<td>Manufacturers producing forgings qualified as continuous grain flow crankshafts (CGF) shall be approved accordingly</td>
</tr>
<tr>
<td>Clean steel forging</td>
<td>VL or W certificate or TR</td>
<td>For each clean steel forging, the cleanliness as given in [1.6.9]shall be reported. Additionally, the contents of the elements sulphur, phosphorus, and oxygen shall be reported</td>
</tr>
</tbody>
</table>
| Hot formed pressed parts    | Z270 - Records     | For pressed parts supplied in the hot pressed condition, documenting:

- that the whole forming operation was carried out within the specified normalizing temperature range
- the method of cooling
- the delivery condition of the starting material.

The records shall be presented to the surveyor on request |
| Machinery forging           | Z250 - Procedure   | For straightening operations of machinery parts; subject to approval by the Society                                                                   |

1.4 Survey, inspection and testing requirements

1.4.1 General survey, inspection and testing requirements are given in Ch.1 Sec.1 [3.3]. Additional specific requirements are given in Table 2 as further detailed in this section.

Table 2 Additional survey, inspection and testing requirements

<table>
<thead>
<tr>
<th>Survey, inspection and testing item</th>
<th>Description</th>
</tr>
</thead>
</table>
| Chemical composition               | — required for all materials
|                                     | — 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 |
### Clean steel forgings

For clean steel forgings, the steels shall have a degree of cleanliness as given in [1.6.10]. Additionally, the contents of the elements sulphur, phosphorus, and oxygen shall be restricted to maximum 0.005%, 0.015%, and 25 ppm, respectively.

### Mechanical testing

Required for all grades in accordance with the requirements of the relevant section.

### Impact toughness test

Relevant for all grades where specified in the following sections.

### Impact toughness test of austenitic steel forgings

Charpy V-notch impact testing is required where the design temperature is below –105°C.

### Hardness test of crankshaft forgings

For forgings which have been batch tested, at least 10% of the forgings to be tested for hardness.

### Hardness test of forgings for gears, forgings for boilers, pressure vessels and piping systems, and forgings for low-temperature service (except austenitic stainless steels)

For forgings which have been batch tested, each forging to be tested.

### Visual survey

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

### NDT

Forgings shall be subject to non-destructive testing as specified in [2] to [9] and shall comply with given requirements. In addition, the relevant construction rules shall be referred for non-destructive testing of finished machined components.

### NDT after repair by grinding or chipping

Complete elimination of the defective material shall be verified by magnetic particle testing or liquid penetrant testing.

### Pressure test

Pressure retaining forgings shall be tested after machining to the test pressure required by the relevant design and construction parts of the rules.

---

### 1.5 Grading system

1.5.1 The forgings concerned are classified by chemical composition into three steel types:

- carbon and carbon-manganese (C and C-Mn) steel
- alloy steel
- stainless steel.

1.5.2 Where applicable, C and C-Mn steels and alloy steels are covered by several grades designated by their specified minimum tensile strength. Stainless steel grades shall be designated in accordance with a recognized standard.

**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.

---end---of---guidance---note---
1.6 Manufacture

1.6.1 All products delivered with VL or works certificate shall be made at works approved by the Society. Manufacturers without own steel making shall 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 [1.6.10].

1.6.2 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.

1.6.3 For forgings with specified minimum ultimate tensile strength 800 N/mm$^2$ 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.

1.6.4 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.

1.6.5 Surface and skin defects, which may be detrimental during the subsequent working and forming operations, shall be removed.

1.6.6 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 in order to give reasonable machining allowance, see also [1.6.8]. 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. Preheating shall to be employed when necessitated by the composition or thickness of the steel. Subsequent grinding or machining is required for certain components. Excessive machining to give the forging its final shape may impair its characteristics e.g. by exposing the core zone. The core zone may have lower mechanical properties, as well as higher density of inclusions and other imperfections. Manufacturer should consider maximum machining allowance suitable for their products. As a general advice, machining allowance should not exceed 20% of final dimension. Necks of shafts, pinions and journals exceeding 1/10 of the outer diameter should be produced as far as possible by stepped forging.

The degree of deformation should be such that the core zone of the forging undergoes sufficient plastic deformation.

Surface hardening and surface carburizing caused by flame-scarfing or air-arc gouging will typically be removed if it is followed by grinding or machining to a depth of 1mm or more.

1.6.7 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, continuous cast products, 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 6:1, see [1.1.1].

$L$ and $D$ are the length and diameter respectively of the part of the forging under consideration.
1.6.8 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.

Guidance note:
Continuous grain flow (cgf) forged means documented forging that results in a flow of segregations tangential to the main principal stress direction in the web fillets. Further details for qualification of cgf are given in the relevant approval of manufacturer program. A crankthrow is among other required to be cut in the crank plane and etched in order to illustrate the grain flow. It is essential that this is made with fillets in finished condition. I.e. for recessed fillets, cgf may be difficult to obtain as the recess normally cuts the grain flow.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

1.6.9 Where two or more forgings are joined by welding to form a composite item, the design and the welding procedure specification shall be approved.

1.6.10 For clean steel forgings, the steels shall have a degree of cleanliness as given in Table 3 when tested according to ISO 4967 method A. Samples shall be obtained from forged or rolled product representative of each heat. Additionally, the contents of the elements sulphur, phosphorus, and oxygen shall be restricted to maximum 0.005%, 0.015%, and 25 ppm, respectively.

Table 3 Cleanliness requirements, see details in ISO 4967

<table>
<thead>
<tr>
<th>Inclusion group</th>
<th>Series</th>
<th>Limiting value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type A</td>
<td>Fine</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Thick</td>
<td>1</td>
</tr>
<tr>
<td>Type B</td>
<td>Fine</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>Thick</td>
<td>1</td>
</tr>
<tr>
<td>Type C</td>
<td>Fine</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Thick</td>
<td>1</td>
</tr>
<tr>
<td>Type D</td>
<td>Fine</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Thick</td>
<td>1</td>
</tr>
<tr>
<td>Type DS</td>
<td>N.A.</td>
<td>1</td>
</tr>
</tbody>
</table>

1.7 Chemical composition

1.7.1 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.

1.7.2 Except where otherwise specified, suitable grain refining elements such as aluminium, niobium or vanadium may be used at the discretion of the manufacturer. The content of such elements shall be reported.

1.7.3 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.

1.8 Heat treatment

1.8.1 All forgings shall be heat-treated for mechanical properties as specified in [2] to [9].
1.8.2 In the case of very large forgings alternative methods for heat treatment will be specially considered.

1.8.3 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 according to a recognized standard (e.g. ASTM A991) at regular intervals as agreed with the Society.

1.8.4 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.

1.8.5 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.

1.8.6 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.

1.8.7 If a forging is locally re-heated 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.

1.9 Test material and test specimens for mechanical testing

1.9.1 Test material, from which test specimens are taken, shall be integral with the forging except as provided in [1.9.2]. 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.

1.9.2 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.

1.9.3 Where batch testing is permitted according to [1.10], 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.

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

1.9.5 The following definitions relevant to orientation of test specimens apply:

Longitudinal test: Longitudinal axis of test specimen parallel to the principal direction of fibre deformation.

Transverse/tangential test: Longitudinal axis of test specimen perpendicular to the principal direction of fibre deformation.

Sketches of specimen orientations are given in Figure 1 to Figure 9.

1.9.6 The longitudinal axis of test specimens shall be positioned as follows:

— for thickness or diameter (as heat treated) up to maximum 50 mm, the axis shall be at mid-thickness or centre of the cross section
— for thickness or diameter greater than 50 mm, the axis shall be at least approximately one quarter thickness (mid-radius) or 80 mm, whichever is less, below any heat-treated surface
— test specimens 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 specimen.

The given positions are relative to the heat treated surface, not the surface after final machining. Other positions are subject to special approval.
1.9.7 Longitudinal tests shall be made except that rings, hollow forgings which are expanded, and disks are subject to tangential tests.

1.9.8 Unless otherwise specified in the following paragraphs, the specified requirements apply to the sampling orientation given in [1.9.7].

1.9.9 The preparation of test specimens and the procedures used for mechanical testing shall comply with the relevant requirements of Ch.1 Sec.2 and Ch.1 Sec.3.

1.9.10 For closed die crankshaft forgings and crankshaft forgings where the method of manufacture has been specially approved in accordance with [1.6.6], the number and position of test specimens shall be agreed with the Society taking into consideration the employed manufacturing method.

1.10 Test units and number of tests

1.10.1 Large forgings: Normalized or solution heat-treated forgings with mass 1000 kg or more and quenched and tempered forgings with mass 500 kg or more shall be individually tested. The limits refer to the as forged or rough machined mass at time of heat treatment but exclude the test material.

1.10.2 Smaller forgings, normalized or solution heat-treated: Batch testing is accepted for normalized or solution heat-treated forgings with mass up to 1000 kg each. 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.

1.10.3 Smaller forgings, quenched and tempered: Batch testing is accepted for quenched and tempered forgings with mass up to 500 kg each. 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.

1.10.4 Rolled bars: Batch testing of rolled bars, see [1.1.1], is accepted under the condition that the test unit 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.

1.10.5 Required tests: Unless otherwise specified in [2] to [9], one set of mechanical tests is required for each test unit. A set of tests shall consist of one tensile test specimen and, when required, three Charpy V-notch test specimens.

1.10.6 Additional tests required for extra large forgings: 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.

1.10.7 Test requirements for multiple components made from one forging: 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.

1.11 Mechanical properties

1.11.1 The material shall meet the mechanical properties specified in [2] to [9].
1.11.2 If the results do not meet the specified requirements, the re-test procedures in Ch.1 Sec.2 [3.7] may be adopted. Where the forgings and test material are submitted to re-heat treatment, they may not be re-austenitized 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.

1.12 Inspection

1.12.1 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. Unless otherwise agreed, the verification of dimensions is the responsibility of the manufacturer.

1.12.2 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. Forgings delivered in the unmachined condition shall have a proper surface condition consistent with the method of manufacture.

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

1.12.4 Forgings subject to non-destructive testing as specified in [2] to [8] shall comply with the following requirements. In addition, the relevant construction rules shall be referred for non-destructive testing of finished machined components.

1) Personnel: All tests shall be carried out by personnel qualified and certified in accordance with recognised standards or schemes, e.g. ISO 9712, ASNT Central Certification Program (ACCP). SNT-TC-1A may be accepted if the NDT company’s written practice is reviewed and accepted by the Society.

2) Methods: 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.
   d) As an alternative to a) to c), methods complying with national or proprietary standards or specifications may be agreed with the Society provided such standards or specifications give reasonable equivalence to the requirements of a) to c) or are especially approved.

3) Extent and acceptance criteria: The extent of non-destructive testing and the acceptance criteria shall be agreed with the Society
   a) for forgings, IACS Recommendation No. 68 is regarded as an example of an acceptable standard
   b) as an alternative to a), acceptance criteria complying with national or proprietary standards or specifications may be agreed with the Society provided such standards or specifications give reasonable equivalence to the requirements of a) or are especially approved.

Guidance note:
Prior to acceptance of the forging by the Society, the ordering information between purchaser and manufacturer regarding NDT should preferably be available for the surveyor. The ordering specification with respect to NDT may typically give reference to recognised standards, and/or specify:
— methods, areas, volume and extent of examination
— documentation requirements
— additional requirements as applicable

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

1.12.5 Definitions relevant to MT or PT indications are given in Sec.1 Table 1.
1.12.6 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 machined condition for subsequent processing and final MT or PT by the purchaser, there will always be a risk of subsurface defects appearing on the surface after final machining. The manufacturer should consider this risk and should e.g. perform suitable intermediate inspections taking into consideration the quality level required in finished condition. The responsibility of the internal quality of the material lies with the manufacturer. Repair of defects discovered after final machining is the responsibility of the manufacturer.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

1.12.7 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. Scanning with both radial and axial sound wave direction, or with two perpendicular directions as relevant, shall be carried out when appropriate for the shape and dimensions of the forging being tested. When the configuration does not allow 100% volumetric examination, the report shall include a description of the areas not covered.

1.12.8 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.

1.12.9 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.

1.12.10 Forgings proven defective during subsequent machining or testing shall be considered rejected notwithstanding any previous certification.

1.13 Repair

1.13.1 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 [1.13.2]. 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.

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

1.13.3 Repair welding of forgings except crankshaft and connecting rod 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 to the Society for approval.

1.13.4 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.
1.14 Identification

1.14.1 Before acceptance, each forging which has been tested and inspected with satisfactory results shall be suitably identified by the manufacturer with the following:
— identification number, heat number or other marking which will enable the full history of the forging to be traced
— the VL certificate number, where applicable and as furnished by the surveyor
— test pressure, where applicable.

1.14.2 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.

2 Forgings for hull structures and equipment

2.1 Scope

2.1.1 These requirements are supplementary to [1] and apply to steel forgings intended for hull structures and equipment such as rudder stocks, pintles, anchors and windlass components. Provision is made for carbon and carbon-manganese and alloy steel grades suitable for assembly by welding or for clad welding.

2.2 Chemical composition

2.2.1 The chemical composition shall comply with the overall limits given in Table 4 or, where applicable, the requirements of the approved specification.

Table 4 Chemical composition limits¹ for steel forgings for hull structures and equipment ²

<table>
<thead>
<tr>
<th>Steel type</th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Cr³)</th>
<th>Mo³)</th>
<th>Ni³)</th>
<th>Cu³)</th>
<th>Total residuals</th>
</tr>
</thead>
<tbody>
<tr>
<td>C and C-Mn</td>
<td>0.23</td>
<td>0.45</td>
<td>0.30 to 1.50</td>
<td>0.035</td>
<td>0.035</td>
<td>0.30</td>
<td>0.15</td>
<td>0.40</td>
<td>0.30</td>
<td>0.85</td>
</tr>
<tr>
<td>Alloy</td>
<td>0.25</td>
<td>0.45</td>
<td>0.30 to 1.00</td>
<td>0.035</td>
<td>0.035</td>
<td>Min. 0.40⁴)</td>
<td>Min. 0.15⁴)</td>
<td>Min. 0.40⁴)</td>
<td>0.30</td>
<td>-</td>
</tr>
</tbody>
</table>

1) Given value is maximum content (by weight) 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 6
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

2.3 Heat treatment

2.3.1 Carbon and carbon-manganese steel forgings shall be supplied in one of the following conditions:
— normalized.
— normalized and tempered at a temperature of not less than 550°C
— quenched and tempered at a temperature of not less than 550°C.
Rolled bars: Subject to qualification, e.g. through the manufacturer approval process, the specified normalizing or normalizing and tempering may be replaced by normalizing rolling (NR) or NR + tempering, respectively.

**Guidance note:**
For large forgings with complex shape, made of carbon or carbon-manganese steel and delivered in normalized condition, a tempering or stress relieving heat treatment may be considered before machining, if the forgings will be extensively machined.

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

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

2.4 Mechanical testing

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

2.4.2 The mechanical properties shall comply with the values given in Table 5 or, where applicable, the requirements of the approved specification.

For materials manufactured to a non-approved specification, the materials shall be grouped according to specified minimum tensile strength, and comply with the corresponding requirements of Table 5.

2.4.3 Forgings may be supplied to any specified minimum tensile strength within the general limits given in Table 5 but subject to any restrictions of the relevant construction rules. Where it is proposed to use steel with a specified minimum tensile strength intermediate to those given in Table 5 corresponding minimum values for the other properties may be obtained by interpolation (relative to the specified minimum tensile strength).

**Table 5 Mechanical properties for steel forgings for hull structures and equipment**

<table>
<thead>
<tr>
<th>Steel type</th>
<th>VL Steel grade</th>
<th>Tensile strength $R_m \text{ min.} (N/mm}^2$</th>
<th>Yield strength $R_{eH} \text{ or } R_{p0.2} \text{ min.} (N/mm}^2$</th>
<th>Elongation $A_5 \text{ min.} (%)$</th>
<th>Reduction of area $Z \text{ min.} (%)$</th>
<th>Charpy V-notch $3, 2)\text{ Test temperature} (°C)$</th>
<th>Minimum average energy (J)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Test temperature $3)\text{ (°C)$}</td>
<td>Minimum average energy (J)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>l</td>
<td>t</td>
</tr>
<tr>
<td><strong>C and C-Mn</strong>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>l</td>
<td>t</td>
</tr>
<tr>
<td>F400UW</td>
<td>400</td>
<td>200</td>
<td>26</td>
<td>19</td>
<td>50</td>
<td>35</td>
<td>0</td>
</tr>
<tr>
<td>F440UW</td>
<td>440</td>
<td>220</td>
<td>24</td>
<td>18</td>
<td>50</td>
<td>35</td>
<td>0</td>
</tr>
<tr>
<td>F480UW</td>
<td>480</td>
<td>240</td>
<td>22</td>
<td>16</td>
<td>45</td>
<td>30</td>
<td>0</td>
</tr>
<tr>
<td>F520UW</td>
<td>520</td>
<td>260</td>
<td>21</td>
<td>15</td>
<td>45</td>
<td>30</td>
<td>0</td>
</tr>
<tr>
<td>F560UW</td>
<td>560</td>
<td>280</td>
<td>20</td>
<td>14</td>
<td>40</td>
<td>27</td>
<td>0</td>
</tr>
<tr>
<td>F600UW</td>
<td>600</td>
<td>300</td>
<td>18</td>
<td>13</td>
<td>40</td>
<td>27</td>
<td>0</td>
</tr>
<tr>
<td><strong>Alloy</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>l</td>
<td>t</td>
</tr>
<tr>
<td>F550AW</td>
<td>550</td>
<td>350</td>
<td>20</td>
<td>14</td>
<td>50</td>
<td>35</td>
<td>0</td>
</tr>
<tr>
<td>F600AW</td>
<td>600</td>
<td>400</td>
<td>18</td>
<td>13</td>
<td>50</td>
<td>35</td>
<td>0</td>
</tr>
<tr>
<td>F650AW</td>
<td>650</td>
<td>450</td>
<td>17</td>
<td>12</td>
<td>50</td>
<td>35</td>
<td>0</td>
</tr>
</tbody>
</table>
Metallic materials

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/tangential
2) test direction shall follow the requirements of [1.9]
3) stricter requirements overriding above requirements are given in the relevant design and construction rules for some applications, e.g. windlass components and polar class ships
4) for ships with DAT notation, forgings with maximum 0.80% Ni but otherwise complying with the composition limits of C and C-Mn steels, may follow the yield, tensile and elongation properties requirements for C and C-Mn steels. For impact toughness requirements, see relevant design and construction rules

2.5 Inspection

2.5.1 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 [1.12.6].

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

3 Forgings for shafting and machinery

3.1 Scope

3.1.1 These requirements are supplementary to [1] and apply to steel forgings intended for shafting and machinery construction which are not within the scope of [4] and [5]. Provision is made for carbon and carbon-manganese steels and alloy steels.

3.1.2 Where stainless steel forgings are intended for machinery application, see [8.1.3].

3.1.3 Forgings intended for welding shall either comply with both the chemical composition and mechanical properties requirements given in [2], or just by the chemical composition requirements of [2] but the mechanical properties requirements given in Table 7. For the latter case, the naming of the grade shall be according to Table 7, where the grade name may be appended with MW in brackets, e.g. VL F600U(MW).

3.2 Chemical composition

3.2.1 The chemical composition shall comply with the overall limits given in Table 6 or, where applicable, the requirements of the approved specification.

<table>
<thead>
<tr>
<th>Steel type</th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Cr</th>
<th>Mo</th>
<th>Ni</th>
<th>Cu</th>
<th>Total residuals</th>
</tr>
</thead>
<tbody>
<tr>
<td>C and C-Mn</td>
<td>0.65</td>
<td>0.45</td>
<td>0.30 to 1.50</td>
<td>0.035</td>
<td>0.035</td>
<td>0.30</td>
<td>0.15</td>
<td>0.40</td>
<td>0.30</td>
<td>0.85</td>
</tr>
<tr>
<td>Alloy</td>
<td>0.45</td>
<td>0.45</td>
<td>0.30 to 1.00</td>
<td>0.035</td>
<td>0.035</td>
<td>Minimum 0.40</td>
<td>Minimum 0.15</td>
<td>Minimum 0.40</td>
<td>0.30</td>
<td>-</td>
</tr>
</tbody>
</table>
3.3 Heat treatment

3.3.1 Carbon and carbon-manganese steel forgings shall be supplied in one of the following conditions:
   a) Fully annealed.
   b) normalized
   c) normalized and tempered at a temperature of not less than 550°C
   d) quenched and tempered at a temperature of not less than 550°C.

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

3.3.3 Where forgings for gearing are not intended for surface hardening, lower tempering temperature may be accepted.

3.4 Mechanical testing

3.4.1 Longitudinal tests shall be made but, at the discretion of the manufacturer, alternative tests as shown in Figure 1 to Figure 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.

3.4.2 The mechanical properties shall comply with the values given in Table 7 appropriate to the specified minimum tensile strength or, where applicable, the requirements of the approved specification.

3.4.3 Forgings may be supplied to any specified minimum tensile strength within the general limits given in Table 7 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 7, corresponding minimum values for the other properties may be obtained by interpolation (relative to the specified minimum tensile strength).

Table 7 Mechanical properties for steel forgings for shafting and machinery

<table>
<thead>
<tr>
<th>Steeltype</th>
<th>VL steel grade</th>
<th>Tensile strength $R_m$ min. (N/mm²)</th>
<th>Yield strength $R_p$ or $R_{p0.2}$ min. (N/mm²)</th>
<th>Elongation $A_L$ min. (%)</th>
<th>Reduction of area $Z$ min. (%)</th>
<th>Charpy V-notch $l$, $t$, $l$, $t$</th>
<th>energy, min. average (J)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C and C-Mn</td>
<td>F400U</td>
<td>400</td>
<td>200</td>
<td>26</td>
<td>19</td>
<td>50</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>F440U</td>
<td>440</td>
<td>220</td>
<td>24</td>
<td>18</td>
<td>50</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>F480U</td>
<td>480</td>
<td>240</td>
<td>22</td>
<td>16</td>
<td>45</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>F520U</td>
<td>520</td>
<td>260</td>
<td>21</td>
<td>15</td>
<td>45</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>F560U</td>
<td>560</td>
<td>280</td>
<td>20</td>
<td>14</td>
<td>40</td>
<td>27</td>
</tr>
</tbody>
</table>
### 3.5 Inspection

#### 3.5.1 Magnetic particle (MT) or liquid penetrant testing (PT) of finished machined forgings shall be carried out as specified in the relevant construction rules.

