RULES
FOR THE CLASSIFICATION OF SHIPS

Part 25 - METALLIC MATERIALS

July 2019
By decision of the General Committee of Croatian Register of Shipping,

**RULES FOR THE CLASSIFICATION OF SHIPS**

PART 25 – Metallic materials

have been adopted on 17th June 2019 and shall enter into force on 1st July 2019
REVIEW OF AMENDMENTS IN RELATION TO PREVIOUS EDITION OF THE RULES

RULES FOR THE CLASSIFICATION OF SHIPS

Part 25 – METALLIC MATERIALS

All major changes throughout the text in respect to the Rules for classification of ships, Part 25 – Metallic materials, 2015 edition are shaded.

Items not being indicated as corrected has not been changed.

The grammatical and print errors, have also been corrected throughout the text of the subject Rules but are not indicated as a correction.
The subject Rules include the requirements of the following international Organisations:

**International Association of Classification Societies (IACS)**


**Recommendations:**  No. 139 (2015)
7.4 TESTING AND CERTIFICATION OF FINISHED CHAIN CABLES ................................................................. 123
7.5 TESTING AND CERTIFICATION OF ACCESSORIES .............................................................................. 125

8 WIRE ROPES ........................................................................................................................................ 127
8.1 GENERAL ........................................................................................................................................ 127
8.2 REQUIREMENTS APPLIED TO WIRE ROPES ................................................................................ 127
8.3 TESTING OF WIRE ROPES ............................................................................................................... 128
8.4 MARKING ........................................................................................................................................ 129
APPENDIX A ....................................................................................................................................... 130
APPENDIX B ....................................................................................................................................... 145
APPENDIX C ....................................................................................................................................... 147
APPENDIX D ....................................................................................................................................... 149
APPENDIX E ....................................................................................................................................... 153
1 GENERAL

1.1 APPLICATION

1.1.1 The present Part of the Rules for the Classification of Ships (hereinafter referred to as: the Rules) applies to materials and products which are intended for the construction, repair and equipping of ships, offshore installations and other structures and installations, which are manufactured in accordance with the Rules and under the supervision of the CROATIAN REGISTER OF SHIPPING (hereinafter referred to as: the Register).

1.1.2 The following materials and products should comply with the requirements of the present Rules, namely which are:

1.1.2.1 under classification supervision of the Register, respectively are subjected to all services relating to the supervision, which are based on the Rules for the Classification of Ships.

1.1.2.2 under certification or supervision respectively for issuance of certificates of all types, such as:
- non-class materials and equipment for ships (e.g. parts for cargo gear),
- non-class materials and equipment relating to ships (e.g. containers).

1.1.2.3 under statutory survey of the Register, or subjected to all activities relating to supervision, based on the national and international regulations, conventions, codes, resolutions and recommendations in force, including pertinent protocols and amendments thereto.

1.1.3 The present Part of the Rules contain valid and agreed IACS requirements, recommendations and guidelines, valid ISO standards and European norms (EN) as well as valid DIN and ASTM standards for materials and testing methods, for which unified IACS requirements, ISO standards or EN have not yet been provided.

1.1.4 Where there are special grounds for so doing, the Register reserves the right to impose more comprehensive requirements with respect to the manufacture, properties and testing of materials and products, where these appear necessary in the light of more recent research or operational experience, and it likewise reserves the right to sanction departures from these Rules, where these are technically justified.

1.1.5 The properties of products not covered by requirements specified in this Part of the Rules are subject to the standards applicable to the product in question or, where appropriate, to the material specifications or conditions of supply which have to be complied with by the manufacturer of the material.

1.1.6 Materials or products to national or international standards or to special material specifications may be permitted by the Register, if their properties are recognised by it as equivalent to those of the products specified in these Rules, or where the Register has given special approval for their use. In these circumstances, the relevant standards or specifications are considered to be an integral part of these Rules.

1.1.7 Subject to the conditions mentioned in 1.1.4, the Register may sanction the supply of materials and products conforming exclusively to the relevant standards or material specifications.

1.1.8 Should differences exist between this Part of the Rules and the relevant standards or specifications with regard to their requirements, the tests shall take account of the most stringent requirements.

1.2 SCOPE OF SUPERVISION

1.2.1 General requirements

The requirements for the procedure of supervision with manufacturer as well as requirements relating to technical documentation of materials and products, are contained in the Rules, Part 1 - General Requirements - Chapter 2 Survey during construction and initial survey.

The requirements for recognition of testing stations, laboratories and institutions are contained in the Rules, Part 1 - General Requirements - Chapter 4 - Approval of Manufacturers and service suppliers.

1.2.2 Approval of materials, products and methods of manufacture

1.2.2.1 All manufactured materials for items and structures subject to supervision of the Register, as well as procedures of material manufacture are to be approved by the Register, in accordance with Rules, Part 1 - Chapter 4, Approval of Manufacturers and Service Suppliers.

1.2.2.2 The Register may deviate from the requirements in 1.2.2.1 in case of manufacture of materials the items of which are to be built into engines and installations, that have been type tested and approved in accordance with Rules, Part 1 - Chapter 3 - Type Approval of products.

1.2.3 Preparation for tests

1.2.3.1 The semi-finished products for structures and items subject to supervision by the Register, during their manufacture shall undergo check tests in accordance with the present Part of the Rules (see 1.2.4.1).

The materials shall meet the requirements of the present Part of the Rules or the technical conditions approved by the Register.

Register shall not give any guarantee that the materials supplied to the customer satisfy in size and mass and that are free from any defects, which may adversely affect the application of the material for the specified purpose.

Products which prove defective in the course of subsequent application or processing, may be rejected, notwithstanding satisfactory previous testing, in accordance with the requirements of the Rules or standards.

1.2.3.2 Quality control of the material is carried out with the manufacturer or at the testing institution approved by the Register.
In all cases the quality control shall be always carried out after the final technological process.

Where samples are manufactured separately, they shall be technologically processed jointly with semi-finished products to which they belong (same batch, same charge or same heat).

1.2.3.3 The manufacturer shall introduce a system which enables the product to be identified after every stage of the manufacturing process and to be traced back to the heat, or to appropriate semi-product or batch, respectively.

1.2.3.4 Marking of semi-products and specimens subject to testing shall be in general carried out in the presence of the Surveyor to the Register.

The Surveyor, taking account of certain conditions, may allow a member to quality control department of the approved manufacturer to apply the personal specimen stamp.