#### 3.5.2 Ultrasonic testing (UT) of forgings shall be carried out as specified in the relevant construction rules.

**Figure 1 Plain shaft**
4 Forgings for crankshafts

4.1 Scope

4.1.1 These requirements are supplementary to [1] and apply to materials for solid forged crankshafts and to the forged throws, webs and pins of semi-built crankshafts. Provision is made for carbon and carbon-manganese steels and alloy steels. Special requirements for clean steel forgings are given in [1.6.10].

4.2 Chemical composition

4.2.1 The chemical composition shall comply with the overall limits given in Table 6 or, where applicable, the requirements of the approved specification.

4.3 Heat treatment

4.3.1 Carbon and carbon-manganese steel forgings shall be supplied in one of the following conditions:
— normalized and tempered at a temperature of not less than 550°C
— quenched and tempered at a temperature of not less than 550°C.

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

4.4 Mechanical testing

4.4.1 For solid forged crankshafts, one set of longitudinal tests shall be taken from the driving shaft end of each forging (one of the longitudinal specimen in Figure 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 (i.e. both longitudinal specimens in Figure 4). Where, however, the crank throws are formed by machining or flame cutting from a preforged crankshaft, see also [1.6.6], the second set of tests shall be taken in a tangential direction from material removed from the crank throw at the end opposite the driving shaft end (indicated as transverse specimen in Figure 4). For this test, the material affected by the flame cutting (heat affected zone) shall be completely removed by machining. This Rule does not apply to webs which are cut out of the starting material before the specified heat treatment is applied.

4.4.2 For crankthrow forgings and other forgings where the method of manufacture has been specially approved in accordance with [1.6], the number and position of the tests shall be agreed.

4.4.3 Forgings with mass up to 500 kg each may be batch tested in accordance with [1.10]. For normalized forgings, one set of mechanical test are required for each test unit. For quenched and tempered forgings, two sets are required for each test unit.

4.4.4 The mechanical properties shall comply with the values given in Table 7 appropriate to the specified minimum tensile strength or, where applicable, the requirements of the approved specification.

4.4.5 For forgings which have been batch tested, hardness tests shall be made on at least 10% of the forgings. For the hardness testing, its testing method, position, acceptance criteria shall be agreed with the Society.

4.5 Inspection

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

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

Figure 4 Solid forged crankshaft
5 Forgings for gearing

5.1 Scope

5.1.1 These requirements are supplementary to [1] and apply to steel forgings intended for use in the construction of gearing such as pinions, gear wheels and rims, etc. intended for the drivers and power transmission. Provision is made for carbon and carbon-manganese steels and alloy steels. Special requirements for clean steel forgings are given in [1.6.10].

Requirements for surface hardening, e.g. carburizing, induction hardening and nitriding, is given in Pt.4 Ch.4 Sec.2 [3].

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

5.2 Chemical composition

5.2.1 The chemical composition shall comply with the overall limits given in Table 6 or, where applicable, the requirements of the approved specification.

5.3 Heat treatment

5.3.1 Carbon and carbon-manganese steel forgings not intended for carburising shall be supplied in one of the following conditions:
— normalized and tempered
— quenched and tempered.

Alloy steel forgings not intended for carburising shall be quenched and tempered.

5.3.2 Where forgings for gearing are not intended for surface hardening, tempering shall be carried out a temperature of not less than 480°C.

5.3.3 For forgings intended for surface hardening, the heat treatment depends on the surface hardening process:
— forgings intended for carburized gears shall be supplied in either the fully annealed or the normalized and tempered condition. Tempering temperature shall be not less than 550°C
— forgings intended for induction hardened or nitride hardened gears shall be heat-treated at an appropriate stage (generally by quenching followed by tempering at a temperature not less than 550°C).

Further requirements for surface hardening are given in the relevant construction rules (e.g. Pt.4 Ch.4 Sec.2 [3]).

5.4 Mechanical testing of forgings not intended for carburising

5.4.1 General requirements: These requirements are applicable for finally heat-treated forgings, including induction hardened and nitride hardened forgings. Requirements for carburized forgings are given in [5.5].

The mechanical properties shall comply with the values given in Table 7 appropriate to the specified minimum tensile strength or, where applicable, the requirements of the approved specification.
5.4.2 Pinions: Where the finished machined diameter of the toothed portion exceeds 200 mm, one set of tests shall be taken in tangential direction adjacent to the toothed portion (test position B in Figure 5). Where the dimensions preclude the preparation of tests from this position, tests in a tangential direction shall be taken from the end of the journal (test position C in Figure 5). If, however, the journal diameter is 200 mm or less, longitudinal tests shall be taken (test position A in Figure 5). Where the finished length of the toothed portion exceeds 1250 mm, one set of tests shall be taken from each end.

5.4.3 Small pinions: Where the finished diameter of the toothed portion is 200 mm or less, one set of longitudinal tests shall be taken from the end of the journal (test position A in Figure 5).

![Figure 5 Pinion](image)

\[
L = \text{Length of toothed portion} \\
D = \text{Diameter of toothed portion} \\
d = \text{Journal diameter}
\]

5.4.4 Gear wheels: One set of tangential tests shall be taken, see Figure 6. Where the finished diameter exceeds 2500 mm tests shall be taken from two diametrically opposite positions.

![Figure 6 Gear wheel](image)

5.4.5 Gear wheel rims (made by expanding): One set of tangential tests shall be taken from one of the test positions A in Figure 7. Where the finished diameter exceeds 2500 mm or the mass (as heat-treated but excluding test material) exceeds 3 tonnes, tests shall be taken from two diametrically opposite positions.
Figure 7 Gear rim (made by expanding)

5.4.6 Hollow pinions: One set of tangential tests shall be taken (test position A in Figure 8). Where the finished length of the toothed portion exceeds 1250 mm, tests shall be taken from each end.

Guidance note:
For hollow pinions forged as solid blanks and then drilled/machined; the tangential sample will be transverse to the grain flow, and the requirements for tangential direction given in Table 7 applies. For hollow pinions produced by piercing a blank followed by ring rolling/forging (expanding) over a mandrel, the tangential sample will be parallel to the grain flow and the requirements for longitudinal direction given in Table 7 applies.

---e-n-d---o-f---g-u-i-d-a-n-c-e---n-o-t-e---

Figure 8 Hollow pinion

5.4.7 Batch testing of small forgings: For forgings which have been batch tested in accordance with [1.10], at least one hardness test shall be made on each forging. The variation in hardness in each batch shall not exceed the values specified in Table 8.
Table 8 Permitted Brinell hardness variation

<table>
<thead>
<tr>
<th>Specified minimum tensile strength $R_m$ (MPa)</th>
<th>Accepted maximum difference in hardness (Brinell)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$&lt; 600$</td>
<td>25</td>
</tr>
<tr>
<td>$600 \leq R_m &lt; 900$</td>
<td>35</td>
</tr>
<tr>
<td>$\geq 900$</td>
<td>42</td>
</tr>
</tbody>
</table>

5.4.8 Mechanical properties for small forgings: The mechanical properties shall comply with the values given in Table 7 appropriate to the specified minimum tensile strength or, where applicable, the requirements of the approved specification.

5.5 Testing of forgings intended for carburising

5.5.1 When forgings are to be carburised, sufficient test material shall be provided both for preliminary tests at the forge and for final tests after completion of carburising.

For this purpose at least duplicate sets of test material shall be taken from positions as detailed in [5.4]. Exception from this is given for forgings with integral journals where one set of test specimens is accepted (irrespective of the dimensions or mass of the forging). The latter shall be cut in a longitudinal direction.

The test material shall be machined to a diameter of $D/4$ or 60mm, whichever is less, where $D$ is the finished diameter of the toothed portion.

For preliminary tests at the forge one set of test material shall be given a blank carburizing and heat treatment cycle simulating that which subsequently will be applied to the forging.

For final acceptance tests, the second set of test material shall be blank carburized and heat-treated along with the forgings which they represent.

At the discretion of the forgemaster or gear manufacturer, test samples of larger cross section may be either carburized or blank carburized, but these shall be machined to the required diameter prior to the final quenching and tempering heat treatment. Alternative procedures for testing of forgings which shall be carburized may be specially agreed with the Society.

The mechanical properties shall comply with the values given in Table 7 appropriate to the specified minimum tensile strength or, where applicable, the requirements of the approved specification.

5.5.2 Requirements for the carburizing are given in the relevant construction rules (e.g. Pt.4 Ch.4 Sec.2 [3]).

5.6 Inspection

5.6.1 Magnetic particle or liquid penetrant testing of finished machined forgings shall be carried out as specified in Pt.4 Ch.4 Sec.2 [3].

5.6.2 Ultrasonic testing of forgings shall be carried out as specified in Pt.4 Ch.4 Sec.2 [3].

6 Forgings for boilers, pressure vessels and piping systems

6.1 Scope

6.1.1 These requirements are supplementary to [1] and apply to steel forgings intended for boilers, pressure vessels and piping systems such as flanges, nozzles, valve housings, socket welding and welding neck components etc., where the design temperature is not lower than 0°C. Provision is made for carbon and carbon-manganese steels and alloy steels.
Requirements for forgings for pressure vessel and piping for cold climate is given in Pt.6 Ch.6.

### 6.2 Chemical composition

#### 6.2.1 The chemical composition shall comply with the overall limits given in Table 9 or, where applicable, the requirements of the approved specification.

**Table 9 Chemical composition limits**

<table>
<thead>
<tr>
<th>Steel type</th>
<th>VL steel grade</th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Cr</th>
<th>Mo</th>
<th>Ni</th>
<th>Cu</th>
<th>Al</th>
</tr>
</thead>
<tbody>
<tr>
<td>C and C-Mn</td>
<td></td>
<td>0.23</td>
<td>0.15</td>
<td>0.50</td>
<td>0.50</td>
<td>0.30</td>
<td>0.15</td>
<td>0.45-0.65</td>
<td>0.40</td>
<td>0.30</td>
<td>0.02-0.05</td>
</tr>
<tr>
<td>½Mo</td>
<td>F0.5Mo</td>
<td>0.30</td>
<td>0.50</td>
<td>0.90</td>
<td>0.30</td>
<td>0.30</td>
<td>0.80-1.25</td>
<td>0.80</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1Cr ½Mo</td>
<td>F1Cr0.5Mo</td>
<td>0.20</td>
<td>0.50</td>
<td>0.30</td>
<td>0.30</td>
<td>0.30</td>
<td>0.80-1.25</td>
<td>0.80</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2¼Cr 1Mo</td>
<td>F2.25Cr1Mo</td>
<td>0.15</td>
<td>0.50</td>
<td>0.80</td>
<td>0.80</td>
<td>0.30</td>
<td>2.00-2.50</td>
<td>1.20</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1) Given value is maximum content (by weight) 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
4) total content of residuals for C and C-Mn steels is 0.85%

### 6.3 Heat treatment

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

— normalized
— normalized and tempered at a temperature of not less than 550°C
— quenched and tempered at a temperature of not less than 550°C.

Other delivery conditions may be accepted based on special approval.

#### 6.3.2 Alloy steel forgings shall be normalized and tempered or quenched and tempered at a temperature of not less than 550°C. Alternatively, they may be supplied in the normalized and tempered condition, in which case the specified mechanical properties shall be agreed with the Society. Other delivery conditions may be accepted based on special approval.

### 6.4 Mechanical properties

#### 6.4.1 The mechanical properties shall comply with the values given in Table 10 or, where applicable, the requirements of the approved specification.

#### 6.4.2 For forgings which have been batch tested, hardness tests shall be made on each forging.
### Table 10 Mechanical properties for steel forgings for boilers, pressure vessels and piping systems

<table>
<thead>
<tr>
<th>Steel type</th>
<th>VL steel grade</th>
<th>Yield strength $R_{eH}$ or $R_{p0.2}$ min. (N/mm²)</th>
<th>Tensile strength $R_m$ (N/mm²)</th>
<th>Elongation A5 min. (%)</th>
<th>Reduction of area Z min. (%)</th>
<th>Charpy V-notch min. average energy (J), test temperature 20°C 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C and C-Mn</td>
<td>F450H</td>
<td>240</td>
<td>450 to 600</td>
<td>22</td>
<td>35</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>F490H</td>
<td>275</td>
<td>490 to 640</td>
<td>18</td>
<td>30</td>
<td>27</td>
</tr>
<tr>
<td>Alloy</td>
<td>F0.5Mo</td>
<td>275</td>
<td>480 to 630</td>
<td>18</td>
<td>35</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>F1Cr0.5Mo</td>
<td>275</td>
<td>480 to 630</td>
<td>18</td>
<td>35</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>F2.25Cr1MoN (Normalized)</td>
<td>315</td>
<td>520 to 670</td>
<td>18</td>
<td>35</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>F2.25Cr1MoQT (Quenched + tempered)</td>
<td>380</td>
<td>580 to 730</td>
<td>16</td>
<td>35</td>
<td>27</td>
</tr>
</tbody>
</table>

1) Stricter requirements overruling above requirements may be given in the relevant design and construction rules for some components

### 6.5 Inspection

#### 6.5.1 Quenched and tempered forgings are subject to magnetic particle testing (MT), see [1.12.6], Pt.4 Ch.6 Sec.10 and Pt.4 Ch.7 Sec.7.

#### 6.5.2 Normalized forgings with mass 1000 kg or more and quenched and tempered forgings with mass 500 kg or more are subject to ultrasonic testing (UT).

### 6.6 Pressure testing

#### 6.6.1 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.

### 7 Ferritic steel forgings for low temperature service

#### 7.1 Scope

#### 7.1.1 These requirements are supplementary to [1] 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.

#### 7.2 Chemical composition

#### 7.2.1 The chemical composition shall comply with the overall limits given in Table 11 or, where applicable, the requirements of the approved specification.
7.2.2 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.

Table 11 Chemical composition limits 1) for ferritic steel forgings for low temperature service

<table>
<thead>
<tr>
<th>Steel type</th>
<th>C</th>
<th>Si (0.15 to 0.35)</th>
<th>Mn (0.30 to 0.90)</th>
<th>P</th>
<th>S</th>
<th>Cr 2)</th>
<th>Mo 2)</th>
<th>Ni</th>
<th>Cu 2)</th>
<th>Al 3)</th>
<th>Total residuals</th>
</tr>
</thead>
<tbody>
<tr>
<td>C and C-Mn</td>
<td>0.23</td>
<td>-</td>
<td>0.60 to 1.50</td>
<td>0.030</td>
<td>0.030</td>
<td>0.40</td>
<td>0.10</td>
<td>0.80</td>
<td>-</td>
<td>-</td>
<td>0.60</td>
</tr>
<tr>
<td>3 ½ Ni</td>
<td>0.20</td>
<td>0.030</td>
<td>0.025</td>
<td>0.025</td>
<td>0.25</td>
<td>0.08</td>
<td>3.25 to 3.75</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 Ni</td>
<td>0.12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4.70 to 5.30</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 Ni</td>
<td>0.10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8.50 to 10.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1) Given value is maximum content (by weight) 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 [7.2.2]

7.3 Heat treatment

7.3.1 Carbon and carbon-manganese steel forgings shall be supplied in one of the following conditions:
— normalized
— normalized and tempered at a temperature of not less than 550°C
— quenched and tempered at a temperature of not less than 550°C
— other delivery conditions may be accepted based on special approval.

7.3.2 Alloy steel forgings shall be normalized and tempered, double normalized and tempered, or quenched and tempered at a temperature of not less than 550°C. Other delivery conditions may be accepted based on special approval.

7.4 Mechanical properties

7.4.1 The mechanical properties shall comply with the values given in Table 12 or, where applicable, the requirements of the approved specification.

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

Table 12 Mechanical properties for ferritic steel forgings for low temperature service

<table>
<thead>
<tr>
<th>Steel type</th>
<th>VL steel grade</th>
<th>Yield strength $R_{el}$ or $R_{p0.2}$ minimum (N/mm²)</th>
<th>Tensile strength $R_m$ minimum (N/mm²)</th>
<th>Elongation A5 minimum (%)</th>
<th>Reduction of area Z minimum (%)</th>
<th>Charpy V-notch Test temperature (°C)</th>
<th>Minimum average energy (J)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C and C-Mn</td>
<td>F450L</td>
<td>240</td>
<td>450 to 600</td>
<td>22</td>
<td>40</td>
<td>-60 1)</td>
<td>27</td>
</tr>
</tbody>
</table>
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**Metallic materials**

<table>
<thead>
<tr>
<th>Nickel alloy</th>
<th>F490L</th>
<th>275</th>
<th>490 to 640</th>
<th>20</th>
<th>40</th>
<th>-60</th>
<th>27</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F3.5Ni</td>
<td>275</td>
<td>490 to 640</td>
<td>20</td>
<td>35</td>
<td>-95</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>F5Ni</td>
<td>380</td>
<td>540 to 690</td>
<td>20</td>
<td>35</td>
<td>-110</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>F9Ni</td>
<td>480</td>
<td>640 to 790</td>
<td>18</td>
<td>35</td>
<td>-196</td>
<td>34</td>
</tr>
</tbody>
</table>

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

### 7.5 Inspection

**7.5.1** Quenched and tempered forgings are subject to magnetic particle testing (MT), see [1.12.6] and the relevant construction rules.

**7.5.2** Normalized forgings with mass 1000 kg or more and quenched and tempered forgings with mass 500 kg or more are subject to ultrasonic testing (UT).

### 7.6 Pressure testing

**7.6.1** 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.

### 8 Stainless steel forgings

#### 8.1 Scope

**8.1.1** These requirements are supplementary to [1] and apply to martensitic, martensitic-austenitic, precipitation hardened, ferritic, ferritic-austenitic (duplex) and austenitic stainless steel forgings, including austenitic steel forgings intended for use in the construction of cargo tanks and piping systems for liquefied gases and chemicals.

**8.1.2** Stainless steel forgings shall be in accordance with recognised standards, e.g. EN 10222, ASTM A473/A965/A1049 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, see Ch.1 Sec.1 [3.4].

**8.1.3** Where stainless steel forgings are intended for machinery application, 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.

#### 8.2 Manufacture

**8.2.1** 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.

#### 8.3 Mechanical properties

**8.3.1** 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.
8.4 Inspection

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

9 Bolts and nuts

9.1 Scope

9.1.1 This sub-section specifies the requirements for bolts and nuts to be used in essential equipment e.g.:
— boilers, vessels, equipment and pipelines
— diesel engines, gears, shafting and propellers
— rudder couplings
— other components for which proof of quality is required as specified in the rules.
Provision is made for carbon and carbon-manganese, alloy, and stainless steels.

9.1.2 The choice of bolts and nuts, together with the form of the requisite material test certificate is set out in the individual chapters of the construction rules.
Requirements for bolts and nuts not covered by this section, as well as for washers, shall comply with the relevant design and construction rules.

9.2 Materials

9.2.1 Bolts and nuts shall be in accordance with recognised standards, as given in [9.2.2]. Recognition of other standards is subject to submission to the Society for evaluation.

9.2.2 Recognized standards for bolts and nuts and materials for bolts and nuts:
— ISO 898 (EN 20898-1 and -2) up to M39 threads. Exempted thereof are bolts of strength categories for which the standard gives no data in respect of impact energy
— ISO 3506-1 and -2 for stainless steel fasteners
— Steels conforming to EN 10269.

Guidance note:
Bolt and nut materials complying with other standards may be accepted by the Society provided the materials are proved suitable.
As an example, materials in accordance with DIN 267-13 may be accepted for general, low temperature and elevated temperature application.

9.2.3 Where required by the relevant design and construction parts of the rules, bolts and nuts shall comply with the requirements of Ch.1, of Sec.1 and this subsection.

9.2.4 Where the use of material with differing requirements is proposed conforming to other standards or the manufacturer’s material specifications, 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 for alternative materials:
— relevant standard/specification and grade
— manufacturing process
— chemical composition
— heat treatment/delivery condition
— test units and number of tests
— mechanical properties: Unless otherwise specified, the materials shall satisfy the requirements of [9.7]
— non-destructive testing.

Further particulars may be required as relevant for the approval. Requirements for approval of manufacturer and certification of materials shall follow Ch.1.

9.3 Manufacture

9.3.1 The starting materials for processing of bolts and nuts covered by this sub-section shall comply with a recognized standard, e.g. EN 10269 and DIN 267-13.

9.3.2 Bolts and nuts may be manufactured by hot or cold forming such as pressing, or rolled/forged bars with subsequent machining according to a recognized standard.

Surface smoothing and rolling of the thread are not regarded as cold forming within the meaning of this paragraph.

9.3.3 For threads exceeding M39 forged semi-finished products shall be used.

9.4 Chemical composition

9.4.1 The chemical composition shall comply with the limits given in Table 6, or the approved standards or specification.

9.5 Heat treatment

9.5.1 Cold formed bolts shall be subjected to subsequent heat treatment. The same applies to hot formed bolts and nuts with the exception of those made of quenched and tempered steels, provided that the latter shall be used at normal ambient temperatures and the hot forming process results in a uniform structure.

9.5.2 Bolts and nuts shall be in the heat-treated condition specified for the material in order to achieve the minimum values. The material shall not undergo unacceptable embrittlement up to the maximum temperature occurring in service. In the case of steels tough at sub-zero temperatures, it shall exhibit toughness even at the minimum design temperature. In the case of quenched and tempered steels, the tempering temperature shall always be a reasonable amount above the maximum in-service temperature.