1.2.3.5 Prior to testing of the material quality, the manufacturer must submit to the Surveyor documents referring to the materials or products to be tested. These documents shall contain at least the following information:

1.2.4 Procedure of testing

1.2.4.1 Acceptance tests shall normally be performed in the manufacturing works in the presence of the Surveyor.

For this purpose, the manufacturer shall give the Surveyor access to the manufacturing and testing departments concerned and shall make available to him all records relating to quality control, in so far as this is necessary for the proper discharge of his duties. The Surveyor is also entitled to witness the manufacturing process, although this shall not interfere with the work flow.

1.2.4.2 For the testing of mechanical and technological properties, use shall be made of the general methods and test specimens mentioned in Chapter 2. Test requirements and results shall be stated in SI units. Test not referred to in Chapter 2 are to be carried out in accordance with national or international standards, unless otherwise agreed.

1.2.4.3 Where non-destructive tests are specified for the various products types, these shall be performed by the manufacturer and the results together with details of the test method are to be evaluated according to recognised criteria of acceptability and documented in a certificate. The Surveyor is entitled to be present at the tests. Where tests are to be performed by the Register, special agreements shall be reached concerning this.

1.2.4.4 The chemical composition of materials shall normally be carried out by the manufacturer as ladle analyses and these shall cover all those elements for which limiting values are prescribed in the present Rules or in the other relevant documents, or which are added in order to guarantee the required mechanical properties. The certificate of the manufacturer is generally accepted as proof of the chemical composition. Where doubts exist as to the composition, Register may also require the performance of semi product or finished product analyses. Possible deviations between the ladle and product analyses must conform to the relevant standards or specifications.

1.2.4.5 The manufacturer shall carry out the surface inspection and check the dimensions of semi-finished products as well as other testing required by the present Rules, standards or specifications on all semi-finished products (e.g. pressure test, Eddy current test, hardness test) and the Register may perform control tests.

1.2.4.6 The Register may require the tests to be repeated if confusion of specimens or test results are detected, or the test results do not define the quality of material with required, degree of accuracy. Thus the Register may require additional tests.

1.2.4.7 Should the material properties slightly deviate from the requirements of the present Rules, the Register may approve their further application, at request of the manufacturer, only upon special consideration of this deviation.

1.2.4.8 Where in exceptional cases due to technical reasons, the tests cannot be performed in accordance with methods specified in the present Rules, equivalent methods or techniques shall be applied.

1.3 MARKING

1.3.1 General

The materials manufactured under the supervision of the Register, shall be marked with the appropriate Register marks, after completion of all tests and surveys.

The Surveyor may have specified certificates for consideration, issued or approved by the Register, although the material is marked with the Register stamp.

1.3.2 Register stamps

For marking of materials and products, the Surveyor shall apply seals, stamps and brands in accordance with guidelines for usage and storage of seals, stamps and brands.

1.3.3 Conditions of marking

Prior to marking with the Register stamp, materials and products are to be marked with trade marks, which unless otherwise stated in the present Part of the Rules, shall contain:

1. grade or quality of material;
2. figures or other designation to indicate the origin of the material or product (e.g. number of plate, number of heat, number of batch and the like);
3. trade mark.
1.3.4 Method of marking

As a rule, the marks shall be impressed on materials, in easily accessible positions for (survey) inspection and after installation into object.

On materials subject to subsequent machining, the marks shall be possibly impressed in positions not subject to further processing.

The marking shall normally be impressed with a punch, unless such marking is precluded by materials with a sensitive surface or which are too thin. In such cases marking may be done with low stress stamps, paint, rubber stamps, adhesive stickers or electrograving.

1.3.4.1 Marking of material delivered in single pieces.

In addition to marks specified in 1.3.3, the following information shall be stamped on every semi-finished product or product:

1. date of final testing (identical with date of the certificate on supervision and testing of materials);
2. number of Register certificate;
3. final stamp of the Register.

1.3.4.2 Marking of material tested in batches

Besides data specified in 1.3.3, materials and products which are tested in batches shall have the following information, impressed on plates:

1. number of pieces per batch,
2. total mass (in kg), or length (in m) or surface (in m²);
3. test pressure or any other specific value intended for testing in accordance with the Rules or specifications;
4. number of Register certificate,
5. final Register stamp.

The plates are to be attached to bunches, drums or cases.

1.3.5 Transfer of marks

The Register marks shall be so applied that their legibility cannot be impaired by the transportation, processing or storage. Where the further processing of the products entails the removal of existing marks, the manufacturer concerned must apply these to a different spot and must arrange for the transfer of the Register stamp. The marks are to be transferred in the presence of Surveyor.

Materials which are not furnished with the Register mark, are considered as not tested by the Surveyor, unless otherwise stated.

Exceptionally, the Surveyor may permit cancellation of Register mark, under supervision of the quality control staff and transfer to other spot. The responsible person of the quality control department shall make a relevant record and impress personal stamp.

On the basis of record and stamp of the quality control responsible person the Surveyor shall impress Register's stamp on the material.

1.3.6 Cancellation of Mark

Should it be shown during further processing of the tested products that these have defects or in some way no longer meet the Register Rules, the material shall be rejected, no matter what has been previously tested and marked by the Surveyor.

The Register stamps shall be cancelled on rejected materials, in the presence of relevant surveyor.

Marks impressed with a steel stamp shall be cancelled by grinding or punched in a way that seal shall be deleted with x.

1.3.7 Storage of brands, stamps and seals

The brands, stamps and seals shall be stored by the Surveyor in a way as to exclude any possibility of misuse.

1.4 TEST DOCUMENTS AND CERTIFICATES

1.4.1 Register's certificates

If, under test, the specified requirements are satisfied, the result is certified by the Surveyor. Proof of this normally takes the form of a Register acceptance test certificate. By agreement, the results may also be attested in the following alternative manners:

1. by confirmation of the test results on an acceptance test report (joint certification by manufacturer and the Surveyor) in the form of stamp and signature of the Surveyor;
2. in the case of products produced in large quantities and subjected to testing by heat or batch, by confirmation of the Surveyor who appends his stamp and signature to the manufacturer's certificate in token that the tests carried out on the consignment in accordance with the Rules have satisfied the requirements. In addition, the manufacturer must stamp the certificates accordingly and must also confirm that the products listed in the schedule have been manufactured in accordance with the Rules.

1.4.2 Manufacturer's acceptance test certificate

Where, in accordance with the Rules for the Classification of Ships or special arrangements, the task and responsibility of materials testing is left to the manufacturer, the latter shall issue a relevant acceptance test certificate (e.g. 3.1 according to EN 10204), which besides the data listed in 1.2.3.5, also contains the following data:

1. method of manufacture, heat numbers and chemical composition;
2. condition in which supplied with details of heat treatment;
3. identifying marks;
.4 results of tests carried out on material.