9.6 Test units and number of tests

9.6.1 Test units: Unless stricter requirements are specified in the standard for test preparation of bolts, the same type and strength category or made from the same material shall be grouped into test batches in accordance with Table 13 with the additional requirements as follows when relevant:
— for nuts with thread diameters ≤ 39 mm and quantities ≤ 200; at least 2 nuts shall be tested
— if proof is furnished that the bolts or nuts in a delivery originate from one heat and have undergone the same heat treatment, testing of four sets of specimens is sufficient, regardless of the quantity supplied.

Testing of the starting material is applicable for:
— nuts with nominal thread diameters ≥ 39 mm
— where after machining, heat treatment is not required and the starting material is in the final heat treated condition.

In such case steel bars from the same heat and with the same diameter and heat treatment shall be grouped into test batches not exceeding 5000 kg each.
Where machining is followed by heat treatment, testing on the finished product is required.

**Table 13 Batch sizes for the testing of mechanical properties**

<table>
<thead>
<tr>
<th>Quantity</th>
<th>No. of sets of specimens for mechanical testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 200</td>
<td>1</td>
</tr>
<tr>
<td>201 to 400</td>
<td>2</td>
</tr>
<tr>
<td>401 to 800</td>
<td>3</td>
</tr>
<tr>
<td>801 to 1200</td>
<td>4</td>
</tr>
<tr>
<td>1201 to 1600</td>
<td>5</td>
</tr>
<tr>
<td>1601 to 3500</td>
<td>6</td>
</tr>
<tr>
<td>&gt; 3500</td>
<td>7</td>
</tr>
</tbody>
</table>

9.6.2 Number of tests: The tests required for each test batch are indicated as follows:

a) testing of the starting material for bolts, when required
   — one tensile test and one set of Charpy V-notch tests

b) testing of bolts
   — one tensile test, and for thread diameters ≥ 16 mm one set of Charpy V-notch impact tests. Turned tensile test specimen may be accepted, see Figure 9

c) testing of nuts with nominal thread diameters ≤ 39 mm
   — one expansion test. For the expansion test a mandrel with a 1:100 taper shall be used, see Figure 10. Before testing, the nuts shall be drilled out to the thread outside diameter. Alternatively, testing in accordance with the referred standard is accepted, see [9.2.2]

d) testing of nuts with nominal thread diameters > 39 mm
   — testing of starting material is sufficient, see 1)

e) testing of bolts and nuts
   — at least 20 pieces shall be subjected to hardness testing by the manufacturer. For quantities ≤ 200 at least 10 pieces shall be tested

f) testing of bolts and nuts intended for elevated temperature application
   — the 0.2% or 1% proof stress shall be verified on one specimen per test batch. The test may be dispensed with when the manufacturer has proven the elevated temperature mechanical properties within the manufacturer approval testing.

9.6.3 Tensile test: For the tensile test, specimens may be machined from the sample material. Specimens of the type shown in Figure 9 may be used, or specimens in accordance with the standards referred in [9.2.2].
9.7 Mechanical properties

9.7.1 Bolts and nuts conforming to the standards specified in [9.2.2] shall meet the mechanical properties set out in these standards.

9.7.2 Except as specified in [9.7.3] to [9.7.5], steels for bolts and nuts with nominal thread diameters > M39 shall have the characteristic values of the material and shall fulfil with longitudinal specimen direction:
— elongation A ≥ 14%,
— impact energy ≥ 52 J for quenched and tempered steels
— impact energy ≥ 40 J for unalloyed steels.

Test temperature is 25°C +/-5 unless otherwise specified in the rules.

9.7.3 Steels for low temperature service for bolts and nuts which are to be used in the construction of gas tanks shall achieve an impact energy ≥ 41 J for longitudinal specimen direction. Test temperature is as per Table 12.

9.7.4 Steels for bolts and nuts intended for foundation of e.g. engine, gear, bearing, propulsion plant, and with nominal thread diameters > M39 as well as according to [9.2.4] shall have the characteristic values of the material and shall fulfill with longitudinal specimen direction the requirements as per Table 7.

9.7.5 Steel bolts for machinery intended for polar class ships, with dimension sufficient for full size Charpy V-notch test shall be tested as follows:
Steel bolts and nuts exposed to sea water or sea water temperature shall be tested at -10°C, e.g. propeller hub and blade bolts, and obtain a value ≥ 27J (longitudinal direction).
Materials of essential bolts exposed to low air temperature shall be tested at 10°C below the lowest design temperature, unless otherwise approved, and obtain a value ≥ 27J (longitudinal direction).

9.7.6 The procedures used for all mechanical tests including retests shall be in accordance with the appropriate requirements of Ch.1.
Where during hardness testing, inspection or non-destructive testing one of the test specimens fails to meet the requirements, a further random sample of 20 specimens (or 10 specimens in the case of quantities ≤ 200) shall be taken, of which all the test specimens shall satisfy the requirements. Otherwise the entire test batch shall be regarded as unacceptable.
For the hardness test, the manufacturer may present this batch for retesting of all tests and inspections after a further heat treatment. If these test specimens still fail to satisfy the requirements, the entire batch shall be rejected for once and for all.

9.8 Inspection

9.8.1 Surface finish and dimensions: The surface finish, dimensions and compliance with tolerances shall be verified by the manufacturer on at least 20 bolts or nuts of each batch, and on at least 10 bolts or nuts in the case of batch sizes of ≤ 200.
If decided as necessary by the surveyor, he performs random checks on the above.

Guidance note:
Special consideration should be given to specifics which influence the effectiveness of the final bolted joint, due to e.g. insufficient contact surfaces, thus resulting in loss of friction. Such aspects are surface finish and quality, e.g. roughness, cleanliness (no rust) and - where applicable - coating. Other specifics concern the geometry, e.g. thread type, angularity and required parallelism between nut face and flange face.

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9.8.2 Non-destructive tests: Non-destructive testing of bolts and nuts shall be carried out as specified in the relevant construction rules.

9.9 Marking

9.9.1 Bolts and nuts shall be marked with the manufacturer's symbol and with the strength category or the steel grade, as well as with the heat number in the case of bolts of M52 size and above. Bolts of M52 size and
above shall be individually marked with the Societies stamp, which in all other cases shall be applied to the packing label.

**9.9.2** Steel bars over 25 mm in diameter for the machining of bolts and nuts shall be marked at one end with the manufacturer's symbol, the steel grade and the Societies stamp, and alloy steel bars shall be additionally marked with the heat number. Where the diameter of the steel bars is 25 mm or less, it is sufficient to apply the corresponding markings to the label attached to the bundle of bars.
SECTION 7 BARS FOR CHAIN CABLES

1 General

1.1 Scope

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

1.2 Certification requirements

1.2.1 General certification requirements are given in Sec.1 [3.1].

1.2.2 The manufacturer shall provide the type of 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.

1.3 Documentation requirements

1.3.1 General documentation requirements are given in Sec.1 [3.2].

1.4 Survey, inspection and testing requirements

1.4.1 General survey, inspection and testing requirements are given in Ch.1 Sec.1 [3.3]. Additional specific requirements are given in Table 1, as further detailed in this section.

Table 1 Additional survey and testing requirements

<table>
<thead>
<tr>
<th>Survey, inspection and testing item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical composition</td>
<td>Required for all materials</td>
</tr>
<tr>
<td>Mechanical testing</td>
<td>Required for all grades</td>
</tr>
<tr>
<td>Impact toughness test</td>
<td>Relevant where specified in the following paragraphs</td>
</tr>
<tr>
<td>Surface inspection</td>
<td>Surface inspection is the responsibility of the manufacturer</td>
</tr>
<tr>
<td>Dimensions and tolerances</td>
<td>Measurements of dimensions are the responsibility of the manufacturer</td>
</tr>
<tr>
<td>Repair</td>
<td>Surface defects may be repaired by grinding provided the tolerances given herein are not exceeded</td>
</tr>
</tbody>
</table>
1.5 Manufacture

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

1.6 Chemical composition

1.6.1 The chemical composition of each heat shall be determined and comply with the overall limits given in Table 2 and, where applicable, the approved specification.

1.7 Mechanical properties

1.7.1 The mechanical properties shall comply with the requirements given in Table 2.

1.8 Heat treatment

1.8.1 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 2.

Table 2 Material requirements for bars for chain cables

<table>
<thead>
<tr>
<th>Grade</th>
<th>VL K1</th>
<th>VL K2</th>
<th>VL K3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deoxidation and fine-grain treatment</td>
<td>Killed</td>
<td>Killed, fine-grain treated with Al</td>
<td>Killed, fine-grain treated</td>
</tr>
<tr>
<td>Heat treatment for finished chain cables</td>
<td>As welded or normalized</td>
<td>As welded or normalized</td>
<td>Quenched and tempered, normalized, or normalized and tempered</td>
</tr>
<tr>
<td>Chemical composition 1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon (%)</td>
<td>Maximum 0.20</td>
<td>Maximum 0.24</td>
<td>Maximum 0.33</td>
</tr>
<tr>
<td>Manganese (%)</td>
<td>0.40 to 1.60</td>
<td>0.50 to 1.60</td>
<td>0.60 to 1.90</td>
</tr>
<tr>
<td>Silicon (%)</td>
<td>0.15 to 0.35</td>
<td>0.15 to 0.55</td>
<td>0.15 to 0.55</td>
</tr>
<tr>
<td>Phosphorus (%)</td>
<td>Maximum 0.040</td>
<td>Maximum 0.035</td>
<td>Maximum 0.035</td>
</tr>
<tr>
<td>Sulphur (%)</td>
<td>Maximum 0.040</td>
<td>Maximum 0.035</td>
<td>Maximum 0.035</td>
</tr>
<tr>
<td>Aluminium (%)</td>
<td>-</td>
<td>0.020 to 0.065</td>
<td>0.020 to 0.065 2)</td>
</tr>
<tr>
<td>Nitrogen (%)</td>
<td>-</td>
<td>-</td>
<td>Maximum 0.015</td>
</tr>
<tr>
<td>Mechanical properties</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yield strength $R_{eth}$ or proof stress $R_{p0.2}$ (MPa)</td>
<td>-</td>
<td>Minimum 295</td>
<td>Minimum 410</td>
</tr>
<tr>
<td>Tensile strength $R_m$ (MPa)</td>
<td>370 to 490</td>
<td>490 to 690</td>
<td>Minimum 690</td>
</tr>
<tr>
<td>Elongation A5 (%)</td>
<td>Minimum 25</td>
<td>Minimum 22</td>
<td>Minimum 17</td>
</tr>
<tr>
<td>Reduction of area Z (%)</td>
<td>-</td>
<td>-</td>
<td>Minimum 40</td>
</tr>
</tbody>
</table>

1) Chemical composition

2) Values for Aluminium and Phosphorus are maximum for Grade VL K3.
2 Testing

2.1 Test units, test material and number of tests

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

2.1.2 Test material shall consist of a suitable length from one bar in each test unit. Where chain cables are supplied in the as-rolled condition, see [1.8.1], the test material shall be simulated heat-treated in full cross-section. Test material shall be suitably marked for identification with the bars represented.

2.1.3 For each test unit, one tensile and, where required, three Charpy V-notch test specimens 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 specimen which was originally approximately perpendicular to the rolled surface.

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

2.2 Mechanical properties

2.2.1 The mechanical properties shall comply with the values given in Table 2.

2.2.2 If the results do not meet the specified requirements the re-test procedures in Ch.1 Sec.2 [3.7] 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.

3 Inspection, tolerances and repair

3.1 Inspection and tolerances

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

3.1.2 The diameter and roundness shall be within the tolerances given in Table 3.

Table 3 Dimensional tolerance of rolled bars

<table>
<thead>
<tr>
<th>Nominal diameter (mm)</th>
<th>Tolerance on diameter (mm)</th>
<th>Tolerance on roundness ( (d_{\text{max}} - d_{\text{min}}) ) (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 25</td>
<td>-0 / +1.0</td>
<td>0.6</td>
</tr>
<tr>
<td>25 to 35</td>
<td>-0 / +1.2</td>
<td>0.8</td>
</tr>
<tr>
<td>36 to 50</td>
<td>-0 / +1.6</td>
<td>1.1</td>
</tr>
<tr>
<td>Range</td>
<td>Tolerance</td>
<td>Width</td>
</tr>
<tr>
<td>------------</td>
<td>-------------</td>
<td>--------</td>
</tr>
<tr>
<td>51 to 80</td>
<td>-0 / +2.0</td>
<td>1.5</td>
</tr>
<tr>
<td>81 to 100</td>
<td>-0 / +2.6</td>
<td>1.95</td>
</tr>
<tr>
<td>101 to 120</td>
<td>-0 / +3.0</td>
<td>2.25</td>
</tr>
<tr>
<td>121 to 160</td>
<td>-0 / +4.0</td>
<td>3.00</td>
</tr>
</tbody>
</table>

3.2 Repair

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

4 Identification

4.1 Marking

4.1.1 The minimum markings required for the bars are:
- the manufacturer's brand mark
- the steel grade
- 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.
SECTION 8 STEEL CASTINGS

1 General requirements

1.1 Scope

1.1.1 Requirements for steel castings to be used in the construction of hulls, equipment, machinery, boilers, pressure vessels and piping systems are specified.

1.1.2 Where required by the relevant design and construction parts of the rules, steel castings shall comply with the requirements of Ch.1, of Sec.1, the general requirements of [1] and the appropriate specific requirements of [2] to [7]. If the specific requirements differ from the general requirements, the specific requirements shall prevail.

1.1.3 As an alternative to [1.1.2], 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, see Ch.1 Sec.1 [3.4]. As a minimum the following particulars shall be specified:

— manufacturing process
— chemical composition
— heat treatment
— mechanical properties
— non-destructive testing.

For machinery components, see also Pt.4.

1.2 Certification requirements

1.2.1 General certification requirements are given in Sec.1 [3.1]. Additional certification requirements for materials covered by this section are given in [1.2.2] and [1.2.3]

1.2.2 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:

— purchaser’s name, order number and vessel identification, where known
— manufacturer’s name
— description of castings and steel quality
— identification marking of castings
— steel making process, heat number and chemical composition
— details of heat treatment, including temperatures and soaking time
— results of mechanical tests
— results of non-destructive tests, where applicable
— test pressure, where applicable
— results of any supplementary and additional test requirements specified.

1.2.3 For propeller castings, the following additional information shall be given:

— drawing number
— diameter, number of blades, pitch, direction of turning
— skew angle for high skew propellers
— final mass
— records of weld repairs.
1.3 Documentation requirements

1.3.1 General documentation requirements are given in Sec.1 [3.2]. Additional product specific documentation requirements are given in Table 1, and additional manufacturer specific documentation requirements are given in Table 2.

Table 1 Documentation requirements – products required to be certified

<table>
<thead>
<tr>
<th>Object</th>
<th>Documentation type</th>
<th>Additional description</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel material</td>
<td>M010 – Material specification, metals</td>
<td>Castings for crankshafts and connecting rods</td>
<td>F1</td>
</tr>
</tbody>
</table>

Table 2 Qualification documentation manufacturer

<table>
<thead>
<tr>
<th>Item</th>
<th>Documentation type</th>
<th>Additional description</th>
</tr>
</thead>
</table>
| Castings                                       | VL or W cCertificate or TR | — the content of grain refining elements shall be reported  
|                                                |                     | — elements designated as residual elements in the individual specifications shall be reported  |
| Castings subject to flame-scarfing or arc-air gouging | Carbon equivalent documentation | Steel casting with carbon equivalent $C_{eq} \geq 0.40$ shall be preheated before flame-scarfing or arc-air gouging |
| Castings subject to major repair by welding    | Z250 - Procedure    | Proposals for major weld repairs shall be accompanied a tailor-made procedure including sketches or photographs showing the extent and positions of the repairs. Special attention should be paid to the high stress areas. A grain refining heat treatment shall be given to the whole casting prior to major repairs, unless otherwise approved. The procedure shall be approved case by case |
| Castings subject to minor repair by welding and where local stress relieving is intended | Z250 - Procedure | Proposal and procedure for local stress relieving heat treatment. Subject to prior approval, local stress relieving heat treatment may be accepted for minor repairs. The proposal shall justify the need for local stress relieving rather than full stress relieving |
| Castings subject to minor repair by welding and where omission of stress relieving is intended | Z250 - Procedure | Proposal for omission of stress relieving heat treatment. 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  
|                                                |                     | — documentation of low operating stress  
|                                                |                     | — documentation showing that the combination of material and welding procedure gives minimized residual stress and hardness |

1.3.2 For general requirements to documentation including definitions, see Pt.1 Ch.3.
1.4 Survey, inspection and testing requirements

1.4.1 General survey, inspection and testing requirements are given in Ch.1 Sec.1 [3.3]. Additional specific requirements are given in Table 3, as further detailed in this section.

Table 3 Additional survey and testing requirements

<table>
<thead>
<tr>
<th>Survey, inspection and testing item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical composition</td>
<td>Required for all materials</td>
</tr>
<tr>
<td>Mechanical testing</td>
<td>Required for all grades in accordance with the requirements of the relevant section</td>
</tr>
<tr>
<td>Impact toughness test</td>
<td>Relevant for all grades where specified in the following sections.</td>
</tr>
<tr>
<td>Impact toughness test of austenitic steel castings</td>
<td>Charpy V-notch impact testing may be omitted if the design temperature is above –105°C</td>
</tr>
<tr>
<td>Test unit for large castings</td>
<td>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</td>
</tr>
<tr>
<td>Test unit for castings made from two or more heats</td>
<td>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</td>
</tr>
<tr>
<td>Visual inspection</td>
<td>The manufacturer shall carry out visual inspection of all casting on accessible surfaces for surface finish and compliance with the dimensional and geometrical tolerances</td>
</tr>
<tr>
<td>Visual survey</td>
<td>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</td>
</tr>
</tbody>
</table>
| NDT                                                                    | — castings shall be subject to non-destructive testing as specified in [2] to [7] and shall comply with given requirements. In addition, the relevant construction rules shall be referred for non-destructive testing of finished machined components  
— 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 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  
— where certification by the Society is required, the surveyor may request to be present during NDT |
| NDT of repairs | — complete elimination of the defective material shall be verified by MT or PT. This applies also for areas which will be subsequently repaired by welding  
— all repaired areas shall be subject to NDT as specified in [1.12] |
| NDT of Propellers | The Society may require NDT such as RT or UT for verification of internal soundness. The extent, method and acceptance criteria shall be agreed between the manufacturer and the Society |
| Pressure test | Pressure retaining castings shall be tested after machining to the test pressure required by the relevant design and construction parts of the rules |

### 1.5 Grading system

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

#### 1.5.2 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.

**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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### 1.6 Manufacture

#### 1.6.1 All castings delivered with VL or works certificate shall be made at foundries approved by the Society.

#### 1.6.2 Steel shall be manufactured by an electric or one of the basic oxygen processes or any other process involving secondary refining. All castings shall be made from killed steel unless otherwise approved.

#### 1.6.3 All flame cutting, scarfing or arc-air gouging to remove surplus metal shall be undertaken in accordance with recognized good practice and, unless otherwise agreed, shall be carried out before the final heat treatment. Preheating shall be employed when necessitated by the chemical composition or thickness of the castings. The affected areas shall be either machined or ground smooth.

#### 1.6.4 Where two or more castings are joined by welding to form a composite item, welding workshop approval is required. The welding procedure specification shall be submitted for approval. Welding procedure qualification testing shall follow the requirements of Ch.4 Sec.5 unless otherwise approved.

The welding procedure specification shall comply with the corresponding requirements of the approved drawing.

### 1.7 Chemical composition

#### 1.7.1 The chemical composition of each heat shall be determined by the manufacturer, and shall be within the specified limits. The sample for chemical composition shall preferably be taken during the pouring.
1) Where one heat is tapped into one or more ladles before pouring into the moulds, the heat analysis shall be determined.
2) Where multiple heats are tapped and mixed in a ladle before pouring into the mould, the ladle analysis shall be determined.
3) Where multiple heats are poured into one mould, without first being mixed in one ladle, the chemical composition of each heat (a) or each ladle (b) shall be determined preferably during pouring.

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

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

1.8 Heat treatment

1.8.1 All castings shall be heat-treated as specified in [2] to [7].

1.8.2 In the case of very large castings alternative methods for heat treatment will be specially considered.

1.8.3 Sufficient thermocouples shall be connected to the furnace charge to measure and record that its temperature is adequately uniform. This requirement does not apply when the temperature uniformity of the furnace is verified according to a recognized standard (e.g. ASTM A991) at regular intervals as agreed with the Society.

1.8.4 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.

1.8.5 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.

Guidance note:
Soaking time at normalizing, quenching and tempering temperature should not be less than one hour per 25.5 mm of the heaviest thickness of the casting, for castings with a thickness up to 127.5 mm. For castings with thickness more than 127.5 mm, at least one hour (or corresponding part thereof) should be added for each addition of 102 mm.

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1.9 Test blocks and test specimens for mechanical testing

1.9.1 Test blocks, from which test specimens are taken, shall be cast integrally with the casting. When this is impracticable, the test blocks shall 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.

If the test block has to be removed from the casting before final heat treatment, e.g. for the purpose of machining, the surveyors shall be invited for witnessing of the process of test block removal before machining and re-welding to the casting after machining but before final heat treatment.

1.9.2 In the case of small castings of about same size and less than 1000 kg in finished mass, the test blocks may alternatively be cast separately provided they are cast from the same heat of steel as the production castings represented and heat-treated with the castings. Separately cast test blocks shall receive substantially the same casting practices as the castings represented.

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

1.9.4 The dimensions of test blocks (integrally cast and separately cast) shall be in accordance with recognised standards but in all cases shall have a thickness of not less than 30 mm. The test specimens shall
be taken with their axis at least 14 mm from the cast surface. If the thickness of the test block is greater than 56 mm, the axis of the test specimen shall be at least one quarter thickness from the cast surface.

1.9.5 For castings where the method of manufacture has been specially approved by the Society, the number and position of test samples shall be agreed with the Society.