The type of certificate is specified in the special parts of the Rules.
2 TEST SPECIMENS AND MECHANICAL TESTING PROCEDURES FOR MATERIALS

2.1 SCOPE

2.1.1 This chapter gives the requirements for test specimens when testing ferrous and non-ferrous metals.

2.1.2 The corresponding testing procedures, generally, are to follow established practice as laid down in international and national standards. Some testing procedures are given in this document.

2.1.3 Alternative specimens, such as those complying with recognised national standards, may be accepted subject to special approval by the Register. The same applies to the given testing procedures.

2.2 GENERAL

2.2.1 Test samples from which test specimens are cut are to have undergone the same treatment as the material from which they have been taken (e.g. heat treatment).

2.2.2 If test samples are cut from material by flame cutting or shearing, a reasonable margin is required to enable sufficient material to be removed from the cut edges during final machining.

2.2.3 The preparation of test specimens is to be done in such a manner that test specimens are not subject to any significant straining or heating.

2.2.4 Any of the test specimen referred to as “alternative” may be used except as otherwise stated or agreed.

2.3 TESTING MACHINES

2.3.1 All tests are to be carried out by competent personnel. Testing machines are to be maintained in a satisfactory and accurate condition and are to be recalibrated at approximately annual intervals. This calibration is to be traced to a nationally recognised authority and is to be to the satisfaction of the Register.

Impact testing machines are to be calibrated in accordance with ISO 148-2 or other recognised standard.

The accuracy of tensile test machines is to be within ± one percent.

Tension/compression testing machines are to be calibrated in accordance with ISO 7500-1 or other recognised standard.

2.4 TENSILE TEST SPECIMENS

2.4.1 Designations

The following designations are used:

- $d$: diameter
- $a$: thickness
- $b$: width
- $L_o$: original gauge length
- $L_c$: parallel test length
- $S_o$: original cross-sectional area
- $R$: transition radius
- $D$: external tube diameter
- $t$: thickness of product

2.4.2 Dimensions

Tests shall be performed in accordance with established standards. This category includes for example: EN 10002, Part 1 - Tensile testing.

2.4.2.1 General

Proportional test specimens with a gauge length $L_o = 5.65 \sqrt{S_o}$ or $= 5d$ should preferably be used as the minimum percentage elongation values specified in the Chapter 2 refer to this gauge length. $L_o$ should preferably be greater than 20 mm. The gauge length may be rounded off to the
nearest 5 mm provided that the difference between this length and $L_o$ is less than 10% of $L_o$.

2.4.2.2 Plates, strips and sections

Flat specimens are usually to be used with dimensions as specified below.

a) Proportional flat specimen
   
   $$\begin{align*}
   a &= t \\
   b &= 25 \text{ mm} \\
   L_o &= 5.65 \sqrt{S_o} \\
   L_c &= L_o + 2 \sqrt{S_o} \\
   R &= 25 \text{ mm}
   \end{align*}$$

b) Non-proportional flat specimen
   
   $$\begin{align*}
   a &= t \\
   b &= 25 \text{ mm} \\
   L_o &= 200 \text{ mm} \\
   L_c &\geq 212.5 \text{ mm} \\
   R &= 25 \text{ mm}
   \end{align*}$$

When the capacity of the available testing machine is insufficient to allow the use of test specimen of full thickness, this may be reduced by machining one of the rolled surfaces.

Alternatively, for materials over about 40 mm thick, proportional round test specimens with dimensions as specified below, may be used.

c) Round specimen
   
   $$\begin{align*}
   d &\geq 10 \text{ mm to } 20 \text{ mm, preferably } 14 \text{ mm} \\
   L_o &= 5d \\
   L_c &\geq L_o + \frac{d}{2} \\
   R &= 10 \text{ mm (for nodular cast iron and materials with a specified elongation less than } 10\%, R \geq 1.5 \, d)\).
   \end{align*}$$

The axes of the round test specimens are to be located at approximately one quarter of the thickness from one the rolled surfaces.

2.4.2.3 Aluminium alloys

Flat tensile test specimens shall be used for specified thicknesses up to and including 12.5 mm. The tensile test specimen shall be prepared so that both rolled surfaces are maintained. For thicknesses exceeding 12.5 mm, round tensile test specimens will be used. For thicknesses up to and including 40 mm, the longitudinal axis of the round tensile test specimen shall be located at a distance from one of the surfaces equal to half of the thickness. For thicknesses over 40 mm, the longitudinal axis of the round tensile test specimen shall be located at a distance from one of the surfaces equal to one quarter of the thickness.

2.4.2.4 Forgings, casting (excluding grey cast iron)

Proportional round test specimens with dimensions, as specified above in 2.4.2.2 c), are usually to be used.

For small size bars and similar products the test specimens may consist of a suitable length of bar or other product tested in the full cross-section.

2.4.2.5 Tubes

The test specimen shall conform with the following:

a) full cross-section specimen with plugged ends:
   
   $$\begin{align*}
   L_o &= 5.65 \sqrt{S_o} \\
   L_c &\geq 5.65 \sqrt{S_o} + \frac{D}{2} \text{ where } L_c \text{ is the distance between the grips or the plugs, whichever is the smallest.}
   \end{align*}$$

b) Strips cut longitudinally
   
   $$\begin{align*}
   a &= t \\
   b &\geq 12 \text{ mm} \\
   L_o &= 5.65 \sqrt{S_o} \\
   L_c &= L_o + 2b
   \end{align*}$$

The parallel test length is not to be flattened, but the enlarged ends may be flattened for gripping in the testing machine.
Round test specimens may also be used, provided that the wall thickness is sufficient to allow the machining of such specimens to the dimensions given in 2.4.2.2.c), with their axes located at the mid-wall thickness.

### 2.4.2.6 Wires

Full cross-section test specimen with the following dimension is to be used:

\[
L_o = 200 \text{ mm} \\
L_c = L_o + 50 \text{ mm}
\]

### 2.4.2.7 Grey cast iron

Round non-cylindrical machined test specimen as shown below, is to be used.

### 2.4.2.8 Weldments

a) Deposited metal tensile test

Round specimen with the following dimensions is to be used:

\[
d = 10 \text{ mm} \\
L_o = 50 \text{ mm} \\
L_c \geq 55 \text{ mm} \\
R \geq 10 \text{ mm}
\]

For specially small or large dimensions other specimens may be used after agreement with the Register, provided they conform with the geometrical relationship given in 2.4.2.2.c).

b) Butt weld tensile test

Flat specimen, (the weld to be machined or ground flush with the surface of plate), with the following dimensions is to be used:

\[
a = t \\
b = 12 \text{ for } t \leq 2 \\
b = 25 \text{ for } t > 2 \\
L_o = \text{ width of weld } + 60 \text{ mm} \\
R > 25 \text{ mm}
\]

### 2.4.2.9 Through thickness tensile test specimen

Round test specimens including built-up type by welding are to be prepared, in accordance with a recognised standard.