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

1.10 Test units and number of tests

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

1.10.2 For small castings of about same size, where each casting is less than 1000 kg in mass, batch testing is permitted and each heat in each heat treatment charge shall be regarded as the test unit.

1.10.3 At least one set of mechanical tests is required for each test unit, except as specified in [1.10.4] and [1.10.5].

1.10.4 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.

1.10.5 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.

1.10.6 Additional requirements for propeller castings are given in [4].

1.11 Mechanical properties

1.11.1 The mechanical properties specified in [2] to [7] refer to test specimens machined from integrally cast or separately cast test blocks and not to the castings themselves.

1.11.2 If the results do not meet the specified requirements, the re-test procedures of Ch.1 Sec.2 [3.7] may be adopted. Where the castings and test blocks are submitted to re-heat treatment, they may not be solution treated or re-austenitized more than twice. All the tests previously performed shall be repeated after re-heat treatment and the results must meet the specified requirements.

1.12 Inspection

1.12.1 The manufacturer shall carry out visual inspection of all casting on accessible surfaces for surface finish and compliance with the dimensional and geometrical tolerances. 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.

1.12.2 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.

1.12.3 When visually inspected, castings shall have a workmanlike finish and 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.
1.12.4 Castings shall be subject to non-destructive testing as specified in [2] to [7] and shall fulfil the following requirements:

1) Personnel: All tests shall be carried out by personnel qualified and certified in accordance with recognised standards or schemes, e.g. ISO 9712 or ASNT Central Certification Program (ACCP). SNT-TC-1A may be accepted if the NDT company’s written practice is reviewed and accepted by the Society.

2) Methods: Non-destructive testing shall be performed in accordance with the general practice of recognised standards, e.g.:
   a) magnetic particle testing (MT): ASTM E709, EN 1369, ISO 17638 (for welds), using wet continuous method
   b) liquid penetrant testing (PT): ISO 3452, ASTM E165, EN 1371-1/2
   c) ultrasonic testing (UT): ASTM A609, ISO 4992-1/2, ISO 17640 (for welds)
   d) radiographic testing (RT): ISO 4993, ISO5579 Class B, ASTM E94
   e) as an alternative to the methods described in 2), methods complying with national or proprietary standards or specifications may be agreed with the Society provided such standards or specifications give reasonable equivalence to the requirements of the listed standards or are especially approved

3) extent and acceptance criteria: The extent of non-destructive testing and the acceptance criteria shall be agreed with the Society
   a) for MT, PT and UT of hull castings, IACS Rec. No.69 is regarded as an example of an acceptable standard
   b) for RT, ASME 16.34 Appendix I is regarded as an example of an acceptable standard
   c) as an alternative to a) and b), acceptance criteria comply with national or proprietary standards or specifications may be agreed with the Society provided such standards or specifications give reasonable equivalence to the requirements of a) or b) or are especially approved.

In addition to this, the construction rules shall be referred for further non-destructive testing requirements.

Guidance note:
Prior to acceptance of the casting by the Society, the ordering information between purchaser and manufacturer regarding NDT should preferably be available for the surveyor. The ordering specification with respect to NDT may typically give reference to recognised standards, and/or specify:
— methods, areas, volume and extent of examination
— documentation requirements
— additional requirements as applicable.

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

1.12.5 The following definitions relevant to MT or PT indications apply (see Figure 1):
**Figure 1 Shape of indications**

- **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. Indications which have any dimension greater than 1.5 mm shall be considered relevant

1.12.6 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, there will always be a risk of subsurface defects appearing on the surface after final machining. The manufacturer should consider this risk and perform suitable intermediate inspections taking into consideration the quality level required in finished condition. The responsibility of the internal quality of the material lies with the manufacturer.

---end---of---guidance---note---

1.12.7 The castings are subject to MT or PT in the following areas:
- at fabrication weld preparations and over a band width of 30 mm from welding edges
- at positions where repair welds are made
- at all accessible fillets and abrupt changes of section
- at positions where surplus metal has been removed by flame cutting, scarfing or arc-air gouging.

1.12.8 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 applies to castings with thickness less than 50 mm.

1.12.9 Unless otherwise required the castings are subject to UT or RT in the following areas:
- in way of fabrication weld preparations for a distance of 50 mm from the edge
- at positions where major repair welds are made
- at any repair welds where the original defect was detected by UT or RT
- at all areas to be subsequently machined, e.g. bores of stern boss castings
- at positions where gates and feeders have been removed.

1.12.10 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.
1.13 Repair

1.13.1 This paragraph gives general requirements for repair of steel castings. Additional requirements for repair of propeller castings are given in [4.7]. Higher requirements may be given for certain castings.

1.13.2 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, provided the remaining thickness is within the given tolerances (including minimum thickness). 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. Surfaces subject to flame-scarfing or air-arc gouging shall be subsequently ground smooth.

Complete elimination of the defective material shall be verified by MT or PT.

Guidance note:
Surface hardening and surface carburizing caused by flame-scarfing or air-arc gouging will typically be removed if it is followed by grinding to a depth of 1 mm or more.

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

1.13.3 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 [1.13.2], 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.

1.13.4 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.

1.13.5 Major weld repairs require the case by case approval of the Society before the repair is commenced. Special attention should be paid to the high stress areas. A tailor-made procedure for each major weld repair shall be prepared including 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.

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.

Cosmetic repair by welding is considered minor weld repairs and shall follow all the requirements for minor weld repairs.

1.13.6 All weld repairs (both minor and major welding repairs) shall be done by qualified welders using approved procedures, see Ch.4.

Guidance note:
Alloy steel castings and crankshafts castings should be suitably pre-heated prior to welding. Castings of carbon or carbon-manganese steels may also need pre-heating depending on chemical composition, dimensions and position of the weld repairs.

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

1.13.7 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
Metallic materials shall be used. Welding consumables shall be stored and handled so as to maintain the hydrogen classification and in accordance with the manufacturer’s recommendations.

1.13.8 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. Unless otherwise agreed, stress relieving heat treatment shall be carried out at a temperature in the range of 550 to 620°C, except for quenched and tempered steels. Quenched and tempered steels shall be stress relieved at a temperature at least 30°C lower than the final tempering temperature, but not below 550°C. The type of heat treatment employed will be dependent on the chemical composition of the casting and the dimensions, positions and nature of the repairs. Subject to prior approval, 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.

1.13.9 On completion of heat treatment the weld repairs and adjacent material shall be ground smooth. All weld repairs are subjected to non-destructive testing as required by [1.12].

1.13.10 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.

1.14 Identification

1.14.1 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
– the VL certificate number, where applicable and as furnished by the surveyor
– test pressure, where applicable.

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

2 Castings for hull structures and equipment

2.1 Scope

2.1.1 The requirements in [2] are supplementary to [1] and apply to steel castings for hull structures and equipment such as stem, stern frames, rudder members, propeller shaft supports, anchors and windlass components. Provision is made for carbon and carbon-manganese steel and alloy steel grades suitable for assembly by welding.

2.1.2 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.

2.2 Chemical composition

2.2.1 The chemical composition shall comply with the overall limits given in Table 4 or, where applicable, the requirements of the approved specification.
### Table 4 Chemical composition limits \(^1\) for steel castings for hull structures and equipment \(^2\)

<table>
<thead>
<tr>
<th>Steel type</th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Cr (^3))</th>
<th>Mo (^3))</th>
<th>Ni (^3))</th>
<th>Cu (^3))</th>
<th>V (^3))</th>
<th>Total residuals</th>
</tr>
</thead>
<tbody>
<tr>
<td>C and C-Mn</td>
<td>0.23 (^4))</td>
<td>0.60</td>
<td>0.50 to 1.60</td>
<td>0.040</td>
<td>0.035</td>
<td>0.30</td>
<td>0.15</td>
<td>0.40</td>
<td>0.30</td>
<td>0.12</td>
<td>0.95</td>
</tr>
<tr>
<td>Alloy</td>
<td>0.25</td>
<td>0.60</td>
<td>0.50 to 1.70</td>
<td>0.035</td>
<td>0.030</td>
<td>Min, 0.40 (^5))</td>
<td>Min, 0.15 (^5))</td>
<td>Min, 0.40 (^5))</td>
<td>0.30</td>
<td>0.12</td>
<td>-</td>
</tr>
</tbody>
</table>

1) given value is maximum content (by weight) 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 6
3) elements are considered as residual elements unless shown as a range or as a minimum
4) an increase is permitted up to maximum 0.30% provided that the Manganese content is reduced to maximum 1.20%
5) one or more of the elements shall comply with the minimum content

### 2.3 Heat treatment

#### 2.3.1 Carbon and carbon-manganese steel castings shall be supplied in one of the following conditions:
- fully annealed
- normalized
- normalized and tempered at a temperature of not less than 550°C
- quenched and tempered at a temperature of not less than 550°C.

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

### 2.4 Mechanical properties

#### 2.4.1 The mechanical properties shall comply with the values given in Table 5 or, where applicable, the requirements of the approved specification.

#### 2.4.2 Where it is proposed to use a steel with a specified minimum tensile strength intermediate to those given in Table 5, corresponding minimum values for the other properties may be obtained by interpolation (relative to the specified minimum tensile strength).

### Table 5 Mechanical properties for steel castings for hull structures and equipment

<table>
<thead>
<tr>
<th>Steel type</th>
<th>VL steel grade</th>
<th>Yield strength (R_{p0.2}) minimum (N/mm(^2))</th>
<th>Tensile strength (R_m) minimum (N/mm(^2))</th>
<th>Elongation A5 minimum (%)</th>
<th>Reduction of area Z minimum (%)</th>
<th>Charpy V-notch impact toughness</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Test temperature (^1) (°C)</td>
</tr>
<tr>
<td>C and C-Mn</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C400UW</td>
<td></td>
<td>200</td>
<td>400</td>
<td>25</td>
<td>40</td>
<td>0</td>
</tr>
<tr>
<td>C440UW</td>
<td></td>
<td>220</td>
<td>440</td>
<td>22</td>
<td>30</td>
<td>0</td>
</tr>
<tr>
<td>C480UW</td>
<td></td>
<td>240</td>
<td>480</td>
<td>20</td>
<td>27</td>
<td>0</td>
</tr>
</tbody>
</table>

Metallic materials

DNV GL AS
Metallic materials

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

1) alternatively, testing at +20°C may be accepted subject to compliance with a specified minimum average energy of 45 J
2) stricter requirements overriding above requirements are given in the relevant design and construction rules for some components. E.g. for cold climate, see Pt.6 Ch.6
3) for ships with DAT notation, castings with maximum 0.80% Ni but otherwise complying with the composition limits of C and C-Mn steels, may follow the yield, tensile and elongation properties requirements for C and C-Mn steels. For impact toughness requirements, see relevant design and construction rules.

2.5 Inspection

2.5.1 The castings shall be subject to magnetic particle and ultrasonic testing, see [1.12].

3 Castings for machinery

3.1 Scope

3.1.1 The requirements in [3] are supplementary to the requirements in [1] and apply to steel castings for machinery construction such as diesel engine components (excluding crankshafts and connecting rods), gears, couplings and windlass components not intended for assembly by welding. Provision is made for carbon and carbon-manganese steels and alloy steels.

3.1.2 Where steel castings are intended for crankshafts or connecting rods, particulars of methods of manufacture, 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.

3.2 Chemical composition

3.2.1 The chemical composition shall comply with the overall limits given in Table 6 or, where applicable, the requirements of the approved specification.

Table 6 Chemical composition limits 1) for steel castings for machinery

Metallic materials

DNV GL AS
3.3 Heat treatment

3.3.1 Carbon and carbon-manganese steel castings shall be supplied in one of the following conditions:
- fully annealed
- normalized
- normalized and tempered at a temperature of not less than 550°C
- quenched and tempered at a temperature of not less than 550°C.

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

3.3.3 Castings for components as specified in Pt.4 and any other castings where dimensional stability and freedom from internal stresses are important, shall be given a stress relief heat treatment. Unless otherwise approved, 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.

3.4 Mechanical properties

3.4.1 The mechanical properties shall comply with the values given in Table 7 or, where applicable, the requirements of the approved specification.

3.4.2 Where it is proposed to use steel with a specified minimum tensile strength intermediate to those given in Table 7, corresponding minimum values for the other properties may be obtained by interpolation.

<table>
<thead>
<tr>
<th>Steel type</th>
<th>Yield strength, (R_{p0.2}) minimum (N/mm²)</th>
<th>Tensile strength, (R_m) minimum (N/mm²)</th>
<th>Elongation, A5 minimum (%)</th>
<th>Reduction of area Z minimum (%)</th>
<th>Charpy V-notch(^1, 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Test temperature (°C)</td>
<td>Minimum average energy (J)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C and C-Mn</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C400U</td>
<td>200</td>
<td>400</td>
<td>25</td>
<td>40</td>
<td>20</td>
</tr>
<tr>
<td>C440U</td>
<td>220</td>
<td>440</td>
<td>22</td>
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<td>20</td>
</tr>
<tr>
<td>C480U</td>
<td>240</td>
<td>480</td>
<td>20</td>
<td>27</td>
<td>20</td>
</tr>
<tr>
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<td>260</td>
<td>520</td>
<td>18</td>
<td>25</td>
<td>20</td>
</tr>
<tr>
<td>C560U</td>
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<td>560</td>
<td>15</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>C600U</td>
<td>320</td>
<td>600</td>
<td>13</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Alloy</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C550A</td>
<td>340</td>
<td>550</td>
<td>16</td>
<td>35</td>
<td>20</td>
</tr>
</tbody>
</table>
3.5 Inspection

3.5.1 The castings are subject to magnetic particle and ultrasonic testing (see [1.12]) as specified in the relevant construction rules.

4 Castings for propellers

4.1 Scope

4.1.1 The requirements are supplementary to the requirements in [1] and apply to stainless steel castings for propellers, blades, hubs and bosses. These requirements may also be used for the repair of propellers damaged in service, subject to prior agreement with the Society.

4.2 Manufacture

4.2.1 Casting shall be performed in dry moulds using degassed liquid metal. The casting process shall be supervised in order to prevent eddies occurring. Special devices or procedures shall be in place to ensure that no slag can enter the mould.

4.3 Chemical composition

4.3.1 The chemical composition shall comply with the overall limits given in Table 8 or, where applicable, the requirements of the approved specification.

4.4 Heat treatment

4.4.1 Martensitic steel castings shall be quenched and tempered. Austenitic steel castings shall be solution heat-treated.

4.5 Mechanical testing

4.5.1 The mechanical properties shall comply with the overall limits given in Table 9 or, where applicable, the requirements of the approved specification.

4.5.2 Test blocks shall be cast integral with the hub of propeller castings, or with the flange of propeller blade castings, or on the blade. The test bars attached on blades shall be located in an area between 0.5R to 0.6R, where R is the radius of the propeller. Removal of test blocks shall be by non-thermal procedures.
4.5.3 One set of tests shall be made on material representing each casting. The mechanical properties shall comply with the values given in Table 9 or, where applicable, the requirements of the approved specification.

4.5.4 As an alternative to [4.5.2] and [4.5.3], batch testing using separately cast test blocks may be adopted for small propellers of about the same size and less than 1 m diameter. For batch testing, one set of tests shall be made for all heat in:

— each furnace charge and
— each multiple of five castings in the batch.

4.6 Inspection

4.6.1 The castings are subject to inspection in accordance with [1.12] and as given in [4.6.2] to [4.6.15].

4.6.2 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:

— zone A is the region where the operation stresses are high
— zone B is a region where the operation stresses may be high
— zone C is a region in which the operation stresses are low and where the blade thicknesses are relatively small.

4.6.3 A distinction shall be made between high skew and low skew propellers. High skew propellers have a skew angle greater than 25°, low skew propellers have a skew angle of up to 25°. 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 Figure 2.

4.6.4 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 CR from the leading edge and 0.2 times CR from the trailing edge respectively, see Figure 3. Where the hub radius (RB) exceeds 0.27 R, the other boundary of zone A shall be increased to 1.5 RB. Zone A also includes the parts of the separate cast propeller hub that are located in the area of the windows as described in Figure 5 and the flange and fillet area of controllable pitch and built-up propeller blades as described in Figure 6.

4.6.5 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 Figure 3.

4.6.6 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 mono-block propeller and all the surfaces of the hub of a controllable pitch propeller other than those designated Zone A above.

4.6.7 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 Figure 4.

4.6.8 Zone B in high skew propellers constitutes the whole of the remaining blade surfaces. See Figure 4.

4.6.9 Bores of bosses of controllable pitch propellers intended for mounting the boss on the propeller shaft shall be classed as Zone “A”. The remaining surface of the blades shall be divided into the zones shown in Figure 3 and Figure 4.
4.6.10 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.

4.6.11 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.

4.6.12 The indications detected may, with respect to their size and number, not exceed the values given in Table 10.

For areas repaired by grinding, 100% re-inspection by PT is required.

For areas repaired by welding and subsequent grinding, independent of the repaired location, 100% PT is required and the repaired areas shall always be assessed according to zone A.

4.6.13 The Society may require NDT such as RT or UT for verification of internal soundness. The extent, method and acceptance criteria are then to be agreed between the manufacturer and the Society.

4.6.14 Minor casting defects which are visible after machining such as small sand and slag inclusions, small cold shuts and scabs shall be trimmed off by the manufacturer, see [4.7].

4.6.15 Casting defects which may impair the serviceability of the castings, e.g. major non-metallic inclusions, shrinkage cavities, blow holes and cracks are not permitted. These may be removed by one of the methods given in [4.7] and repaired within the limits and restrictions for the respective severity zones.

4.7 Repair

4.7.1 Defective castings shall be repaired in accordance with [1.13] and as given in [4.7.2] to [4.7.12].

4.7.2 The foundry shall record all repairs, subsequent heat treatment and inspections traceable to each repaired area for each casting repaired. The records shall be presented to the surveyor on request.

4.7.3 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.

4.7.4 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.

4.7.5 Zone A

Repair by grinding: Grinding in severity zone A may be carried out to an extent that maintains the specified blade thickness.

Repair by welding: Repair welding is not permitted in severity zone A unless allowed after special consideration.

4.7.6 Zone B

Repair by grinding: Defects in severity zone B shall be removed by grinding to a depth of t/40 mm where t is the minimum local thickness according to the rules, or 2 mm, whichever is greatest.

Repair by welding: Deeper defects shall be repaired by welding after grinding to sound material.

4.7.7 Zone C

Repair welding is permitted in severity zone C.
4.7.8 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.

4.7.9 The scope of the welding procedure qualification test is given in Ch.4 Sec.5.

4.7.10 All welding work shall preferably be performed inside the shop, in an atmosphere free from draughts and influence from the weather. Areas for welding shall be clean and dry. Welding consumables shall be stored and handled in accordance with the manufacturer's specification. Slag, undercuts and other imperfections shall be removed before depositing the next run.

4.7.11 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.

4.7.12 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.

4.8 Identification

4.8.1 Castings shall be identified in accordance with [1.14] and with the following additional particulars:
— ice class symbol, where applicable
— skew angle for high skew propellers
— date of final inspection.

4.9 Welding procedure qualification test

4.9.1 Requirements for welding procedure qualification test are given in Ch.4 Sec.5 [14].
Figure 2 Definition of skew angle

Figure 3 Severity zones for low skew propeller and separately cast blades
Figure 4 Severity zones for high skew propellers and separately cast blades

Figure 5 Severity zones for separately cast propeller hubs
**Figure 6** Severity zones for controllable pitch propellers

**Table 8** Chemical composition limits ¹) for steel propeller castings

<table>
<thead>
<tr>
<th>Alloy type</th>
<th>VL steel grade</th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Cr</th>
<th>Mo</th>
<th>Ni</th>
</tr>
</thead>
<tbody>
<tr>
<td>Martensitic</td>
<td>C12Cr1Ni</td>
<td>0.15</td>
<td>1.5</td>
<td>1.0</td>
<td>0.035</td>
<td>0.025</td>
<td>11.5 to 14.0</td>
<td>1.0</td>
<td>0.4 to 2.0</td>
</tr>
<tr>
<td></td>
<td>C13Cr4Ni</td>
<td>0.06</td>
<td>1.0</td>
<td>1.5</td>
<td>0.035</td>
<td>0.025</td>
<td>11.5 to 14.0</td>
<td>1.0</td>
<td>3.5 to 5.0</td>
</tr>
<tr>
<td></td>
<td>C16Cr5Ni</td>
<td>0.06</td>
<td>1.0</td>
<td>1.0</td>
<td>0.035</td>
<td>0.025</td>
<td>15.0 to 17.5</td>
<td>1.5</td>
<td>3.5 to 6.0</td>
</tr>
<tr>
<td>Austenitic</td>
<td>C19Cr11Ni</td>
<td>0.12</td>
<td>1.5</td>
<td>1.5</td>
<td>0.040</td>
<td>0.030</td>
<td>17.0 to 21.0</td>
<td>2.0</td>
<td>9.0 to 13.0</td>
</tr>
</tbody>
</table>

¹) given value is maximum content (by weight) unless shown as a range or as a minimum

**Table 9** Mechanical properties for steel propeller castings

<table>
<thead>
<tr>
<th>Alloy type</th>
<th>VL steel grade</th>
<th>Proof stress $R_{p0.2}$ minimum (N/mm²)</th>
<th>Tensile strength $R_m$ minimum (N/mm²)</th>
<th>Elongation A5 minimum (%)</th>
<th>Reduction of area Z minimum (%)</th>
<th>Charpy V-notch ¹)</th>
<th>Test temperature (°C)</th>
<th>Minimum average energy (J)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Martensitic</td>
<td>C12Cr1Ni</td>
<td>440</td>
<td>590</td>
<td>15</td>
<td>30</td>
<td>–10</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C13Cr4Ni</td>
<td>550</td>
<td>750</td>
<td>15</td>
<td>35</td>
<td>–10</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C16Cr5Ni</td>
<td>540</td>
<td>760</td>
<td>15</td>
<td>35</td>
<td>–10</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Austenitic</td>
<td>C19Cr11Ni</td>
<td>180 ²)</td>
<td>440</td>
<td>30</td>
<td>40</td>
<td>–</td>
<td>–</td>
<td></td>
</tr>
</tbody>
</table>

¹) testing is required only for relevant class notations covered under Pt.6 Ch.6

²) $R_{p1.0}$ value is 205 N/mm²

**Table 10** Allowable number and size of indications depending on severity zones

<table>
<thead>
<tr>
<th>Severity zone</th>
<th>Maximum number of indications</th>
<th>Indication type</th>
<th>Maximum number for each type ¹, ²)</th>
<th>Maximum length of indication (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>7</td>
<td>Non-linear</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Linear or aligned</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>B</td>
<td>14</td>
<td>Non-linear</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Linear or aligned</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>C</td>
<td>20</td>
<td>Non-linear</td>
<td>14</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Linear or aligned</td>
<td>6</td>
<td>6</td>
</tr>
</tbody>
</table>

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
5 Castings for boilers, pressure vessels and piping systems

5.1 Scope

5.1.1 These requirements are supplementary to the requirements in [1] 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. Requirements for castings for pressure vessel and piping for cold climate ships are given in Pt.6 Ch.6.

5.2 Chemical composition

5.2.1 The chemical composition shall comply with the overall limits given in Table 11 or, where applicable, the requirements of the approved specification.

Table 11 Chemical composition limits 1) for steel castings for boilers, pressure vessels and piping systems

<table>
<thead>
<tr>
<th>Steel type</th>
<th>VL steel grade</th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Cr</th>
<th>Mo</th>
<th>Ni</th>
<th>Cu</th>
<th>V</th>
<th>Total residual</th>
</tr>
</thead>
<tbody>
<tr>
<td>C and C-Mn</td>
<td>C450H</td>
<td>0.25</td>
<td>0.60</td>
<td>0.50 to 1.20</td>
<td>0.035</td>
<td>0.035</td>
<td>0.40</td>
<td>0.15</td>
<td>0.40</td>
<td>0.40</td>
<td>0.03</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>C490H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>C0.5Mo</td>
<td>0.23</td>
<td>0.60</td>
<td>0.50 to 1.00</td>
<td>0.035</td>
<td>0.035</td>
<td>0.30</td>
<td>0.40 to 0.65</td>
<td>0.40</td>
<td>0.40</td>
<td>0.05</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>C1Cr0.5Mo</td>
<td>0.20</td>
<td>0.60</td>
<td>0.50 to 1.00</td>
<td>0.035</td>
<td>0.035</td>
<td>1.00 to 1.50</td>
<td>0.45 to 0.65</td>
<td>0.40</td>
<td>0.40</td>
<td>0.05</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>C2.25Cr1Mo</td>
<td>0.20</td>
<td>0.60</td>
<td>0.40 to 0.90</td>
<td>0.035</td>
<td>0.035</td>
<td>2.00 to 2.75</td>
<td>0.90 to 1.20</td>
<td>0.40</td>
<td>0.40</td>
<td>0.05</td>
<td>-</td>
</tr>
</tbody>
</table>

1) given value is maximum content (by weight) 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

5.3 Heat treatment

5.3.1 Carbon and carbon-manganese steel castings shall be supplied in one of the following conditions:
— normalized
— normalized and tempered at a temperature of not less than 550°C.
— quenched and tempered at a temperature of not less than 550°C.

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

5.4.1 The mechanical properties shall comply with the values given in Table 12 or, where applicable, the requirements of the approved specification.

Table 12 Mechanical properties for steel castings for boilers, pressure vessels and piping systems

<table>
<thead>
<tr>
<th>Steel type</th>
<th>VL steel grade</th>
<th>Yield strength $R_{p0.2}$ min. (N/mm²)</th>
<th>Tensile strength $R_m$ (N/mm²)</th>
<th>Elongation A5 min. (%)</th>
<th>Reduction of area Z min. (%)</th>
<th>Charpy V-notch min. average energy (J), at test temperature 20°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>C and C-Mn</td>
<td>C450H</td>
<td>240</td>
<td>450 to 600</td>
<td>22</td>
<td>35</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>C490H</td>
<td>275</td>
<td>490 to 640</td>
<td>18</td>
<td>30</td>
<td>27</td>
</tr>
<tr>
<td>Alloy</td>
<td>C0.5Mo</td>
<td>250</td>
<td>450 to 600</td>
<td>21</td>
<td>35</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>C1Cr 0.5Mo</td>
<td>275</td>
<td>480 to 630</td>
<td>17</td>
<td>35</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>C2.25Cr 1Mo N (Normalized)</td>
<td>275</td>
<td>480 to 630</td>
<td>17</td>
<td>35</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>C2.25Cr1MoQT (Quenched + tempered)</td>
<td>380</td>
<td>580 to 730</td>
<td>16</td>
<td>35</td>
<td>27</td>
</tr>
</tbody>
</table>

5.5 Inspection

5.5.1 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 are 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.

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

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

5.6 Pressure testing

5.6.1 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.

6 Ferritic steel castings for low temperature service

6.1 Scope

6.1.1 These requirements are supplementary to the requirements in [1] 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.
6.2 Chemical composition

6.2.1 The chemical composition shall comply with the limits given in Table 13 or, where applicable, the requirements of the approved specification.

Table 13 Chemical composition limits 1) for ferritic steel castings for low temperature service

<table>
<thead>
<tr>
<th>Steel type</th>
<th>VL steel grade</th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Cr 2)</th>
<th>Mo 2)</th>
<th>Ni</th>
<th>Cu 2)</th>
<th>V 2)</th>
<th>Total residuals</th>
</tr>
</thead>
<tbody>
<tr>
<td>C and C-Mn</td>
<td>C450L</td>
<td>0.25</td>
<td>0.60</td>
<td>1.60</td>
<td>0.035</td>
<td>0.035</td>
<td>0.40</td>
<td>0.15</td>
<td>0.80</td>
<td>0.30</td>
<td>0.03</td>
<td>0.60</td>
</tr>
<tr>
<td></td>
<td>C490L</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alloy</td>
<td>C2.25Ni</td>
<td>0.25</td>
<td>0.60</td>
<td>0.50–0.80</td>
<td>0.035</td>
<td>0.035</td>
<td>0.40</td>
<td>0.15</td>
<td>2.00–3.00</td>
<td>0.30</td>
<td>0.03</td>
<td>0.60</td>
</tr>
<tr>
<td></td>
<td>C3.5Ni</td>
<td>0.15</td>
<td>0.60</td>
<td>0.50–0.80</td>
<td>0.035</td>
<td>0.035</td>
<td>0.40</td>
<td>0.15</td>
<td>3.00–4.00</td>
<td>0.30</td>
<td>0.03</td>
<td>0.60</td>
</tr>
</tbody>
</table>

1) given value is maximum content (by weight) 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

6.3 Heat treatment

6.3.1 Castings shall be supplied in one of the following conditions:
— normalized
— normalized and tempered at a temperature of not less than 550°C
— quenched and tempered at a temperature of not less than 550°C.

6.4 Mechanical properties

6.4.1 The mechanical properties shall comply with the values given in Table 14 or, where applicable, the requirements of the approved specification.

Table 14 Mechanical properties for ferritic steel castings for low temperature service

<table>
<thead>
<tr>
<th>Steel type</th>
<th>VL steel grade</th>
<th>Yield strength $R_{p0.2}$ minimum (N/mm²)</th>
<th>Tensile strength $R_m$ (N/mm²)</th>
<th>Elongation $A_5$ minimum (%)</th>
<th>Charpy V-notch</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Test temperature (°C)</td>
</tr>
<tr>
<td>C and C-Mn</td>
<td>C450L</td>
<td>240</td>
<td>450 to 600</td>
<td>22</td>
<td>-60 1)</td>
</tr>
<tr>
<td></td>
<td>C490L</td>
<td>275</td>
<td>490 to 640</td>
<td>20</td>
<td>-60 1)</td>
</tr>
<tr>
<td>Alloy</td>
<td>C2.25Ni</td>
<td>275</td>
<td>490 to 640</td>
<td>20</td>
<td>-70</td>
</tr>
<tr>
<td></td>
<td>C3.5Ni</td>
<td>275</td>
<td>490 to 640</td>
<td>20</td>
<td>-95</td>
</tr>
</tbody>
</table>

1) the test temperature may be 5°C below the design temperature if the latter is above –55°C, but test temperature shall not be higher than –20°C
6.5 Inspection

6.5.1 For each test unit, at least one casting shall be subjected to magnetic particle testing. As an alternative, where a number of castings representing multiple test units are 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.

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

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

6.6 Pressure testing

6.6.1 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.

7 Stainless steel castings

7.1 Scope

7.1.1 These requirements are supplementary to the requirements in [1] and apply to stainless steel castings for use in piping systems for liquefied gases and chemicals, and cast sleeves and bushings for propeller shafts and rudder stocks.

7.2 Chemical composition

7.2.1 The chemical composition shall comply with the overall limits given in Table 15 or, where applicable, the requirements of the approved specification.

Table 15 Chemical composition limits 1) for stainless steel castings

<table>
<thead>
<tr>
<th>Steel type</th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Cr</th>
<th>Mo</th>
<th>Ni</th>
</tr>
</thead>
<tbody>
<tr>
<td>GX 2 CrNi 18 10 (304L)</td>
<td>0.03</td>
<td>2.0</td>
<td>1.5</td>
<td>0.040</td>
<td>0.030</td>
<td>17.0 to 21.0</td>
<td>-</td>
<td>8.0 to 12.0</td>
</tr>
<tr>
<td>GX 5 CrNi 19 9 (304)</td>
<td>0.08</td>
<td>2.0</td>
<td>1.5</td>
<td>0.040</td>
<td>0.030</td>
<td>18.0 to 21.0</td>
<td>-</td>
<td>8.0 to 11.0</td>
</tr>
<tr>
<td>GX 6 CrNiNb 19 10 (347) 2)</td>
<td>0.08</td>
<td>2.0</td>
<td>1.5</td>
<td>0.040</td>
<td>0.030</td>
<td>18.0 to 21.0</td>
<td>-</td>
<td>9.0 to 12.0</td>
</tr>
<tr>
<td>GX 2 CrNiMo 19 11 2 (316L)</td>
<td>0.03</td>
<td>1.5</td>
<td>1.5</td>
<td>0.040</td>
<td>0.030</td>
<td>17.0 to 21.0</td>
<td>2.0 to 3.0</td>
<td>9.0 to 13.0</td>
</tr>
<tr>
<td>GX 5 CrNiMo19 11 2 (316)</td>
<td>0.08</td>
<td>1.5</td>
<td>1.5</td>
<td>0.040</td>
<td>0.030</td>
<td>17.0 to 21.0</td>
<td>2.0 to 3.0</td>
<td>9.0 to 12.0</td>
</tr>
<tr>
<td>GX 5 CrNiMo19 11 3 (317)</td>
<td>0.08</td>
<td>1.5</td>
<td>1.5</td>
<td>0.040</td>
<td>0.030</td>
<td>17.0 to 21.0</td>
<td>3.0 to 4.0</td>
<td>9.0 to 13.0</td>
</tr>
</tbody>
</table>

1) given value is maximum content (by weight) unless shown as a range or as a minimum
2) niobium content shall be minimum 8 times the carbon content, and maximum 1.00%
7.3 Heat treatment

7.3.1 All steel castings shall be supplied in a heat-treated condition appropriate to the grade of cast steel, e.g. austenitic stainless steel castings shall be supplied in the solution treated condition.

7.4 Mechanical properties

7.4.1 The mechanical properties shall comply with the values given in Table 16 or, where applicable, the requirements of the approved specification.

Table 16 Mechanical properties for stainless steel castings

<table>
<thead>
<tr>
<th>Steel type</th>
<th>Proof stress $R_{p0.2}$ minimum (N/mm²)</th>
<th>Tensile strength $R_m$ minimum (N/mm²)</th>
<th>Elongation $A_5$ minimum (%)</th>
<th>Charpy V-notch</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Test temperature (°C)</td>
<td>Minimum average energy (J)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GX 2 CrNi 18 10 (304L)</td>
<td>180</td>
<td>440</td>
<td>30</td>
<td>-196</td>
</tr>
<tr>
<td>GX 5 CrNi 19 9 (304)</td>
<td>180</td>
<td>440</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>GX 6 CrNiNb 19 10 (347)</td>
<td>180</td>
<td>440</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>GX 2 CrNiMo 19 11 2 (316L)</td>
<td>180</td>
<td>440</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>GX 5 CrNiMo19 11 2 (316)</td>
<td>180</td>
<td>440</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>GX 5 CrNiMo19 11 3 (317)</td>
<td>180</td>
<td>440</td>
<td>30</td>
<td></td>
</tr>
</tbody>
</table>

1) the minimum $R_{p1.0}$ value is 25 N/mm² higher
2) impact tests may be omitted if the design temperature is above $-105^°C$

7.5 Inspection

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

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

7.5.3 All castings repaired by welding shall be non-destructive tested.
SECTION 9 IRON CASTINGS

1 General

1.1 Scope

1.1.1 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.

1.1.2 As an alternative to [1.1.1], 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, see Ch.1 Sec.1 [3.4]. As a minimum the following particulars shall be specified:

— manufacturing process
— chemical composition
— heat treatment
— mechanical properties
— non-destructive testing.

For machinery components, see also Pt.4.

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

1.1.4 General requirements with respect to retesting and identification are outlined in Ch.1 Sec.2 [3.7].

1.2 Certification requirements

1.2.1 General certification requirements are given in Sec.1 [3.1].

1.3 Documentation requirements

1.3.1 General documentation requirements are given in Sec.1 [3.2]. Additional manufacturer specific documentation requirements are given in Table 1.

Table 1 Qualification documentation for manufacturer

<table>
<thead>
<tr>
<th>Item</th>
<th>Documentation type</th>
<th>Additional description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Castings</td>
<td>Z250 - Procedure</td>
<td>Proposal for repair by impregnation. Subject to the prior approval of the surveyor, castings containing local porosity may be rectified by impregnation with suitable plastic filler, provided that the extent of the porosity is such that it does not adversely affect the strength of the casting.</td>
</tr>
</tbody>
</table>
1.4 Survey, inspection and testing requirements

1.4.1 General survey, inspection and testing requirements are given in Ch.1 Sec.1 [3.3]. Additional specific requirements are given in Table 2, as further detailed in this section.

**Table 2 Additional survey and testing requirements**

<table>
<thead>
<tr>
<th>Survey, inspection and testing item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical composition</td>
<td>Required for all materials.</td>
</tr>
<tr>
<td>Mechanical testing</td>
<td>Required for all grades in accordance with the requirements of the relevant section.</td>
</tr>
<tr>
<td>Impact toughness test</td>
<td>Relevant for all grades where specified in the following sections.</td>
</tr>
<tr>
<td>Metallographic examination</td>
<td>For nodular cast iron samples for metallographic examination shall be prepared for every ladle of metal, treated to produce nodular graphite.</td>
</tr>
<tr>
<td>Pressure test</td>
<td>When required by the relevant construction Rules, castings shall be pressure tested before final acceptance.</td>
</tr>
<tr>
<td>Visual inspection</td>
<td>The manufacturer shall carry out visual inspection of all casting on accessible surfaces for surface finish and compliance with the dimensional and geometrical tolerances.</td>
</tr>
<tr>
<td>Visual survey</td>
<td>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.</td>
</tr>
<tr>
<td>Repair</td>
<td>At the discretion of the surveyor, small surface blemishes may be removed by local grinding within the negative tolerance of the wall thickness.</td>
</tr>
</tbody>
</table>

1.5 Quality of castings

1.5.1 All castings shall have a clean surface compatible with the conditions of manufacture. Minor casting defects such as sand and slag marks, small cold shuts and scabs may be trimmed off within the negative tolerance on the wall thickness. The manufacturer shall make sure that the castings are free from external and internal defects liable to impair their subsequent use, including the machining operations, to more than an insignificant extent.

*Guidance note:*
Where it is relevant for purchaser to specify more detailed surface quality requirements, reference should be made to a relevant standard, e.g. EN 1369, EN 1371-1, EN 12680-3 or EN 12681.

---e-n-d-o-f-g-u-i-d-a-n-c-e-n-o-t-e---

1.6 Manufacture

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

1.6.2 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.
1.6.3 Where castings of the same type are regularly produced in quantity, the manufacturer shall, in agreement with the Society, make all 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.

1.7 Chemical composition

1.7.1 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.

1.8 Heat treatment

1.8.1 Except as given in [1.8.2], the castings may be supplied either in the as cast condition or in the heat-treated condition.

1.8.2 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.

1.9 Testing

1.9.1 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.

1.9.2 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. In the case of chill casting, centrifugal casting and continuous casting, special agreements shall be reached with the Society regarding the selection of samples.

1.9.3 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.

1.9.4 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.

1.9.5 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.

1.10 Visual and non-destructive examination

1.10.1 The manufacturer shall do visual inspection of all castings on all accessible surfaces. The castings shall comply with specified surface finish, dimensions and geometrical tolerances. Where applicable, this shall include the inspection of internal surfaces and bores. All surfaces shall be cleaned and adequately prepared for examination. The surfaces shall not be hammered, peened or treated in any way which may obscure defects.

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

1.10.3 NDT other than visual examination is not required unless otherwise specified, e.g. by the applicable design and construction rules.
The surveyor may require areas to be examined by suitable means of NDT for the purpose of investigating the soundness of the casting.

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

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

1.10.6 The surveyor may require areas to be etched for the purpose of investigating weld repairs.

1.11 Repair of defects

1.11.1 At the discretion of the surveyor, small surface blemishes may be removed by local grinding within the negative tolerance of the wall thickness. Castings shall be free from defects liable to impair machining operations and their subsequent use to a more than an insignificant extent.

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

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

2 Nodular cast iron

2.1 Scope

2.1.1 This subsection gives the specific requirements to nodular cast iron

2.2 Test material

2.2.1 Test material, sufficient for the required tests and for possible re-test purposes, shall be provided for each casting or batch of castings.

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

2.2.3 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 according to a recognized standard, e.g. EN1563.

2.2.4 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.

2.2.5 As an alternative to [2.2.3], 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.
Figure 1 Type A test samples (U-type)

Figure 2 Type B test samples (double U-type)
2.2.6 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.

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

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

2.2.9 One tensile test specimen shall be prepared from each test sample and shall be machined to the dimensions given in Ch.1 Sec.3 [3.1.10].

2.2.10 All tensile tests shall be carried out using test procedures in accordance with Ch.1 Sec.3 [3.1]. Unless otherwise agreed all tests shall be carried out in the presence of the surveyor.

2.2.11 Charpy V-notch impact tests are required for grades VL NCI-1 and VL NCI-2, see Table 3. Where impact tests are required for other grades, 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 Sec.3 [3.2].
2.3 Mechanical properties

2.3.1 Ferritic nodular cast iron with special requirements shall meet the values for grade VL NCI-1 and VL NCI-2, given in Table 3.

2.3.2 Nodular cast iron for ordinary use shall be in accordance with the requirements for grades VL NCI370 to VL NVI800, given in Table 3. 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, i.e. relative to the specified minimum tensile strength.

2.3.3 Mechanical properties for integrally cast specimens shall be agreed with the Society.

Table 3 Nodular cast iron - mechanical properties of separately cast test samples

<table>
<thead>
<tr>
<th>Grade</th>
<th>Tensile strength $R_m$ minimum (N/mm²)</th>
<th>Proof stress $R_p0.2$ minimum (N/mm²)</th>
<th>Elongation A5 (%)</th>
<th>Average impact energy, KV</th>
<th>Hardness (HB)</th>
<th>Predominant structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>VL NCI-1</td>
<td>350</td>
<td>220</td>
<td>22</td>
<td>12 (9)</td>
<td>110 to 170</td>
<td>Ferrite</td>
</tr>
<tr>
<td>VL NCI-2</td>
<td>400</td>
<td>250</td>
<td>18</td>
<td>12 (9)</td>
<td>140 to 200</td>
<td>Ferrite</td>
</tr>
<tr>
<td>VL NCI370</td>
<td>370</td>
<td>230</td>
<td>17</td>
<td>-</td>
<td>120 to 180</td>
<td>Ferrite</td>
</tr>
<tr>
<td>VL NCI400</td>
<td>400</td>
<td>250</td>
<td>12</td>
<td>-</td>
<td>140 to 200</td>
<td>Ferrite</td>
</tr>
<tr>
<td>VL NCI500</td>
<td>500</td>
<td>320</td>
<td>7</td>
<td>-</td>
<td>170 to 240</td>
<td>Ferrite/pearlite</td>
</tr>
<tr>
<td>VL NCI600</td>
<td>600</td>
<td>370</td>
<td>3</td>
<td>-</td>
<td>190 to 270</td>
<td>Pearlite/ferrite</td>
</tr>
<tr>
<td>VL NCI700</td>
<td>700</td>
<td>420</td>
<td>2</td>
<td>-</td>
<td>230 to 300</td>
<td>Pearlite</td>
</tr>
<tr>
<td>VL NCI800</td>
<td>800</td>
<td>480</td>
<td>2</td>
<td>-</td>
<td>250 to 350</td>
<td>Pearlite or tempered structure</td>
</tr>
</tbody>
</table>

1) for intermediate values of specified minimum tensile strength, the minimum values for 0.2% proof and elongation may be obtained by interpolation (relative to the specified minimum tensile strength)

2) the 0.2% proof stress values are given for information purposes and unless otherwise agreed do not require to be verified by test. In the case of ferritic grades, the yield point revealed by the curve plotted by the testing machine may be stated instead of the 0.2% proof stress

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 VL NCI-1 and VL NCI-2

2.4 Metallographic examination

2.4.1 Each sample as defined in [2.2] shall be subjected to metallographic examination. At least 90% of the graphite shall be in spheroidal form
3 Grey cast iron

3.1 Scope

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

3.2 Test material

3.2.1 Test material sufficient for the required tests and for possible re-tests shall be provided for each casting or batch of castings.