### 2.4.2.10 Tolerances

The tolerances on specimen dimensions are to be in accordance with ISO 6892-98 or other recognised standards, as appropriate.

### 2.5 TENSILE PROPERTIES AT AMBIENT TEMPERATURE

#### 2.5.1 Yield stress (yield point) \( R_{eH} \)

The value of stress measured at the commencement of plastic deformation at yield, or the value of stress measured at the first peak obtained during yielding even when that peak is equal to or less than any subsequent peaks observed during plastic deformation at yield. The test is to be carried out with an elastic stress, within the following limits:

<table>
<thead>
<tr>
<th>Modulus of Elasticity of the material (E)</th>
<th>Rate of stressing ( N/mm^2s^{-1} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>N/mm²</td>
<td>Min.</td>
</tr>
<tr>
<td>&lt; 150 000</td>
<td>2</td>
</tr>
<tr>
<td>( \geq 150 000 )</td>
<td>6</td>
</tr>
</tbody>
</table>

#### 2.5.2 Proof stress (yield strength) \( R_p \)

When no well defined yield phenomenon exists, the 0.2% proof stress \( (R_{p0.2}) \) is to be determined according to the applicable specification. For austenitic and duplex stainless steel products, the 1% proof stress \( (R_{p1}) \) may be determined in addition to \( R_{p0.2} \).

The rate of loading shall be as stated in 2.5.1 above.

#### 2.5.3 Tensile strength \( (R_m) \)

After reaching the yield or proof load, for ductile material the machine speed during the tensile test is not to exceed that corresponding to a strain rate of 0.008s⁻¹. For brittle materials, such as cast iron, the elastic stress rate is not to exceed 10 N/mm² per second.

#### 2.5.4 Fracture elongation \( (A) \)

The elongation value is, in principle, valid only if the distance between the fracture and the nearest gauge mark is not less than one third of the original gauge length. However the result is valid irrespective of the location of the fracture, if the percentage elongation after fracture is equal to or greater than the expected value.

The elongation generally means elongation \( A_5 \) determined on a proportional gauge length \( 5.65 \sqrt{S_o} = 5d \) but may also be given for other specified gauge lengths.

If material is a ferritic steel of low or medium strength and not cold worked and the elongation as measured on a non-proportional gauge length, the required elongation \( A_o \) on that gauge length \( L_o \) may after agreement be calculated from the following formula:

\[
A_o = 2A_5 \left( \frac{S_o}{L_o} \right)^{0.40}
\]

For tables and graphs see ISO/DIS 2566.
2.6 BEND TEST SPECIMENS

2.6.1 Flat bend test specimen, as given in the following, is to be used. Edges on tension side to be rounded to a radius of 1 to 2 mm.

2.6.2 Forgings, castings and semi-finished products

\[ a = 20 \text{ mm} \]
\[ b = 25 \text{ mm} \]

2.6.3 Plates, structural sections, sheets:

\[ a = t \]
\[ b = 30 \text{ mm} \]

2.6.4 Butt welds, transverse specimen

a) face and root bend

\[ a = t \]
\[ b = 30 \text{ mm} \]

If the as rolled thickness \( t \) is greater than 25 mm, it may be reduced to 25 mm by machining on the compression side of the bend specimen. The surfaces of the welds are to be machined (ground) flush with the surface of the plate.

b) side bend

\[ a = 10 \text{ mm} \]
\[ b = t \]

If \( t \geq 40 \text{ mm} \), the side-bend specimen may be subdivided, each part being at least 20 mm wide.

2.6.5 Butt weld, longitudinal specimens

The test specimens, for longitudinal face and root test, are to be in accordance with an appropriate recognised standard.

2.7 TOUGHNESS TESTING

2.7.1 Charpy V-notch impact specimens

The test specimens shall comply with the following dimensions:

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Nominal</th>
<th>Tolerances</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>55 mm</td>
<td>± 0,60 mm</td>
</tr>
<tr>
<td>Width - standard specimen</td>
<td>10 mm</td>
<td>± 0,11 mm</td>
</tr>
<tr>
<td>- subsize specimen</td>
<td>7,5 mm</td>
<td>± 0,11 mm</td>
</tr>
<tr>
<td>- subsize specimen</td>
<td>5 mm</td>
<td>± 0,06 mm</td>
</tr>
<tr>
<td>Angle of notch</td>
<td>45°</td>
<td>± 2°</td>
</tr>
<tr>
<td>Thickness</td>
<td>10 mm</td>
<td>± 0,06 mm</td>
</tr>
<tr>
<td>Dept below notch</td>
<td>8 mm</td>
<td>± 0,06 mm</td>
</tr>
<tr>
<td>Root radius</td>
<td>0,25 mm</td>
<td>± 0,025 mm</td>
</tr>
<tr>
<td>Distance of notch from end of test specimen</td>
<td>27,5 mm</td>
<td>± 0,42 mm</td>
</tr>
<tr>
<td>Angle between plane of symmetry of notch and longitudinal axis of test specimen</td>
<td>90°</td>
<td>± 2°</td>
</tr>
</tbody>
</table>

2.7.2 Sub size Charpy requirements

The testing and requirements for smaller than 5.0 mm size specimens are to be in accordance with the following table. Minimum average values for subsized specimens are as follows:

<table>
<thead>
<tr>
<th>Charpy V-notch specimen size</th>
<th>Minimum energy, average of 3 specimens</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 mm x 10 mm</td>
<td>E</td>
</tr>
<tr>
<td>10 mm x 7,5</td>
<td>5E/6</td>
</tr>
<tr>
<td>10 mm x 5,0 mm</td>
<td>2E/3</td>
</tr>
</tbody>
</table>

\( E = \) the values of energy specified for full thickness 10 mm x 10 mm specimens

All other dimensions and tolerances are to be as specified in 2.7.1.

Only one individual value may be below the specified average value, provided it is not less than 70% of that value.

In all cases, the largest size Charpy specimens possible for the material thickness, shall be machined.

2.7.3 Testing machines and temperature control in Charpy V-notch impact testing

All impact tests are to be carried out on Charpy machines complying with the requirements of ISO 148 or other national and international recognised standards, and having a striking energy of not less than 150 J.
Where the test temperature is other than ambient the temperature of the test specimen at the moment of breaking shall be the specified temperature within ± 2°.

2.7.4 Dropweight specimens

Dropweight specimens for determination of no-break performance according to ASTM specification (E-208) are to comply with this ASTM standard and have one of the following dimensions (mm):

- Type P-1: 25 by 90 by 360
- Type P-2: 19 by 50 by 130
- Type P-3: 16 by 50 by 130

The following is to be noted if not otherwise specified:

- the specimen sides shall be saw-cut or machined (minimum 25 mm to flame-cut surface),
- the machining of the plate to prescribed specimen thickness shall be on one side only,
- the specimens may be of any orientation, but the orientation shall be the same for all specimens.