3.2.2 Separately cast test samples in the form of bars 30 mm in diameter and of a suitable length shall be used unless otherwise agreed between the manufacturer and purchaser. 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. They 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 Figure 4.

![Figure 4 Test sample for grey cast iron](image)
3.2.3 Integrimly cast samples may be used when a casting is more than 20 mm thick and its mass exceed 200 kg, subject to agreement with the Society. The type and location of the sample shall be agreed, e.g. according to a recognized standard like EN 1561.

3.2.4 With the exception of [3.2.7], at least one test sample shall be cast with each batch.

3.2.5 With the exception of [3.2.6], a batch consists of the castings poured from a single ladle of metal, provided they are all of similar type and dimensions. A batch cannot exceed two tonnes of fettled castings. A single casting will constitute a batch if its mass is 2 tonnes or more.

3.2.6 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.

3.2.7 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.

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

3.2.9 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.

3.2.10 One tensile test specimen shall be prepared from each test sample and for 30mm diameter samples shall be machined to the dimensions given in Ch.1 Sec.3 [3.1.11]. Where test samples of other dimensions are specially required, the tensile test specimens shall be machined to agreed dimensions.

3.2.11 All tensile tests shall be carried out using test procedures in accordance with Ch.1 Sec.3 [3.1]. Unless otherwise agreed all tests shall be carried out in the presence of the surveyor.

3.3 Mechanical properties

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

Mechanical properties for integrally cast specimens shall be agreed with the Society.

3.3.2 The fractured surfaces of all tensile test specimens shall be granular and grey in appearance.
SECTION 10 ALUMINIUM ALLOYS

1 Wrought aluminium alloys

1.1 Scope

1.1.1 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.

1.1.2 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 a recognized standard or specification.

1.2 Certification requirements

1.2.1 General certification requirements are given in Sec.1 [3.1].

1.2.2 The product shall be delivered with 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.

1.2.3 Where the alloys are not cast in the same works in which they are made into semi-finished products, a works (W) certificate giving chemical composition is required for each charge. Semi-finished products (ingots or extrusion billets) used as base material for wrought products shall be made at works approved by the Society. The chemical composition analysis produced by the manufacturer is normally accepted (works certificate), with the surveyor reserving the right to have occasional check analyses carried out.

1.3 Documentation requirements

1.3.1 General documentation requirements are given in Sec.1 [3.2]. Additional manufacturer specific documentation requirements are given in Table 1.

Table 1 Qualification documentation for manufacturer

<table>
<thead>
<tr>
<th>Item</th>
<th>Documentation type</th>
<th>Additional description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wrought aluminium alloys</td>
<td>Reference micrographs</td>
<td>When metallographic examination is used as an alternative to corrosion test:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>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</td>
</tr>
</tbody>
</table>
1.4 Survey, inspection and testing requirements

1.4.1 General survey, inspection and testing requirements are given in Ch.1 Sec.1 [3.3]. Additional specific requirements are given in Table 2, as further detailed in this section.

Table 2 Additional survey and testing requirements

<table>
<thead>
<tr>
<th>Survey, inspection and testing item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical composition</td>
<td>Required for all materials.</td>
</tr>
<tr>
<td>Mechanical testing</td>
<td>Required for all grades in accordance with the requirements of the relevant paragraph</td>
</tr>
<tr>
<td>Macrosection test, Drift expansion test</td>
<td>Manufacturer shall verify and document proper fusion of press welds for closed profile extrusions by macrosection tests or drift expansion tests. Other tests may be accepted after consideration. The testing and test results shall be recorded. The surveyor shall be given the opportunity to survey and check the sampling, testing, test laboratory, etc. at any time, and the test records shall be presented to the surveyor on request</td>
</tr>
<tr>
<td>Corrosion test</td>
<td>Rolled 5000 series alloys of certain grades and 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</td>
</tr>
<tr>
<td>Microstructure/metallographic evaluation</td>
<td>As an alternative to corrosion test, the manufacturers may establish the relationship between microstructure and resistance to corrosion, and evaluate corrosion resistance based on photomicrographs</td>
</tr>
<tr>
<td>Visual inspection</td>
<td>Wrought aluminium products shall be subject to visual inspection and measurements of dimensions by the manufacturer</td>
</tr>
</tbody>
</table>

1.5 Materials

1.5.1 Alloy grades suitable for marine environment are listed in Table 3. 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.

1.5.2 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.

As an alternative to [1.5.1], 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 Sec.1 [3.4].

1.5.3 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.
1.6 Manufacture

1.6.1 All wrought aluminium products delivered with VL or works (W) certificate shall be manufactured at works approved by the Society. The semi-finished products (ingots or extrusion billets) used shall be made at works approved by the Society.

1.6.2 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.

1.7 Chemical composition

1.7.1 The chemical composition of each heat shall, unless otherwise agreed, be determined by the manufacturer on a sample taken during the pouring of the heat. The chemical composition shall comply with the limits given in Table 3.

### Table 3 Chemical composition limits ¹) for wrought aluminium alloys

<table>
<thead>
<tr>
<th>Grade</th>
<th>Si</th>
<th>Fe</th>
<th>Cu</th>
<th>Mn</th>
<th>Mg</th>
<th>Cr</th>
<th>Zn</th>
<th>Ti</th>
<th>Other elements ²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Each</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Total</td>
</tr>
<tr>
<td>VL-5052</td>
<td>0.25</td>
<td>0.40</td>
<td>0.10</td>
<td>0.10</td>
<td>2.2 to 2.8</td>
<td>0.15 to 0.35</td>
<td>0.10</td>
<td>-</td>
<td>0.0</td>
</tr>
<tr>
<td>VL-5059</td>
<td>0.45</td>
<td>0.50</td>
<td>0.25</td>
<td>0.6 to 1.2</td>
<td>5.0 to 6.0</td>
<td>0.25</td>
<td>0.40 to 0.9</td>
<td>0.20</td>
<td>0.05 ⁵)</td>
</tr>
<tr>
<td>VL-5083</td>
<td>0.40</td>
<td>0.40</td>
<td>0.10</td>
<td>0.40 to 1.0</td>
<td>4.0 to 4.9</td>
<td>0.05 to 0.25</td>
<td>0.25</td>
<td>0.15</td>
<td>0.05</td>
</tr>
<tr>
<td>VL-5086</td>
<td>0.40</td>
<td>0.50</td>
<td>0.10</td>
<td>0.20 to 0.7</td>
<td>3.5 to 4.5</td>
<td>0.05 to 0.25</td>
<td>0.25</td>
<td>0.15</td>
<td>0.05</td>
</tr>
<tr>
<td>VL-5154A</td>
<td>0.50</td>
<td>0.50</td>
<td>0.10</td>
<td>0.50</td>
<td>3.1 to 3.9</td>
<td>0.25</td>
<td>0.20</td>
<td>0.20</td>
<td>0.05</td>
</tr>
<tr>
<td>VL-5383</td>
<td>0.25</td>
<td>0.25</td>
<td>0.20</td>
<td>0.7 to 1.0</td>
<td>4.0 to 5.2</td>
<td>0.25</td>
<td>0.40</td>
<td>0.15</td>
<td>0.05 ⁴)</td>
</tr>
<tr>
<td>VL-5454</td>
<td>0.25</td>
<td>0.40</td>
<td>0.10</td>
<td>0.50 to 1.0</td>
<td>2.4 to 3.0</td>
<td>0.05 to 0.20</td>
<td>0.25</td>
<td>0.20</td>
<td>0.05</td>
</tr>
<tr>
<td>VL-5456</td>
<td>0.25</td>
<td>0.40</td>
<td>0.10</td>
<td>0.50 to 1.0</td>
<td>4.7 to 5.5</td>
<td>0.05 to 0.20</td>
<td>0.25</td>
<td>0.20</td>
<td>0.05</td>
</tr>
<tr>
<td>VL-5754</td>
<td>0.40</td>
<td>0.40</td>
<td>0.10</td>
<td>0.50 ³)</td>
<td>2.6 to 3.6</td>
<td>0.30 ³)</td>
<td>0.20</td>
<td>0.15</td>
<td>0.05</td>
</tr>
<tr>
<td>VL-6005A</td>
<td>0.50 ⁶)</td>
<td>0.35</td>
<td>0.30</td>
<td>0.50 ⁶)</td>
<td>0.40 to 0.7</td>
<td>0.30 ⁶)</td>
<td>0.20</td>
<td>0.10</td>
<td>0.05</td>
</tr>
<tr>
<td>VL-6060</td>
<td>0.30 ⁶)</td>
<td>0.10 to 0.30</td>
<td>0.10</td>
<td>0.35 to 0.6</td>
<td>0.05</td>
<td>0.15</td>
<td>0.10</td>
<td>0.05</td>
<td>0.15</td>
</tr>
<tr>
<td>VL-6061</td>
<td>0.40 to 0.8</td>
<td>0.7</td>
<td>0.15 to 0.40</td>
<td>0.15</td>
<td>0.8 to 1.2</td>
<td>0.04 to 0.35</td>
<td>0.25</td>
<td>0.15</td>
<td>0.05</td>
</tr>
</tbody>
</table>
Metallic materials

<table>
<thead>
<tr>
<th>Grade</th>
<th>Temper</th>
<th>Thickness, t (mm)</th>
<th>Yield strength $R_{p0.2}$ min. or range</th>
<th>Tensile strength $R_m$ min. or range</th>
<th>Elongation $A_{50}$ min.</th>
<th>$A_{5d}$ min.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>(MPa)</td>
<td>(MPa)</td>
<td>(%)</td>
<td>(%)</td>
</tr>
<tr>
<td>VL-5052</td>
<td>O</td>
<td>$t \leq 50$</td>
<td>65</td>
<td>165 to 215</td>
<td>19</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>H32</td>
<td>$t \leq 6$</td>
<td>130</td>
<td>210 to 260</td>
<td>10</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$6 &lt; t \leq 50$</td>
<td>130</td>
<td>210 to 260</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>H34</td>
<td>$t \leq 6$</td>
<td>150</td>
<td>230 to 280</td>
<td>7</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$6 &lt; t \leq 50$</td>
<td>150</td>
<td>230 to 280</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>VL-5059</td>
<td>O</td>
<td>$t \leq 50$</td>
<td>160</td>
<td>330</td>
<td>-</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>H111</td>
<td>$t \leq 50$</td>
<td>160</td>
<td>330</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>H116</td>
<td>$t \leq 20$</td>
<td>270</td>
<td>370</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$20 &lt; t \leq 50$</td>
<td>260</td>
<td>360</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>H321</td>
<td>$t \leq 20$</td>
<td>270</td>
<td>370</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>

1.7.2 Other alloys or alloys which do not fully comply with Table 3 may be accepted after consideration in each particular case. Special tests and other relevant information, e.g. which confirm satisfactory corrosion resistance and weldability, may be required.

1.8 Temper conditions

1.8.1 5000 series alloys shall be supplied in any of the temper conditions given in Table 4 and Table 5, as applicable. 6000 series alloys shall be supplied in any of the temper conditions given in Table 5.

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

1.9 Mechanical testing

1.9.1 The mechanical properties shall comply with the values given in Table 4 and Table 5, as applicable. Other temper conditions with related mechanical properties may be accepted by the Society after consideration in each particular case.
<table>
<thead>
<tr>
<th>Grade</th>
<th>Temper</th>
<th>Thickness, t (mm)</th>
<th>Yield strength $R_{p0.2}$ min. or range</th>
<th>Tensile strength $R_m$ min. or range</th>
<th>Elongation $A_{50\text{mm}}$ min.</th>
<th>$A_{5\text{d}}$ min.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>(MPa)</td>
<td>(MPa)</td>
<td>(%)</td>
<td>(%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20 &lt; t ≤ 50</td>
<td>260</td>
<td>360</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>VL-5083</td>
<td>O</td>
<td>t ≤ 50</td>
<td>125</td>
<td>275 to 350</td>
<td>16</td>
<td>14</td>
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<tr>
<td></td>
<td>H111</td>
<td>t ≤ 50</td>
<td>125</td>
<td>275 to 350</td>
<td>16</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>H112</td>
<td>t ≤ 50</td>
<td>125</td>
<td>275</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>H116</td>
<td>t ≤ 50</td>
<td>215</td>
<td>305</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>H128</td>
<td>4 &lt; t ≤ 8</td>
<td>215</td>
<td>305 to 385</td>
<td>10</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>H321</td>
<td>t ≤ 50</td>
<td>215 to 295</td>
<td>305 to 385</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0 t ≤ 50</td>
<td>95</td>
<td>240 to 305</td>
<td>16</td>
<td>14</td>
</tr>
<tr>
<td>VL-5086</td>
<td>H111</td>
<td>t ≤ 50</td>
<td>95</td>
<td>240 to 305</td>
<td>16</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>H112</td>
<td>t ≤ 12.5</td>
<td>125</td>
<td>250</td>
<td>8</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12.5 &lt; t ≤ 50</td>
<td>105</td>
<td>240</td>
<td>-</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>H116</td>
<td>t ≤ 6.3</td>
<td>195</td>
<td>275</td>
<td>8</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6.3 &lt; t ≤ 50</td>
<td>195</td>
<td>275</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>V</td>
<td>O</td>
<td>t ≤ 50</td>
<td>85</td>
<td>215 to 275</td>
<td>17</td>
<td>16</td>
</tr>
<tr>
<td>VL-5154A</td>
<td>H32</td>
<td>t ≤ 6</td>
<td>180</td>
<td>250 to 305</td>
<td>8</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6 &lt; t ≤ 50</td>
<td>180</td>
<td>250 to 305</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>H34</td>
<td>t ≤ 50</td>
<td>200</td>
<td>270 to 325</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>V</td>
<td>O</td>
<td>t ≤ 50</td>
<td>145</td>
<td>290</td>
<td>-</td>
<td>17</td>
</tr>
<tr>
<td>VL-5383</td>
<td>H111</td>
<td>t ≤ 50</td>
<td>145</td>
<td>290</td>
<td>-</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>H116</td>
<td>t ≤ 50</td>
<td>220</td>
<td>305</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>H321</td>
<td>t ≤ 50</td>
<td>220</td>
<td>305</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>V</td>
<td>O</td>
<td>t ≤ 50</td>
<td>85</td>
<td>215 to 285</td>
<td>17</td>
<td>16</td>
</tr>
<tr>
<td>VL-5454</td>
<td>H32</td>
<td>t ≤ 6</td>
<td>180</td>
<td>250 to 305</td>
<td>8</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6 &lt; t ≤ 50</td>
<td>180</td>
<td>250 to 305</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>H34</td>
<td>t ≤ 50</td>
<td>200</td>
<td>270 to 325</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>V</td>
<td>O</td>
<td>t ≤ 6.3</td>
<td>130 to 205</td>
<td>290 to 365</td>
<td>16</td>
<td>-</td>
</tr>
<tr>
<td>VL-5456</td>
<td>H116</td>
<td>t ≤ 30</td>
<td>230</td>
<td>315</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>H321</td>
<td>30 &lt; t ≤ 40</td>
<td>215</td>
<td>305</td>
<td>-</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>40 &lt; t ≤ 50</td>
<td>200</td>
<td>285</td>
<td>-</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>t ≤ 12.5</td>
<td>230 to 315</td>
<td>315 to 405</td>
<td>12</td>
<td>-</td>
</tr>
</tbody>
</table>
### Table 5 Mechanical properties for extruded aluminium alloys

<table>
<thead>
<tr>
<th>Grade</th>
<th>Temper</th>
<th>Thickness, t (mm)</th>
<th>Yield strength $R_{p0.2}$ min. or range(^1) (MPa)</th>
<th>Tensile strength $R_m$ min. or range(^1) (MPa)</th>
<th>Elongation (^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Y$\pm$50 mm min.</td>
<td>Y$\pm$5d min.</td>
<td>A$\pm$50 mm min. (%)</td>
</tr>
<tr>
<td>VL-5059</td>
<td>H112</td>
<td>t ≤ 50</td>
<td>200</td>
<td>330</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>O</td>
<td>t ≤ 50</td>
<td>110</td>
<td>270 to 350</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>H111</td>
<td>t ≤ 50</td>
<td>165</td>
<td>275</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>H112</td>
<td>t ≤ 50</td>
<td>110</td>
<td>270</td>
<td>12</td>
</tr>
<tr>
<td>VL-5083</td>
<td>O</td>
<td>t ≤ 50</td>
<td>95</td>
<td>240 to 315</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>H111</td>
<td>t ≤ 50</td>
<td>145</td>
<td>250</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>H112</td>
<td>t ≤ 50</td>
<td>95</td>
<td>240</td>
<td>12</td>
</tr>
<tr>
<td>VL-5086</td>
<td>O</td>
<td>t ≤ 50</td>
<td>145</td>
<td>290</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>H111</td>
<td>t ≤ 50</td>
<td>145</td>
<td>290</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>H112</td>
<td>t ≤ 50</td>
<td>190</td>
<td>310</td>
<td>13</td>
</tr>
<tr>
<td>VL-6005A</td>
<td>T4</td>
<td>t ≤ 50</td>
<td>90</td>
<td>180</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>T5</td>
<td>t ≤ 50</td>
<td>215</td>
<td>260</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>T6</td>
<td>t ≤ 10</td>
<td>215</td>
<td>260</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10 &lt; t ≤ 50</td>
<td>200</td>
<td>250</td>
<td>8</td>
</tr>
<tr>
<td>VL-6060</td>
<td>T4</td>
<td>t ≤ 50</td>
<td>60</td>
<td>120</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>T5</td>
<td>t ≤ 50</td>
<td>100</td>
<td>140</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>T6</td>
<td>t ≤ 50</td>
<td>140</td>
<td>170</td>
<td>8</td>
</tr>
<tr>
<td>VL-6061</td>
<td>T4</td>
<td>t ≤ 50</td>
<td>110</td>
<td>180</td>
<td>15</td>
</tr>
</tbody>
</table>

1) Specified minimum where one value is given. Specified minimum to maximum value where a range is specified.
2) Elongation in 50 mm applies for thicknesses up to and including 12.5 mm and in 5d for thicknesses over 12.5 mm.
### Metallic materials


<table>
<thead>
<tr>
<th>Grade</th>
<th>Temper</th>
<th>Thickness, t (mm)</th>
<th>Yield strength $R_{p0.2}$ min. (MPa)</th>
<th>Tensile strength $R_m$ min. or range (MPa)</th>
<th>Elongation $^{1)}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$A_{50 \text{ mm min.}}$ (%)</td>
</tr>
<tr>
<td>T5</td>
<td>t ≤ 50</td>
<td>205</td>
<td>240</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>T6</td>
<td>t ≤ 50</td>
<td>240</td>
<td>260</td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>VL-6063</td>
<td>T4</td>
<td>t ≤ 50</td>
<td>65</td>
<td>130</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>T5</td>
<td>t ≤ 50</td>
<td>110</td>
<td>150</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>T6</td>
<td>t ≤ 50</td>
<td>170</td>
<td>205</td>
<td>10</td>
</tr>
<tr>
<td>VL-6082</td>
<td>T4</td>
<td>t ≤ 50</td>
<td>110</td>
<td>205</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>T5</td>
<td>t ≤ 50</td>
<td>110</td>
<td>230</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>T6</td>
<td>t ≤ 5</td>
<td>250</td>
<td>290</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 &lt; t ≤ 50</td>
<td>260</td>
<td>310</td>
<td>10</td>
</tr>
</tbody>
</table>

$^{1)}$ elongation in 50 mm applies for thicknesses up to and including 12.5 mm and in 5d for thicknesses over 12.5 mm

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

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

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

1.9.5 For rolled products, the test material shall be taken at one third of the width from a longitudinal edge. The test specimens are normally to be cut with their longitudinal axis transverse to the final rolling direction. If the width is less than 300 mm, longitudinal tests will be permitted.

1.9.6 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 specimens are normally to be cut with their longitudinal axes parallel to the extruding direction.

1.9.7 Flat tensile test specimen of width 12.5 mm shall be used for thicknesses up to and including 12.5 mm. The test specimen shall be prepared so that both rolled surfaces are maintained. Unless otherwise agreed, round tensile test specimen of 10 mm diameter and with an initial gauge length of 50 mm 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 specimen 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.

1.10 Press weld testing of closed sections

1.10.1 Proper fusion of press welds for closed profile extrusions shall be verified either by macrosection tests or by drift expansion tests. Other tests may be accepted after consideration.

For closed profiles affecting the global strength of the vessel, every fifth profile 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.

For profiles for structures not affecting the global strength of the vessel (e.g. helidecks), the extent of press weld testing structures may be reduced as agreed with the Society, e.g. typical minimum extent of testing would be:

a) testing of the two first profiles and of the last profile of each heat and each production batch, and
b) one test from each heat treatment batch if this is less than that given by a).

1.10.2 Where verification is by macrosection tests, no indication of lack of fusion at the press welds is permitted.

1.10.3 Where verification is by drift expansion test, the test specimens 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 specimen 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 end diameter and/or tested end circumference of the profile shall be expanded by minimum 30% or until fracture. The test is considered to be unacceptable if it fails with a clean split along the weld line.

Guidance note:
For non-tubular closed profiles, macro test will typically be more suitable. For further description of the drift expansion test method, reference is made to ISO 8493 and IACS UR W25.

1.11 Corrosion testing

1.11.1 Rolled 5000 series alloys of grade 5083, 5383, 5059, 5086 and 5456 in the H128 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. Extent is one test from each test unit. Accepted test standards are ASTM G66 (ASSET) and G67 (NAMLT) or equivalent standards.

The indices for exfoliation corrosion shall be within the level EA and those for crevice corrosion rate shall be within PB according to ASTM-G66. In case of testing in accordance with ASTM-G67 the mass loss shall not exceed 15 mg/cm$^2$.

1.11.2 As an alternative, the manufacturers may establish the relationship between microstructure and resistance to corrosion. A reference photomicrograph taken at 500x, under the conditions specified in ASTM B928-9.4.1 shall be established for each of the alloy-tempers and thickness ranges relevant. The reference photographs shall be taken from samples which have undergone satisfactory testing according to [1.11.1].

1.11.3 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.

1.11.4 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 [1.11.1]. If the results from testing satisfy the acceptance criteria stated in [1.11.1] the test unit is accepted, else it is rejected.
1.12 Inspections, dimensions and tolerances

1.12.1 Wrought aluminium products shall be subject to visual inspection and measurements of dimensions by the manufacturer, in accordance with the requirements of the relevant standard and as given in [1.12.2] and [1.12.3].

1.12.2 The materials shall have a smooth surface compatible with the method of manufacture and shall be free from defects liable to impair further manufacturing processes or the intended application of the product, e.g. cracks, laps, appreciable inclusions of extraneous substances and major mechanical damage.

1.12.3 Permissible underthickness tolerances for rolled products are given in Table 6. The underthickness tolerances for extruded products shall be in accordance with the requirements of recognized international or national standards, e.g. ISO 6362-5/6, EN-755-3, ANSI H35.2.

Table 6 Underthickness tolerances for rolled products (mm)

<table>
<thead>
<tr>
<th>Nominal thickness, t (mm)</th>
<th>Width of plate, w (mm)</th>
<th>w ≤ 1500</th>
<th>1500 &lt; w ≤ 2000</th>
<th>2000 &lt; w ≤ 3500</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0 ≤ t &lt; 4.0</td>
<td>0.10</td>
<td></td>
<td>0.15</td>
<td>0.15</td>
</tr>
<tr>
<td>4.0 ≤ t &lt; 8.0</td>
<td>0.20</td>
<td></td>
<td>0.20</td>
<td>0.25</td>
</tr>
<tr>
<td>8.0 ≤ t &lt; 12.0</td>
<td>0.25</td>
<td></td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td>12.0 ≤ t &lt; 20.0</td>
<td>0.35</td>
<td></td>
<td>0.40</td>
<td>0.50</td>
</tr>
<tr>
<td>20.0 ≤ t &lt; 50.0</td>
<td>0.45</td>
<td></td>
<td>0.50</td>
<td>0.65</td>
</tr>
</tbody>
</table>

1.12.4 Dimensional tolerances other than under-thickness tolerances shall comply with a recognized national or international standard.

1.12.5 The under-thickness tolerance acceptable for classification shall be considered as the lower limit of a “plus-minus” range of thickness tolerances which could be found in the normal production of a plant producing rolled or extruded products, on average, to the nominal thickness.

1.13 Repair

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

1.14 Identification

1.14.1 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, and
— identification number, heat number or other marking which will enable the full history of the product to be traced.

1.14.2 Where a number of items are securely fastened together in bundles, marking of the top item of each bundle is sufficient. Alternatively, a durable label may be attached to each bundle.
2 Aluminium Casting Alloys

2.1 Scope

2.1.1 This sub-section is applicable to aluminium casting alloys which are intended for the fabrication of vessels’ hulls and also machine construction parts and other components.

2.1.2 Suitable grades of castings to international or national standards, e.g. to EN 1706 shall be used, unless otherwise agreed. Where castings conforming to manufacturer’s specifications are to be used, the specification shall be submitted to the Society for approval.

2.1.3 For the applications mentioned in [2.1.1], casting alloys conforming to EN 1706 listed in Table 7 may be applied.

Other alloys may be applied provided these are suitable for the intended application and approved by the Society.

Table 7 Aluminium-casting alloys

<table>
<thead>
<tr>
<th>Designation of alloy</th>
<th>Cast procedure</th>
<th>Material condition</th>
<th>Sea water suitability</th>
</tr>
</thead>
<tbody>
<tr>
<td>EN AC-41000</td>
<td>S, K</td>
<td>F, T6</td>
<td>Good</td>
</tr>
<tr>
<td>(AlSi2MgTi)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EN AC-42100</td>
<td>S, K, L</td>
<td>T6, T64</td>
<td>Good</td>
</tr>
<tr>
<td>(AlSi7Mg0.3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EN AC-42200</td>
<td>S, K, L</td>
<td>T6, T64</td>
<td>Good</td>
</tr>
<tr>
<td>(AlSi7Mg0.6)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EN AC-43100</td>
<td>S, K, L</td>
<td>F, T6, T64</td>
<td>Good/moderate</td>
</tr>
<tr>
<td>(AlSi10Mg(b))</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EN AC-44100</td>
<td>S, K, L, D</td>
<td>F</td>
<td>Good/moderate</td>
</tr>
<tr>
<td>(AlSi12(b))</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EN AC-51000</td>
<td>S, K, L</td>
<td>F</td>
<td>Very good</td>
</tr>
<tr>
<td>(AlMg3(b))</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EN AC-51300</td>
<td>S, K, L</td>
<td>F</td>
<td>Very good</td>
</tr>
<tr>
<td>(AlMg5)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EN AC-51400</td>
<td>S, K, L</td>
<td>F</td>
<td>Very good</td>
</tr>
<tr>
<td>(AlMg5(Si))</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

S = sand casting  
K = permanent mould casting  
L = investment casting  
D = pressure die casting  
F = cast condition  
T6 = solution annealed and completely artificially aged  
T64 = solution annealed and not completely artificially aged - under aged (only for permanent mould casting)
2.2 Certification requirements

2.2.1 General certification requirements are given in Sec.1 [3.1]. Additional certification requirements for materials covered by this section are given in [2.2.2].

2.2.2 The product shall be delivered with the type of inspection certificate required in the relevant construction Rules giving the following particulars for each test unit which has been accepted:

— purchaser and order number
— type of casting and grade of casting
— item numbers and quantities
— method of manufacture
— heat numbers and chemical composition
— details of heat treatment
— test pressures, where applicable
— weight of the delivery.

2.3 Documentation requirements

2.3.1 General documentation requirements are given in Sec.1 [3.2]. Additional specific documentation requirements are given in Table 8.

Table 8 Additional documentation requirements

<table>
<thead>
<tr>
<th>Object</th>
<th>Documentation type</th>
<th>Additional description</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>Castings subject to welding</td>
<td>M060 – Welding procedure (WPS)</td>
<td>The WPS qualified in accordance with Ch.4 Sec.5 shall be approved</td>
<td>AP, L</td>
</tr>
</tbody>
</table>

\[ \text{AP} = \text{for approval} \\
\text{L} = \text{locally} \]

2.4 Survey, inspection and testing requirements

2.4.1 General survey, inspection and testing requirements are given in Ch.1 Sec.1 [3.3]. Additional specific requirements are given in Table 9, as further detailed in this section.

Table 9 Additional survey and testing requirements

<table>
<thead>
<tr>
<th>Survey, inspection and testing item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical composition</td>
<td>Required for all materials.</td>
</tr>
<tr>
<td>Mechanical testing</td>
<td>Required for all grades in accordance with the requirements of the relevant paragraph</td>
</tr>
<tr>
<td>Visual inspection</td>
<td>Aluminium alloy castings shall be subject to visual inspection and measurements of dimensions by the manufacturer</td>
</tr>
</tbody>
</table>
2.5 Manufacture

2.5.1 All aluminium castings delivered with VL or works (W) certificate shall be made at works approved by the Society.

2.6 Chemical composition

2.6.1 The chemical composition of the castings shall correspond to the standards or to recognized manufacturer’s specifications and shall be demonstrated by the manufacturer of the castings for each charge.

2.7 Temper conditions

2.7.1 Aluminium casting alloys shall be supplied in any of the temper conditions given in Table 7, as applicable.

2.8 Mechanical testing

2.8.1 With regard to mechanical properties, the requirements stated in the standards or the manufacturer’s specifications are applicable.

2.8.2 For the tensile test, one test specimen shall be provided from each test unit. Each heat in each heat treatment batch is considered a test unit. For unfinished castings weighing 300 kg and over, a tensile test specimen is required for each casting.

2.8.3 Specimens for tensile testing shall be taken from integrally cast sample bars which shall not be separated from the casting before the final heat treatment has been performed. The use of separately cast samples will only be accepted subject to special agreement with the Society. When applicable, the manufacturer shall evaluate the effect of casting of separate samples on the mechanical properties. The acceptance criteria shall be adjusted accordingly.

2.9 Inspections, dimensions and tolerances

2.9.1 Cast aluminium products shall be subject to visual inspection and measurements of dimensions by the manufacturer in accordance with the requirements of the relevant standard and as given in [2.9.2].

2.9.2 All castings shall be free from internal and external defects which affect the application or the further manufacturing processes. Where defects shall be repaired by welding, a welding procedure specification (WPS) shall be produced by the manufacturer and approved by the Society.

2.10 Identification

2.10.1 As a minimum requirement, the manufacturer shall apply the following marks on the castings:
   — manufacturer’s mark
   — short designation of the casting alloys
   — short designation of the condition of the material
   — charge number or some other mark to permit identification of the casting.
SECTION 11 COPPER ALLOY CASTINGS

1 General requirements

1.1 Scope

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

1.1.2 Where required by the relevant design and construction parts of the Rules, copper alloy castings shall comply with the requirements in Ch.1, Sec.1, the general requirements of this subsection and the appropriate specific requirements of subsections [2] and [3]. If the specific requirements differ from the general requirements, the specific requirements shall prevail.

1.1.3 As an alternative to [1.1.2], 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. Unless otherwise agreed, such materials shall comply with the appropriate requirements of Ch.1.

1.2 Certification requirements

1.2.1 General certification requirements are given in Sec.1 [3.1]. Additional certification requirements for materials covered by this section are given in [1.2.2] and [1.2.3]

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

a) manufacturer’s and purchaser’s name, order number and vessel identification, where known
b) description of castings and alloy type
c) identification marking of castings
d) heat number and chemical composition
e) details of heat treatment, including temperatures and soaking time
f) results of mechanical tests
g) results of non-destructive tests, where applicable
h) test pressure, where applicable
i) results of any supplementary and additional test requirements specified.

1.2.3 For propeller castings, the following additional information shall be given:

a) drawing number
b) diameter, number of blades, pitch, direction of turning
c) skew angle for high skew propellers
d) final mass
e) for certification, the manufacturer shall provide records of weld repairs as detailed below.

1.3 Documentation requirements

1.3.1 General documentation requirements are given in Sec.1 [3.2]. Additional manufacturer specific documentation requirements are given in Table 1.
Table 1 Qualification documentation for manufacturer

<table>
<thead>
<tr>
<th>Item</th>
<th>Documentation type</th>
<th>Additional description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Castings subject to major repair by welding, and propeller castings subject to repair by welding in zones A and B</td>
<td>Z250 - Procedure</td>
<td>Proposals for major weld repairs shall be accompanied by a tailor-made procedure including sketches or photographs showing the extent and positions of the repairs. Special attention should be paid to the high stress areas. The procedure shall be approved case by case</td>
</tr>
</tbody>
</table>

1.4 Survey, inspection and testing requirements

1.4.1 General survey, inspection and testing requirements are given in Ch.1 Sec.1 [3.3]. Additional specific requirements are given in Table 2, as further detailed in this section.

Table 2 Additional survey and testing requirements

<table>
<thead>
<tr>
<th>Survey, inspection and testing item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical composition</td>
<td>Required for all materials</td>
</tr>
<tr>
<td>Mechanical testing</td>
<td>Required for all grades in accordance with the requirements of the relevant section</td>
</tr>
<tr>
<td>Metallographic examination</td>
<td>The proportion of alpha phase shall be determined for Cu1 and Cu2</td>
</tr>
<tr>
<td>Test unit for castings made from two or more heats</td>
<td>Where castings are made from two or more heats, which are not mixed in a ladle prior to pouring, one set of tests are required from each heat</td>
</tr>
<tr>
<td>Visual inspection</td>
<td>The manufacturer shall carry out visual inspection of all casting on accessible surfaces for surface finish and compliance with the dimensional and geometrical tolerances</td>
</tr>
<tr>
<td>Visual survey</td>
<td>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</td>
</tr>
<tr>
<td>Dimensional measurements</td>
<td>The dimensions and tolerances are governed by the data contained in the approval drawings or order documents. These shall be submitted to the surveyor at the time of the test. Unless otherwise agreed between the purchaser and the manufacturer, the verification of dimensions is the responsibility of the manufacturer</td>
</tr>
</tbody>
</table>
| NDT                                                             | — castings shall be subject to non-destructive testing as specified in subsequent subsections and shall comply with given requirements  
|                                                                 | — in addition, the relevant construction rules shall be referred for non-destructive testing of finished machined components  
|                                                                 | — where 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  
|                                                                 | — where certification by the Society is required, the surveyor may request to be present during NDT |
### NDT related to repair
- Complete elimination of the defective material shall be verified by PT. This applies also for areas which will be subsequently repaired by welding
- All areas repaired by welding shall be subject to NDT

### NDT of propellers
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

### NDT of propellers
The Society may require NDT such as RT or UT for verification of internal soundness. The extent, method and acceptance criteria are then to be agreed between the manufacturer and the Society

### Pressure test
Pressure retaining castings shall be tested after machining to the test pressure required by the relevant design and construction parts of the rules

### 1.5 Grading system

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

### 1.6 Manufacture

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

1.6.2 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.

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

### 1.7 Chemical composition

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

1.7.2 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.

1.7.3 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.

### 1.8 Heat treatment

1.8.1 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.

1.8.2 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.
1.8.3 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.

1.8.4 If a casting is locally re-heated or any straightening operation is performed, a subsequent stress relieving heat treatment is required unless otherwise approved.

1.9 Test blocks and test specimens for mechanical testing

1.9.1 Test blocks, from which test specimens 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 moulding and casting practices as the castings represented.

For alloys with a long freezing range, e.g. as given in Table 3, test bars fed at one or both ends are recommended. The test bars, whether sand cast or permanent mould cast, may be tested as cast (i.e. without machining).

For other alloys, e.g. as given by Table 5, test bars fed all along its length are preferred, ref. Figure 1

1.9.2 The test block size and dimensions propeller castings are given in Figure 1. Alternatively, test blocks complying with other recognized standards may be accepted, however, for propeller castings, test blocks smaller in size requires special approval.

![Figure 1 Test sample castings](image)

1.9.3 Where cast propeller test specimens are taken from integrally cast sample bars, this shall be the subject to special agreement with the Society. Wherever possible, the sample bars shall be located on the blades at a point lying between 0.5 and 0.6 R, where R is the radius of the propeller. The sample material shall not be removed from the propeller by thermal cutting process.

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

1.9.5 All test blocks shall be suitably marked to identify them with the castings represented. Where castings are supplied in the heat-treated condition, the test block shall be subjected to the same heat treatment.
1.9.6 The preparation of test specimens and the procedures used for mechanical testing shall comply with the relevant requirements in Ch.1.

1.10 Test units and number of tests

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

1.10.2 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.

1.10.3 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.

1.11 Mechanical properties

1.11.1 The mechanical properties specified in subsequent subsections refer to test specimens machined from separately cast test blocks and not to the castings themselves. The mechanical properties of integral-cast test material shall be specially approved.

1.11.2 If the results of the mechanical tests do not conform to the specified requirements, the re-test procedures of Ch.1 Sec.2 [3.7] may be adopted.

1.12 Inspection

1.12.1 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.

1.12.2 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.

1.12.3 When visually inspected, castings shall have a workmanlike finish and 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 or the further manufacturing processes.

1.12.4 The dimensions and the dimensional and geometrical tolerances are governed by the data specified in the approval drawings or order documents. These shall be submitted to the surveyor at the time of the test. Unless otherwise agreed, the verification of dimensions is the responsibility of the manufacturer.

1.12.5 Castings are subject to non-destructive testing where specified in subsequent sub-sections. 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.

1.12.6 For definitions relevant to PT indications the relevant parts of Sec.8 [1.12] apply.

1.12.7 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 the Society is required, the surveyor may request to be present during PT.

1.12.8 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.

1.13 Repair

1.13.1 This paragraph gives general requirements for repair. Additional requirements are given in [2] and [3].

1.13.2 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.

1.13.3 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.

1.13.4 All weld repairs shall be done by qualified welders using qualified procedures. For qualification of welding procedures for copper alloy props, see Ch.4 Sec.5 [13].

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

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

1.13.7 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.

1.14 Identification

1.14.1 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
— the VL certificate No., where applicable and as furnished by the surveyor
— test pressure, where applicable.

2 Castings for valves, fittings and general application

2.1 Scope

2.1.1 These requirements are supplementary to subsection [1] and apply to copper alloy castings for valves, fittings and other castings for use in vessel construction and machinery or piping systems.

2.2 Chemical composition

2.2.1 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 3. The copper alloys shall have a satisfactory resistance to sea water corrosion, where applicable.
### Table 3 Chemical composition limits for principal elements in copper alloy castings

<table>
<thead>
<tr>
<th>Alloy type</th>
<th>Designation</th>
<th>Cu</th>
<th>Sn</th>
<th>Zn</th>
<th>Pb</th>
<th>Ni</th>
<th>P</th>
<th>Typical applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phosphor bronze</td>
<td>Cu Sn11P</td>
<td>87.9</td>
<td>10.0</td>
<td>0.05</td>
<td>0.25</td>
<td>0.10</td>
<td>0.5</td>
<td>Liners, bushes, valves and fittings</td>
</tr>
<tr>
<td></td>
<td>Cu Sn11Zn2</td>
<td>89.5</td>
<td>11.5</td>
<td>0.05</td>
<td>0.7</td>
<td>2.0</td>
<td>0.60</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cu Sn12</td>
<td>85.9</td>
<td>11.0</td>
<td>0.50</td>
<td>0.7</td>
<td>2.0</td>
<td>0.60</td>
<td></td>
</tr>
<tr>
<td>Gunmetal</td>
<td>Cu Sn10 Zn2</td>
<td>9.5</td>
<td>1.75</td>
<td>1.5</td>
<td>1.0</td>
<td>-</td>
<td>-</td>
<td>Liners, valves and fittings</td>
</tr>
<tr>
<td></td>
<td>Remainder</td>
<td>10.5</td>
<td>2.75</td>
<td>1.5</td>
<td>1.0</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Leaded gunmetal</td>
<td>Cu Sn5 Zn5 Pb5</td>
<td>83.0</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>2.0</td>
<td>0.10</td>
<td>Bushes, valves and fittings</td>
</tr>
<tr>
<td></td>
<td>Cu Sn7 Zn2 Pb3</td>
<td>85.0</td>
<td>6.0</td>
<td>1.5</td>
<td>2.5</td>
<td>2.0</td>
<td>0.10</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cu Sn7 Zn4 Pb7</td>
<td>81.0</td>
<td>6.0</td>
<td>2.0</td>
<td>5.0</td>
<td>2.0</td>
<td>0.10</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cu Sn6 Zn4 Pb2</td>
<td>86.0</td>
<td>5.5</td>
<td>3.0</td>
<td>1.0</td>
<td>2.0</td>
<td>0.10</td>
<td></td>
</tr>
<tr>
<td>Leaded bronze</td>
<td>Cu Sn10 Pb10</td>
<td>78.0</td>
<td>9.0</td>
<td>2.0</td>
<td>8.0</td>
<td>2.0</td>
<td>0.10</td>
<td>Bushes</td>
</tr>
<tr>
<td></td>
<td>Cu Sn5 Pb9</td>
<td>80.0</td>
<td>4.0</td>
<td>2.0</td>
<td>10.0</td>
<td>2.0</td>
<td>0.10</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cu Sn7 Pb15</td>
<td>74.0</td>
<td>6.0</td>
<td>2.0</td>
<td>13.0</td>
<td>2.0</td>
<td>0.10</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cu Sn5 Pb20</td>
<td>70.0</td>
<td>4.0</td>
<td>2.0</td>
<td>18.0</td>
<td>2.0</td>
<td>0.10</td>
<td></td>
</tr>
</tbody>
</table>

#### 2.3 Condition of supply

**2.3.1** The castings shall be supplied in either the as-cast condition or the heat-treated condition as specified in the relevant recognised standard.

#### 2.4 Mechanical properties

**2.4.1** The test blocks and test specimens for mechanical testing shall be as described in the approved recognised standard, see [2.2.1]. In addition subsections [1.9] to [1.11] shall apply.
2.4.2 The mechanical properties shall comply with the approved recognised standard, ref. [2.2.1] and where appropriate, with the values given in Table 4.

Table 4 Mechanical properties for copper alloy castings

<table>
<thead>
<tr>
<th>Alloy type</th>
<th>Designation</th>
<th>Proof stress $R_{p0.2}$ minimum (N/mm$^2$)</th>
<th>Tensile strength $R_m$ minimum (N/mm$^2$)</th>
<th>Elongation, minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Sand</td>
<td>Centrifugal</td>
<td>Sand</td>
</tr>
<tr>
<td>Phosphor bronze</td>
<td>Cu Sn11 P</td>
<td>130</td>
<td>170</td>
<td>250</td>
</tr>
<tr>
<td></td>
<td>Cu Sn12</td>
<td>140</td>
<td>150</td>
<td>260</td>
</tr>
<tr>
<td>Gunmetal</td>
<td>Cu Sn10 Zn2</td>
<td>130</td>
<td>130</td>
<td>270</td>
</tr>
<tr>
<td>Leaded gunmetal</td>
<td>Cu Sn5 Zn5 Pb5</td>
<td>90</td>
<td>110</td>
<td>200</td>
</tr>
<tr>
<td></td>
<td>Cu Sn7 Zn2 Pb3</td>
<td>130</td>
<td>130</td>
<td>230</td>
</tr>
<tr>
<td></td>
<td>Cu Sn7 Zn4 Pb7</td>
<td>120</td>
<td>120</td>
<td>230</td>
</tr>
<tr>
<td></td>
<td>Cu Sn6 Zn4 Pb2</td>
<td>110</td>
<td>110</td>
<td>220</td>
</tr>
<tr>
<td>Leaded bronze</td>
<td>Cu Sn10 Pb10</td>
<td>80</td>
<td>110</td>
<td>180</td>
</tr>
<tr>
<td></td>
<td>Cu Sn5 Pb9</td>
<td>60</td>
<td>90</td>
<td>160</td>
</tr>
<tr>
<td></td>
<td>Cu Sn7 Pb15</td>
<td>80</td>
<td>90</td>
<td>170</td>
</tr>
<tr>
<td></td>
<td>Cu Sn5 Pb20</td>
<td>70</td>
<td>80</td>
<td>150</td>
</tr>
</tbody>
</table>

2.5 Inspection

2.5.1 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.