2.8 DUCTILITY TESTS FOR PIPES AND TUBES

2.8.1 Flattening test specimens

Length is to be from 10 mm to 100 mm. Plain and smoothed ends cut perpendicular to the tube axis. Reference is made to ISO 8493.

2.8.2 Drift expanding test

The lengths \( L \) of the drift expanding test specimens are to be as follows. Reference is made to ISO 8492.

Metallic tubes: \( L \) equal to twice the external diameter \( D \) of the tube if the angle of the drift \( \beta \) is 30°, and \( L \) equal to 1.5 \( D \) if the angle of the drift is 45° or 60°. The test piece may be shorter provided that after testing the remaining cylindrical portion is not less than 0.5 \( D \).

The rate of penetration of the mandrel shall not exceed 50 mm/min.

2.8.3 Flanging test

The flanging test specimen is to be of length \( L \) equal to approximately 1.5 \( D \). The test piece may be shorter provided that after testing the remaining cylindrical portion is not less than 0.5 \( D \).

The rate of penetration of forming tool shall not exceed 50 mm/min. Reference is made to ISO 8494.

2.8.4 Ring expanding test

The test piece consist of a ring having a length of between 10 and 16 mm. The rate of penetration of the mandrel shall not exceed 30 mm/s. Reference is made to ISO 8495.

2.8.5 Ring tensile test

The ring shall have a length of about 15 mm with plain and smoothed ends cut perpendicular to the tube axis.

The ring is to be drawn to fracture by means of two mandrels placed inside the ring and pulled in tensile testing machine. The rate shall not exceed 5 mm/s. Reference is made to ISO 8496.

2.9 RE-TESTING

2.9.1 General

2.9.1.1 If the test sections or specimens specified for a test are not properly taken and prepared, the test results obtained with them shall be invalid. The tests shall then be repeated on properly prepared test specimens.

2.9.1.2 If, in a properly performed test, the requirements are not met, then, before the corresponding unit test quantities are rejected, re-testing may be carried out subject to conditions stated below. Re-testing is not allowed if it is suspected that the wrong material is concerned.

2.9.1.3 If the unsatisfactory result of a test is due to obvious defects in the execution of the test or to a narrowly defined fault in the test specimen, the result shall be disregarded and the test in question shall be repeated on a test specimen of the same type which shall be taken from the same test section. This also applies to tensile specimens which, when tested, fractured outside the valid measuring length.

2.9.1.4 If the unsatisfactory result of a test is attributable to improper heat treatment of the products, they may be re-subjected to heat treatment. Subsequently, the entire test shall be repeated and the original test result shall be disregarded.
2.9.1.5 The manufacturer may also follow the procedure described in 2.9.1.4 in the case of those products which, according to the specifications, may be supplied without heat treatment but which have failed to meet the requirements in this condition.

2.9.1.6 If, under test, a large proportion of the products fail because of constantly recurring manufacturing defects, the entire delivery may be rejected.

2.9.2 Unsatisfactory tensile test specimens (excluding pipes)

2.9.2.1 Individual tests

When the tensile test fails to meet the requirements, two further tests may be made from the same piece. If both of these additional tests are satisfactory, the item and/or batch (as applicable) is acceptable. If one or both of these tests fail, the item and/or batch is to be rejected.

The additional tests detailed above are to be taken, preferably from material taken adjacent to the original tests, but alternatively from another test position or sample representative of the item/batch.

2.9.2.2 Testing by heats or batches

The manufacturer shall have the option of separating the sample which has yielded unsatisfactory results or of continuing to treat it as part of the unit test quantity.

If the sample in question is separated, then, for each unsatisfactory tensile specimen, two substitute specimens shall be tested which shall be taken from different samples of the unit test quantity.

If the sample in question continues to be treated as part of the unit test quantity, one of the retests shall be performed on this sample and the other on a different sample.

Both of retests must satisfy the requirements.

2.9.3 Unsatisfactory impact test specimens (excluding pipes)

2.9.3.1 Individual tests

Where specified the following Charpy re-test procedure will apply:

When the average value of three initial Charpy V-notch impact specimens fails to meet the stated requirement, or the value for more than one specimen is below the required average value, or when the value of any one specimen is below 70% of the specified average value, three additional specimens from the same material may be tested and the results added to those previously obtained to form a new average. If this new average complies with the requirements and if not more than two individual results are lower than the required average and of these, not more than one result is below 70% of the specified average value the piece or batch (as specified for each product) may be accepted.

2.9.3.2 Testing by heats or batches

If the average value of 3 impact test specimens fails to satisfy the requirements or if a single value is less than 70% of the stipulated average value, then the procedure described in 2.9.3.1 shall be applied initially.

If re-testing also produces an unsatisfactory result, the sample tested shall be rejected and two further samples, of the same or the next smaller thickness, from the same unit test quantity shall be tested.

If, again, one of the samples fails to satisfy the requirements, then the entire unit test quantity shall be rejected. With the consent of the Surveyor, the remaining sample quantities in the unit test quantity may, however, be subjected to individual testing.

2.9.4 Unsatisfactory drop weight specimens

2.9.4.1 Individual tests

If one or both of the two test specimens fail(s), two similar substitute specimens may be taken from the same sample and tested. Both substitute specimens shall satisfy the requirements. If they fail to do so, the relevant sample shall be rejected.

2.9.4.2 Testing by heats

If one or both of the two test specimens to be taken from the thickest sample of the heat fail(s), then, from the same sample and from a different sample of the same thickness (or, if not available, from the next smaller thickness) two specimens of the same type each shall be taken and tested. All four specimens shall satisfy the requirements. If they fail to do so, then the relevant heat shall be rejected.

With the consent of the Surveyor, the remaining sample quantities in the rejected heat may, however, be subjected to individual testing.

2.9.5 Unsatisfactory results in the testing of pipes

2.9.5.1 Testing by batches

If, when subjected to the tensile test, the ring test or notched bar impact test, pipes fail to satisfy the requirements, the test which has produced unsatisfactory results shall be repeated on the same end of the pipe selected for the test. If the new test fails to satisfy the requirements, the pipe in question shall be discarded. In its place two further pipes shall be taken from the batch concerned and shall be subjected to the full range of tests. If, during testing, one of the requirements is not met, then the entire batch shall be deemed unacceptable.

However, with the consent of the Surveyor, the characteristic which failed to meet the requirements may be checked on each individual pipe.

2.9.6 Retesting specified in standards

Where a national or international standard specifies a wider scope for the performance of repeat tests, this shall take precedence over retests described in 2.9.5.1.
3 STEEL AND IRON MATERIALS

3.1 GENERAL

3.1.1 This Chapter contains requirements to be applied to normal and higher strength hull structural steel, hull structural steels for low temperature application, unalloyed structural steels for welded structures, high-strength quenched and tempered steels for welded structures, high-temperature steels, steels tough at sub-zero temperatures, stainless steels, clad plates, steels with requirements in the direction of product thickness, steel pipes, steel forgings, cast steels, grey, nodular and malleable cast iron, then fittings, pressed parts and fasteners.

3.2 NORMAL AND HIGHER STRENGTH HULL STRUCTURAL STEELS

3.2.1 General

3.2.1.1 These requirements apply to weldable normal and higher strength hot-rolled steel plates, wide flats, sections and bars intended for use in hull construction.

3.2.1.2 The requirements are primarily intended to apply to steel products with a thickness as follows:

- For steel plates and wide flats:
  - All grades: Up to 100 mm in thickness
- For sections and bars:
  - All grades: Up to 50 mm in thickness

3.2.1.3 Provision is made for four grades of normal strength steel based on the impact test requirements.

3.2.1.4 Steels differing in chemical composition, deoxidation practice, conditions of supply and mechanical properties may be accepted, subject to the special approval of the Register. Such steels are to be given a special designation.

3.2.1.5 These requirements also apply to normal and higher strength 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. These requirements apply to plates, wide flats, sections and bars in all grades up to a maximum thickness of 50 mm.

3.2.2 Approval

3.2.2.1 All materials are to be manufactured at works which have been approved by the Register for the type and grade of steel which is being supplied. The suitability of each grade of steel for forming and welding is to be demonstrated during the initial approval tests at the steelworks. The approval procedure shall be carried out in accordance with the Rules, Part I-General Requirements, Chapter 4-Approval of Manufacturers and Service Suppliers, and Approval of the steel works shall follow a scheme given in Appendix A. For the steels intended for high heat input welding over 50 kJ/cm, the approval of the manufacturers is to follow a scheme given in Appendix B. For steels intended for a corrosion resistant designation, the approval of the manufacturer is to additionally follow the scheme given in Appendix C.

3.2.2.2 It is the manufacturer’s responsibility to assure that effective process and production controls in operation are adhered to within the manufacturing specifications. Where control imperfection inducing possible inferior quality of product occurs, the manufacturer is to identify the cause and establish a countermeasure to prevent its recurrence. Also, the complete investigation report is to be submitted to the Surveyor.

3.2.2.3 When steel is not produced at works at which it is rolled, a certificate is to be supplied to the Surveyor at the rolling mill stating the process, by which it was manufactured, the name of the manufacturer who supplied it, the number of the cast from which it was made and the ladle analysis.

3.2.2.4 The Surveyor is to have access to the works at which the steel was produced.

NOTE:
1. The attention of the users must be drawn to the fact that when fatigue loading is present, the effective fatigue strength of a welded joint of higher strength steel may not be greater than that of a welded joint in normal strength steels.

2. Before subjecting steels produced by thermo-mechanical rolling to further heating for forming or stress relieving, or using high heat-input welding, special consideration must be given to the possibility of a consequent reduction in mechanical properties.

3.2.3 Method of Manufacture

3.2.3.1 Steel is to be manufactured by the basis oxygen, electric furnace or open hearth processes or by other processes specially approved by the Register.

3.2.3.2 The deoxidisation practice used for each grade is to comply with the appropriate requirements of Tables 3.2.4.1-1 and 3.2.4.1-2.
3.2.3.3 The rolling practice applied for each grade is to comply with the appropriate condition of supply of Tables 3.2.5.1-1 and 3.2.5.1-2.

The applicable rolling procedures are defined as follows and the schematic diagrams are given in the Figures 3.2.3.3.1:

a) As Rolled, AR
This procedure involves steel being cooled as it is rolled with no further heat treatment. The rolling and finishing temperatures are typically in the austenite recrystallisation region and above the normalising temperature. The strength and toughness properties of steel produced by this process are generally less than steel heat treated after rolling or than steel produced by advanced processes.

b) Normalising, N
Normalising involves heating rolled steel above the critical temperature, Ac3, and in the lower end of the austenite recrystallisation region for a specific period of time, followed by air cooling. The process improves the mechanical properties of as rolled steel by refining the grain size and homogenising the microstructure.

c) Controlled Rolling, CR (Normalising Rolling, NR):
A rolling procedure in which the final deformation is carried out in the normalising temperature range, allowed to cool in air, resulting in a material condition generally equivalent to that obtained by normalising.

d) Quenching and Tempering, QT
Quenching involves a heat treatment process in which steel is heated to an appropriate temperature above the Ac3, held for a specific period of time, and then cooled with an appropriate coolant for the purpose of hardening the microstructure. Tempering subsequent to quenching is a process in which the steel is reheated to an appropriate temperature not higher than the Ac1, maintained at that temperature for a specific period of time to restore toughness properties by improving the microstructure and reduce the residual stress caused by the quenching process.

e) Thermo-Mechanical Rolling, TM (Thermo-Mechanical Controlled Processing, TMCP):
This is a procedure which involves the strict control of both the steel temperature and the rolling reduction. Generally, a high proportion of the rolling reduction is carried out close to the Ar3 temperature and may involve the rolling in the dual phase temperature region. Unlike controlled rolled (normalised rolling) the properties conferred by TM(TMCP) cannot be reproduced by subsequent normalising or other heat treatment.
The use of accelerated cooling on completion of TM-rolling may also be accepted subject to the special approval of the Register. The same applies for the use of tempering after completion of the TM-rolling.

f) Accelerated Cooling, AcC
Accelerated cooling is a process, which aims to improve mechanical properties by controlled cooling with rates higher than air cooling immediately after the final TM-rolling operation. Direct quenching is excluded from accelerated cooling.
The material properties conferred by TM and AcC cannot be reproduced by subsequent normalising or other heat treatment. Where NR (CR) and TM with / without AcC are applied, the programmed rolling schedules are to be verified by the Register at the time of the steel works approval, and are to be made available when required by the attending Surveyor. On the manufacturer’s responsibility, the programmed rolling schedules are to be adhered to during the rolling operation, refer to the above 3.2.2.2. To this effect, the actual rolling records are to be reviewed by the manufacturer and occasionally by the Surveyor.