2.6 Repair

2.6.1 Defective castings shall be repaired in accordance with [1.12] and as given in [2.6.2] to [2.6.5].

2.6.2 Small surface defects shall be removed by grinding to a depth of up to 10% of the section thickness provided the dimensional tolerances are not exceeded. Where the repair entails removal of more than 10% of the thickness, the defective area shall be repaired by welding.

2.6.3 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.

2.6.4 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.

2.6.5 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.
2.6.6 Cosmetic repair by welding is considered minor weld repairs and shall follow all the requirements for minor weld repairs.

2.6.7 Bearing bushes and liners of cast CuPbSn alloys shall not be welded unless otherwise approved by the Society.

3 Castings for propellers

3.1 Scope

3.1.1 These requirements are supplementary to subsection [1] and apply to copper alloy castings for propellers and separately cast blades and hubs.

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

3.2 Manufacture

3.2.1 The pouring shall be carried out into dried moulds using degassed liquid metal. The pouring shall be controlled as to avoid turbulence of flow. Special devices and/or procedures must prevent slag flowing into the mould.

3.3 Chemical composition

3.3.1 The chemical composition shall comply with the limits given in Table 5, unless otherwise specially approved by the Society.

Table 5 Chemical composition limits ¹) for copper alloy propeller castings

<table>
<thead>
<tr>
<th>Alloy type</th>
<th>Grade</th>
<th>Cu</th>
<th>Al</th>
<th>Mn</th>
<th>Fe</th>
<th>Ni</th>
<th>Zn</th>
<th>Sn</th>
<th>Pb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mn-bronze ²)</td>
<td>VL Cu1</td>
<td>52-62</td>
<td>0.5-3.0</td>
<td>0.5-4.0</td>
<td>0.5-2.5</td>
<td>1.0</td>
<td>35-40</td>
<td>1.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Mn-Ni-bronze ²)</td>
<td>VL Cu2</td>
<td>50-57</td>
<td>0.5-2.0</td>
<td>1.0-4.0</td>
<td>0.5-2.5</td>
<td>3.0-8.0</td>
<td>33-38</td>
<td>1.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Ni-Al-bronze</td>
<td>VL Cu3</td>
<td>77-82</td>
<td>7.0-11.0</td>
<td>0.5-4.0</td>
<td>2.0-6.0</td>
<td>3.0-6.0</td>
<td>1.0</td>
<td>0.1</td>
<td>0.03</td>
</tr>
<tr>
<td>Mn-Al-Bronze</td>
<td>VL Cu4</td>
<td>70-80</td>
<td>6.5-9</td>
<td>8.0-20.0</td>
<td>2.0-5.0</td>
<td>1.5-3.0</td>
<td>6.0</td>
<td>1.0</td>
<td>0.05</td>
</tr>
</tbody>
</table>

¹) given value is maximum content (by weight) unless shown as a range or as a minimum
²) Zinc equivalent shall not exceed 45% when calculated using the following formula:
   Zinc equivalent (%) = 100 − [(100 × %Cu) / (100 + A)]

   in which A is the algebraic sum of the following values:
   A = %Sn + (5 × %Al) − (0.5 × %Mn) − (0.1 × %Fe) − (2.3 × %Ni)

Note: The negative sign in front of the elements Mn, Fe and Ni signifies that these elements tend to reduce the proportion of beta phase.
3.4 Heat treatment

3.4.1 Propeller castings need not to be heat-treated except as specified in [1.7]. If propellers are subjected to a heat treatment the test samples shall be heat-treated together with the propeller.

3.4.2 When required, stress relieving heat treatment shall be performed in order to reduce the residual stresses. For this purpose, the manufacturer shall submit a specification containing the details of the heat treatment to the Society for approval.

3.5 Mechanical and metallographic testing

3.5.1 The mechanical properties shall meet the requirements in Table 6, unless otherwise specially approved by the Society. For integrally cast test specimens the requirements shall be agreed with the Society.

3.5.2 The proportion of alpha phase shall be determined for VL Cu1 and VL Cu2, see Table 6. The average value of 5 counts on a test specimen shall be determined. For this purpose, at least one specimen shall be taken from each heat. The microstructure shall contain an alpha phase component of at least 25%.

Table 6 Mechanical properties for copper alloy propeller castings

<table>
<thead>
<tr>
<th>Alloy type</th>
<th>Grade</th>
<th>Yield strength $R_{p0.2}$ minimum (N/mm²)</th>
<th>Tensile strength $R_m$ minimum (N/mm²)</th>
<th>Elongation $A5$ minimum (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mn-bronze&lt;sup&gt;1)&lt;/sup&gt;</td>
<td>VL Cu1</td>
<td>175</td>
<td>440</td>
<td>20</td>
</tr>
<tr>
<td>Mn-Ni-bronze&lt;sup&gt;1)&lt;/sup&gt;</td>
<td>VL Cu2</td>
<td>175</td>
<td>440</td>
<td>20</td>
</tr>
<tr>
<td>Ni-Al-bronze</td>
<td>VL Cu3</td>
<td>245</td>
<td>590</td>
<td>16</td>
</tr>
<tr>
<td>Mn-Al-Bronze</td>
<td>VL Cu4</td>
<td>275</td>
<td>630</td>
<td>18</td>
</tr>
</tbody>
</table>

1) the proportion of alpha phase shall be determined as the average value of 5 counts on a test specimen. For this purpose, at least one specimen shall be taken from each heat. The microstructure shall contain an alpha phase component of at least 25%

3.6 Inspection

3.6.1 The castings are subject to inspection in accordance with [1.11] and as given in [3.6.2] to [3.6.4].

3.6.2 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.8 [4.6]. 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.

3.6.3 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.

3.6.4 The indications detected shall, with respect to their size and number, not exceed the values given in Ch.4 Sec.5 Table 17. Weld repairs are, independent of their location, always to be assessed according to the requirements for zone A. The zone A requirements are applicable for the welded areas after final machining and/or final grinding.

Guidance note:
Radiographic test (RT); the absorption of the X-rays and gamma-rays is stronger in copper-based alloys than in steel. For propeller bronzes, 300 kV X-rays can normally be used up to 50 mm and Co60 gamma-rays up to 160 mm thickness. Due to the limited thicknesses that can be radiographed as well as for other practical reasons radiography is generally not a realistic method for checking of subsurface defects in the thicker parts of large propellers.

Ultrasonic test (UT); as a general rule, ultrasonic testing of VL Cu1 and VL Cu2 is not feasible due to the high damping capacity of these materials. For VL Cu3 and VL Cu4, ultrasonic inspection of subsurface defects is possible. If UT is applied, the procedure should be qualified.

### 3.6.5 Minor casting defects which may still be visible after machining such as small sand and slag inclusions, small cold shuts and scabs shall be trimmed off by the manufacturer, see [3.7].

### 3.6.6 Casting defects which may impair the serviceability of the casting, e.g. major non-metallic inclusions, shrinkage cavities, blow holes and cracks, are not permitted. The defects shall be removed by one of the methods given in accordance with [3.7] and repaired within the limits and restrictions for the applicable severity zone.

### 3.7 Repair

#### 3.7.1 Defective castings shall be repaired in accordance with [1.13] and as given in [3.7.2] to [3.7.9].

#### 3.7.2 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.

#### 3.7.3 Weld repairs in zone A and zone B 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. Welding of areas less than 5 cm$^2$ shall be avoided.

#### 3.7.4 Grinding in severity zone A may be carried out to an extent that maintains the blade thickness. If blade thickness after grinding is below specified under-thickness tolerance, the blade is either rejected, or the grinding repair may be evaluated and possibly case-by-case approved by the Society. The balance test shall be repeated. Repair welding is not permitted in severity zone A and will only be allowed after special consideration by the Society.

#### 3.7.5 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 greater, may be removed by grinding. Those defects that are deeper may be repaired by welding.

#### 3.7.6 Repair welding is permitted in severity zone C.

#### 3.7.7 Requirements for the welding workshop are given in Ch.4. Proof of compliance shall be furnished to the satisfaction of the Society prior to welding. All welding work shall be carried out preferably inside the shop free from draughts and influence of the weather.

#### 3.7.8 Before welding is started, a detailed repair procedure shall be submitted including the approved WPS (ref. Ch.4 Sec.5 [13]), weld preparation, welding parameters, filler metals, preheating, post weld heat treatment and inspection procedures. Recommendations for welding are given in Ch.4 Sec.5 Table 16.

**Guidance note:**
Arc welding is recommended for all repairs on bronze propellers. Where the material thickness is less than 30 mm, gas fusion welding may be performed on casting grades VL Cu1 and VL Cu2 with satisfactory results. Arc welding with covered electrodes and gas-shielded metal arc process (GMAW) should be applied. Argon-shielded tungsten welding (GTAW) should be used with care due to the higher specific heat input of this process. Recommended filler metals, pre-heating and stress relieving temperatures are listed in Table 8.
3.7.9 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 are given in Ch.4 Sec.5 Table 16. The cooling rate shall not exceed 50°C/h until a temperature of 200°C is reached.

3.8 Identification

3.8.1 Castings shall be identified in accordance with [1.13] and with the following additional particulars:
— ice Class symbol, where applicable
— skew angle for high skew propellers
— date of final inspection.

3.9 Welding procedure qualification

3.9.1 Requirements for welding procedure qualification test are given in Ch.4 Sec.5 [13].
SECTION 12 NON-FERROUS TUBES

1 General requirements

1.1 Scope

1.1.1 This section specified requirements for copper and copper alloy tubes and fittings to be used in pressurized lines and for condenser and heat exchangers, and for titanium and titanium alloy tubes to be used in shipboard systems.

1.2 Certification requirements

1.2.1 General certification requirements are given in Sec.1 [3.1].

1.2.2 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/fittings and material quality
   d) identification marking of tubes/fittings
   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.

1.2.3 Where the copper alloys are not cast in the same works in which they are made into finished or semi-finished products, the works shall be approved by the Society, and the surveyor shall be given a works (W) material certificate validated by the smelting plant which indicates charge numbers and chemical composition.

1.3 Documentation requirements

1.3.1 General documentation requirements are given in Sec.1 [3.2]. Additional product specific documentation requirements are given in Table 1.

Table 1 Documentation requirements – products required to be certified

<table>
<thead>
<tr>
<th>Object</th>
<th>Documentation type</th>
<th>Additional description</th>
<th>Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper material</td>
<td>M010 – Material specification, metals</td>
<td>When material other than those specified in this rule section is proposed</td>
<td>FI</td>
</tr>
<tr>
<td>Titanium material</td>
<td>M010 – Material specification, metals</td>
<td>When material other than those specified in this rule section is proposed</td>
<td>FI</td>
</tr>
</tbody>
</table>

1) FI = For Information, AP = For Approval, L = by Local station. For full definition of abbreviations, see Pt.1 Ch.3.

1.3.2 For general requirements to documentation including definitions, see Pt.1 Ch.3.
1.4 Survey, inspection and testing requirements

1.4.1 General survey, inspection and testing requirements are given in Ch.1 Sec.1 [3.3]. Additional specific requirements are given in Table 2, as further detailed in this section.

Table 2 Additional survey and testing requirements

<table>
<thead>
<tr>
<th>Survey, inspection and testing item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical composition</td>
<td>Required for all materials.</td>
</tr>
<tr>
<td>Mechanical testing</td>
<td>Required for all grades in accordance with the requirements of the relevant standard</td>
</tr>
<tr>
<td>NDT and pressure test for copper alloy tubes</td>
<td>Each tube shall be subjected to eddy current testing or pressure testing in accordance with the requirements of a recognised standard</td>
</tr>
<tr>
<td>NDT and pressure test for copper alloy fittings</td>
<td>Fittings shall be tested and inspected in accordance with the requirements of the relevant standard</td>
</tr>
<tr>
<td>Testing of titanium alloy tubes</td>
<td>Titanium alloy tubes shall be subjected to testing in accordance with the requirements of a recognised standard</td>
</tr>
</tbody>
</table>

2 Copper and copper alloy tubes

2.1 Scope

2.1.1 This subsection specifies requirements for copper and copper alloy tubes to be used in pressurized lines and for condensers and heat exchangers. Provision is made for phosphorus-deoxidised copper, aluminium brass and copper-nickel alloys. In the case of finned pipes, specifications shall be submitted to the Society for approval.

2.1.2 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.

2.2 Materials

2.2.1 Tubes shall be in accordance with recognised standards, e.g. ASTM B 111, ASTM B 543, EN 12449, 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, see Ch.1 Sec.1 [3.4].

2.2.2 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.

2.2.3 All tubes delivered with VL or works (W) certificate shall be made by works approved by the Society. The copper used shall be made at works approved by the Society.

2.2.4 Tubes for Class I and II pressure systems shall be seamless drawn. Tubes for Class III pressure systems may be seamless drawn or welded.
2.2.5 For welded tubes, the characteristics of these and the method of manufacture employed shall be made known to the Society. The Society reserves the right to demand a procedure approval test in these cases.

2.3 Chemical composition

2.3.1 The chemical composition shall comply with the requirements of a recognised standard and with the limits for principal elements given in Table 3.

2.4 Condition of supply

2.4.1 Copper tubes shall be supplied in the annealed or half-hard condition.

2.4.2 Copper alloy tubes shall be supplied in the annealed condition.

2.4.3 Tubes made of copper zinc alloys shall be free from stresses liable to cause stress cracks.

2.4.4 With the exception of tubes made of phosphorus-deoxidised copper in condition hard, all pipes shall be capable of being cold formed with the degrees of deformation customary in workshop practice, e.g. by bending and expansion.

Table 3 Chemical composition limits ¹ for principal elements in copper and copper alloy tubes

<table>
<thead>
<tr>
<th>Designation</th>
<th>Cu</th>
<th>As</th>
<th>P</th>
<th>Pb</th>
<th>Fe</th>
<th>Zn</th>
<th>Ni</th>
<th>Al</th>
<th>Mn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phosphorus-deoxidised copper</td>
<td>Minimum 99.9 ²</td>
<td>-</td>
<td>0.015 to 0.040</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Aluminium brass</td>
<td>76.0 to 79.0</td>
<td>0.02 to 0.06</td>
<td>-</td>
<td>0.07</td>
<td>0.06</td>
<td>Remainder</td>
<td>-</td>
<td>1.8 to 2.5</td>
<td>-</td>
</tr>
<tr>
<td>Copper-Nickel 90-10 ³</td>
<td>Remainder</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1.0 to 2.0</td>
<td>-</td>
<td>9.0 to 11.0</td>
<td>-</td>
<td>0.5 to 1.0</td>
</tr>
<tr>
<td>Copper-Nickel 70-30 ³</td>
<td>Remainder</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.40 to 1.0</td>
<td>-</td>
<td>29.0 to 33.0</td>
<td>-</td>
<td>0.5 to 1.5</td>
</tr>
</tbody>
</table>

1) given value is maximum content (by weight) unless shown as a range or as a minimum
2) including silver
3) when the product is intended for subsequent welding, the following maximum limits apply: Zinc 0.50%, Lead 0.02%, Phosphorus 0.02%, Sulphur 0.02% and Carbon 0.05%

2.5 Mechanical testing

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

2.5.2 The mechanical properties shall comply with the requirements of a recognised standard and with the minimum values given in Table 4.

2.5.3 Requirements with respect to retesting, identification and certification are outlined in Ch.1.
2.6 Inspection

2.6.1 Each tube shall be subjected to eddy current testing or pressure testing in accordance with the requirements of a recognised standard.

2.7 Repair

2.7.1 Defects may be removed by grinding providing the dimensional tolerances are not exceeded. Repair by welding is not permitted.

2.8 Identification

2.8.1 Tubes shall be suitably marked for identification by the manufacturer. Hard stamping of tubes is not permitted.

**Table 4 Mechanical properties for copper and copper alloy tubes**

<table>
<thead>
<tr>
<th>Designation</th>
<th>Condition</th>
<th>Yield strength $R_{P0.2}$ minimum (N/mm²)</th>
<th>Tensile strength $R_m$ minimum (N/mm²)</th>
<th>Elongation A5 minimum (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phosphorus-deoxidised copper</td>
<td>Annealed</td>
<td>100</td>
<td>220</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Half-hard</td>
<td>150</td>
<td>250</td>
<td>20</td>
</tr>
<tr>
<td>Aluminium brass</td>
<td>Annealed</td>
<td>120</td>
<td>330</td>
<td>35</td>
</tr>
<tr>
<td>Copper-Nickel 90-10</td>
<td>Annealed</td>
<td>100</td>
<td>290</td>
<td>30</td>
</tr>
<tr>
<td>Copper-Nickel 70-30</td>
<td>Annealed</td>
<td>120</td>
<td>360</td>
<td>30</td>
</tr>
</tbody>
</table>

3 Copper and copper alloy fittings

3.1 Scope

3.1.1 This subsection specifies requirements to be used in saddles, T-shaped fittings, tapered transition pieces and pipe elbows. Fittings conforming to recognized standards shall be used.

3.2 Manufacture

3.2.1 All tubes delivered with VL or works (W) certificate shall be made by works approved by the Society. The copper used shall be made by works approved by the Society.

3.3 Testing and inspection

3.3.1 Fittings shall be tested and inspected in accordance with the requirements of the relevant standard.
3.4 Identification

3.4.1 Fittings shall be suitably marked for identification by the manufacturer. Hard stamping of tubes is not permitted.

4 Titanium and titanium alloy tubes and fittings

4.1 Scope

4.1.1 This subsection specifies requirements for titanium and titanium alloy tubes and fittings to be used in shipboard systems. Provision is made for grade 1 and grade 2 unalloyed titanium and grade 9 titanium alloys.

4.1.2 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 also are met. Recognition of other standards is subject to submission to the Society for evaluation, see Ch.1 Sec.1 [3.4].

4.1.3 Fittings shall be in accordance with recognised standards.

4.1.4 Where required by the relevant design and construction parts of the Rules, tubes and fittings shall comply with the requirements of Ch.1 and the requirements of this subsection.

4.1.5 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.

4.2 Manufacture

4.2.1 All tubes and fittings shall be made at works approved by the Society.

4.2.2 Tubes for class I and II pressure systems shall be seamless. Tubes for class III pressure systems may be seamless or welded.
# SECTION 13 REFERENCES

## 1 References

A list of references given for Ch.2. Unless otherwise agreed, the latest version of the referred standards valid at the date of release for the current rules is applicable.

### Table 1 References

<table>
<thead>
<tr>
<th>Reference</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>AD 2000 Merkblatt (AD Data Sheet) HP/7.3</td>
<td>Heat treatment - Austenitic steels</td>
</tr>
<tr>
<td>ANSI H35.1</td>
<td>American National Standard Alloy and Temper Designation Systems for Aluminum</td>
</tr>
<tr>
<td>ASME 16.34</td>
<td>Valves - Flanged, Threaded and Welding End</td>
</tr>
<tr>
<td>ASTM A53</td>
<td>Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless</td>
</tr>
<tr>
<td>ASTM A106</td>
<td>Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service</td>
</tr>
<tr>
<td>ASTM A210</td>
<td>Standard Specification for Seamless Medium-Carbon Steel Boiler and Superheater Tubes</td>
</tr>
<tr>
<td>ASTM A234</td>
<td>Standard Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and High Temperature Service</td>
</tr>
<tr>
<td>ASTM A262</td>
<td>Standard Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels</td>
</tr>
<tr>
<td>ASTM A264</td>
<td>Standard Specification for Stainless Chromium-Nickel Steel-Clad Plate</td>
</tr>
<tr>
<td>ASTM A269</td>
<td>Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service</td>
</tr>
<tr>
<td>ASTM A275</td>
<td>Standard Practice for Magnetic Particle Examination of Steel Forgings</td>
</tr>
<tr>
<td>ASTM A312</td>
<td>Standard Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes</td>
</tr>
<tr>
<td>ASTM A333</td>
<td>Standard Specification for Seamless and Welded Steel Pipe for Low-Temperature Service and Other Applications with Required Notch Toughness</td>
</tr>
<tr>
<td>ASTM A334</td>
<td>Standard Specification for Seamless and Welded Carbon and Alloy-Steel Tubes for Low-Temperature Service</td>
</tr>
<tr>
<td>ASTM A335</td>
<td>Standard Specification for Seamless Ferritic Alloy-Steel Pipe for High-Temperature Service</td>
</tr>
<tr>
<td>Standard Specification</td>
<td>Description</td>
</tr>
<tr>
<td>------------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>ASTM A388</td>
<td>Standard Practice for Ultrasonic Examination of Steel Forgings</td>
</tr>
<tr>
<td>ASTM A403</td>
<td>Standard Specification for Wrought Austenitic Stainless Steel Piping Fittings</td>
</tr>
<tr>
<td>ASTM A420</td>
<td>Standard Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Low-Temperature Service</td>
</tr>
<tr>
<td>ASTM A578</td>
<td>Standard Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications</td>
</tr>
<tr>
<td>ASTM A609</td>
<td>Standard Practice for Castings, Carbon, Low-Alloy, and Martensitic Stainless Steel, Ultrasonic Examination Thereof</td>
</tr>
<tr>
<td>ASTM A770</td>
<td>Standard Specification for Through-Thickness Tension Testing of Steel Plates for Special Applications</td>
</tr>
<tr>
<td>ASTM A789</td>
<td>Standard Specification for Seamless and Welded Ferritic/Austenitic Stainless Steel Tubing for General Service</td>
</tr>
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<td>ASTM A790</td>
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