When deviation from the programmed rolling schedules or normalizing or quenching and tempering procedures occurs, the manufacturer shall take further measures required in the above 3.2.2.2 to the Surveyor’s satisfaction.
NOTES:
AR: As Rolled
N: Normalizing
CR (NR): Controlled Rolling (Normalizing Rolling)
QT: Quenching and Tempering
TM: Thermo-Mechanical Rolling (Thermo-Mechanical Controlled Process)
R: Reduction
(*) Sometimes rolling in the dual-phase temperature region of austenite and ferrite
AcC: Accelerated Cooling
3.2.4 Chemical Composition

3.2.4.1 The chemical composition of samples taken from each ladle of each cast is to be determined by the manufacturer in an adequately equipped and competently staffed laboratory and is to comply with the appropriate requirements of Tables 3.2.4.1-1 and 3.2.4.1-2. For steel plates and wide flats over 50 mm thick, slight deviations in the chemical composition may be allowed as approved by the Register.

3.2.4.2 The manufacturer’s declared analysis will be accepted subject to occasional checks required by the Surveyor.

Table 3.2.4.1-1

<table>
<thead>
<tr>
<th>Grade</th>
<th>A</th>
<th>B</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>For t ≤ 50 mm</td>
<td>For t ≤ 50 mm</td>
<td>For t ≤ 25 mm</td>
<td>Killed and fine grain treated</td>
</tr>
<tr>
<td></td>
<td>Any method except rimmed steel (1)</td>
<td>Any method except rimmed</td>
<td>Killed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>For t &gt; 50 mm Killed</td>
<td>For t &gt; 50 mm Killed</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Chemical Composition % (4)(7)(8) (ladle samples)

Carbon plus 1/6 of the manganese content is not to exceed 0.40%

<table>
<thead>
<tr>
<th>Component</th>
<th>Grade</th>
<th>A</th>
<th>B</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>C max.</td>
<td>0.21(2)</td>
<td>0.21</td>
<td>0.21</td>
<td>0.18</td>
<td></td>
</tr>
<tr>
<td>Mn min.</td>
<td>2.5 x C</td>
<td>0.80(3)</td>
<td>0.60</td>
<td>0.70</td>
<td></td>
</tr>
<tr>
<td>Si max.</td>
<td>0.50</td>
<td>0.35</td>
<td>0.35</td>
<td>0.35</td>
<td></td>
</tr>
<tr>
<td>P max.</td>
<td>0.035</td>
<td>0.035</td>
<td>0.035</td>
<td>0.035</td>
<td></td>
</tr>
<tr>
<td>S max.</td>
<td>0.035</td>
<td>0.035</td>
<td>0.035</td>
<td>0.035</td>
<td></td>
</tr>
<tr>
<td>Al (acid soluble min)</td>
<td>-</td>
<td>-</td>
<td>0.015(5)(6)</td>
<td>0.015(6)</td>
<td></td>
</tr>
</tbody>
</table>

Notes:
(1) Grade A sections up to a thickness of 12.5 mm may be accepted in rimmed steel subject to the special approval of the Register.
(2) Max. 0.23% for sections.
(3) When Grade B steel is impact tested the minimum manganese content may be reduced to 0.60%.
(4) When any grade of steel is supplied in the thermo-mechanically rolled condition variations in the specified chemical composition may be allowed or required by the Register.
(5) For Grade D steel over 25 mm thick.
(6) For Grade D steel over 25 mm thick and Grade E steel the total aluminium content may be determined instead of acid soluble content. In such cases the total aluminium content is to be not less than 0.020%. A maximum aluminium content may also be specified by the Register. Other suitable grain refining elements may be used subject to the special approval of the Register.
(7) The Register may limit the amount of residual elements which may have an adverse effect on the working and use of the steel, e.g. copper and tin.
(8) Where additions of any other element have been made as part of the steelmaking practice, the content is to be indicated.
Table 3.2.4.1-2
Chemical composition and deoxidation practice for higher strength steels

<table>
<thead>
<tr>
<th>Grade (1)</th>
<th>A32</th>
<th>D32</th>
<th>E32</th>
<th>F32</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A36</td>
<td>D36</td>
<td>E36</td>
<td>F36</td>
</tr>
<tr>
<td></td>
<td>A40</td>
<td>D40</td>
<td>E40</td>
<td>F40</td>
</tr>
</tbody>
</table>

| Deoxidation Practice | Killed and fine grain treated |

<table>
<thead>
<tr>
<th>Chemical Composition</th>
<th>% (5)(7) (ladle samples)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C max.</td>
<td>0.18</td>
</tr>
<tr>
<td>Mn (90-1.60(2))</td>
<td>0.90-1.60</td>
</tr>
<tr>
<td>Si max.</td>
<td>0.50</td>
</tr>
<tr>
<td>P max.</td>
<td>0.035</td>
</tr>
<tr>
<td>S max.</td>
<td>0.035</td>
</tr>
<tr>
<td>Al (acid soluble min)</td>
<td>0.015(3)(4)</td>
</tr>
<tr>
<td>Nb</td>
<td>0.02 - 0.05(4) total:</td>
</tr>
<tr>
<td>V</td>
<td>0.05 - 0.10(4)</td>
</tr>
<tr>
<td>Ti max.</td>
<td>0.02 max.</td>
</tr>
<tr>
<td>Cu max.</td>
<td>0.35</td>
</tr>
<tr>
<td>Cr max.</td>
<td>0.20</td>
</tr>
<tr>
<td>Ni max.</td>
<td>0.40</td>
</tr>
<tr>
<td>Mo max.</td>
<td>0.08</td>
</tr>
<tr>
<td>N max.</td>
<td>- 0.009(0.012 if Al is present)</td>
</tr>
<tr>
<td>Carbon Equivalent (6)</td>
<td></td>
</tr>
</tbody>
</table>

Notes:
(1) The letter “H” may be added either in front or behind the grade mark e.g. HA 32 or AH 32.
(2) Up to a thickness of 12.5 mm the minimum manganese content may be reduced to 0.70%.
(3) The total aluminium content may be determined instead of the acid soluble content. In such cases the total aluminium content is to be not less than 0.020%.
(4) The steel is to contain aluminium, niobium, vanadium or other suitable grain refining elements, either singly or in any combination. When used singly the steel is to contain the specified minimum content of the grain refining element. When used in combination, the specified minimum content of a fine graining element is not applicable.
(5) When any grade of higher strength steel is supplied in the thermo-mechanically rolled condition variations in the specified chemical composition may be allowed or required by the Register.
(6) When required, the carbon equivalent value is to be calculated from the ladle analysis using the following formula.

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

This formula is applicable only to steels which are basically of the carbon-manganese type and gives a general indication of the weldability of the steel.
(7) Where additions of any other element have been made as part of the steel making practice, the content is to be indicated.
3.2.4.3 For TM (TMCP) steels the following special requirements apply:

a) The carbon equivalent value is to be calculated from the ladle analysis using the following formula and to comply with the requirements of Table 3.2.4.3-1.

\[
Ceq = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15} \quad \% 
\]

b) The following formula (cold cracking susceptibility) may be used for evaluating weldability instead of the carbon equivalent at the discretion of the Register.

\[
Pcm = C + \frac{Si}{30} + \frac{Mn}{20} + \frac{Cu}{20} + \frac{Ni}{60} + \frac{Cr}{20} + \frac{Mo}{15} + \frac{V}{10} + 5B^{[\%]} 
\]

In such cases the cold cracking susceptibility value required may be specified by the Register.

### Table 3.2.4.3-1
Carbon equivalent for higher strength steels up to 100 mm in thickness produced by TM

<table>
<thead>
<tr>
<th>Grade</th>
<th>Carbon Equivalent, max. (%)&lt;sup&gt;(1)&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>t ≤ 50</td>
</tr>
<tr>
<td>A32, D32, E32, F32</td>
<td>0.36</td>
</tr>
<tr>
<td>A36, D36, E36, F36</td>
<td>0.38</td>
</tr>
<tr>
<td>A40, D40, E40, F40</td>
<td>0.40</td>
</tr>
</tbody>
</table>

Notes:

<sup>(1)</sup> It is a matter for the manufacturer and shipbuilder to mutually agree in individual cases as to whether they wish to specify a more stringent carbon equivalent.

### Table 3.2.5.1-1
Condition of supply for normal strength steels<sup>(1)</sup>

<table>
<thead>
<tr>
<th>Grades</th>
<th>Thickness</th>
<th>Condition of Supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>≤ 50 mm</td>
<td>Any</td>
</tr>
<tr>
<td></td>
<td>&gt; 50 mm ≤ 100 mm</td>
<td>Normalised, controlled rolled or thermo-mechanically rolled&lt;sup&gt;(2)&lt;/sup&gt;</td>
</tr>
<tr>
<td>B</td>
<td>≤ 50 mm</td>
<td>Any</td>
</tr>
<tr>
<td></td>
<td>&gt; 50 mm ≤ 100 mm</td>
<td>Normalised, controlled rolled or thermo-mechanically rolled&lt;sup&gt;(2)&lt;/sup&gt;</td>
</tr>
<tr>
<td>D</td>
<td>≤ 35 mm</td>
<td>Any</td>
</tr>
<tr>
<td></td>
<td>&gt; 35 mm ≤ 100 mm</td>
<td>Normalised, controlled rolled or thermo-mechanically rolled&lt;sup&gt;(3)&lt;/sup&gt;</td>
</tr>
<tr>
<td>E</td>
<td>≤ 100 mm</td>
<td>Normalised or thermo-mechanically rolled&lt;sup&gt;(3)&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Notes:

<sup>(1)</sup> These conditions of supply and the impact test requirements are summarised in Table 3.2.13.2-1.
<sup>(2)</sup> Subject to the special approval of the Register, Grades A and B steel plates may be supplied in the as rolled condition - see Table 3.2.14.2-1.
<sup>(3)</sup> Subject to the special approval of Register, sections in Grade D steel may be supplied in the as rolled condition provided satisfactory results are consistently obtained from Charpy V-notch impact tests. Similarly sections in Grade E steel may be supplied in the as rolled or controlled rolled condition. The frequency of impact tests is to be in accordance with 3.2.14.2(b) and 3.2.14.3(c) respectively.
Table 3.2.5.1-2
Condition of supply for higher strength steels (1)

<table>
<thead>
<tr>
<th>Grades</th>
<th>Grain Refining Elements Used</th>
<th>Thickness</th>
<th>Condition of supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>A32</td>
<td>Nb and/or V</td>
<td>≤ 12.5 mm</td>
<td>Any</td>
</tr>
<tr>
<td>A36</td>
<td></td>
<td>&gt; 12.5 mm ≤ 100 mm</td>
<td>Normalised, controlled rolled or thermo-mechanically rolled(3)</td>
</tr>
<tr>
<td>A32</td>
<td>Al alone or with Ti</td>
<td>≤ 20 mm</td>
<td>Any</td>
</tr>
<tr>
<td>A36</td>
<td></td>
<td>&gt; 20 mm ≤ 35 mm</td>
<td>Any, as rolled subject to special approval of the Register (2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt; 35 mm ≤ 100 mm</td>
<td>Normalised, controlled rolled or thermo-mechanically rolled(3)</td>
</tr>
<tr>
<td>A40</td>
<td>Any</td>
<td>≤ 12.5 mm</td>
<td>Any</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;12.5 mm ≤ 50 mm</td>
<td>Normalised, controlled rolled or thermo-mechanically rolled</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;50 mm ≤ 100 mm</td>
<td>Normalised, thermo-mechanically rolled or quenched and tempered</td>
</tr>
<tr>
<td>D32</td>
<td>Nb and/or V</td>
<td>≤ 12.5 mm</td>
<td>Any</td>
</tr>
<tr>
<td>D36</td>
<td></td>
<td>&gt; 12.5 mm ≤ 100 mm</td>
<td>Normalised, controlled rolled or thermo-mechanically rolled(3)</td>
</tr>
<tr>
<td>D32</td>
<td>Al alone or with Ti</td>
<td>≤ 20 mm</td>
<td>Any</td>
</tr>
<tr>
<td>D36</td>
<td></td>
<td>&gt; 20 mm ≤ 25 mm</td>
<td>Any, as rolled subject to special approval of the Register (2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt; 25 mm ≤ 100 mm</td>
<td>Normalised, controlled rolled or thermo-mechanically rolled(3)</td>
</tr>
<tr>
<td>D40</td>
<td>Any</td>
<td>≤ 50 mm</td>
<td>Normalised, controlled rolled or thermo-mechanically rolled</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;50 mm ≤ 100 mm</td>
<td>Normalised, thermo-mechanically rolled or quenched and tempered</td>
</tr>
<tr>
<td>E32</td>
<td>Any</td>
<td>≤ 50 mm</td>
<td>Normalised, controlled rolled or thermo-mechanically rolled(3)</td>
</tr>
<tr>
<td>E36</td>
<td></td>
<td>&gt; 50 mm ≤ 100 mm</td>
<td>Normalised, thermo-mechanically rolled or quenched and tempered</td>
</tr>
<tr>
<td>E40</td>
<td>Any</td>
<td>≤ 50 mm</td>
<td>Normalised, controlled rolled or quenched and tempered(4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;50 mm ≤ 100 mm</td>
<td>Normalised, thermo-mechanically rolled or quenched and tempered</td>
</tr>
<tr>
<td>F32</td>
<td>Any</td>
<td>≤ 50 mm</td>
<td>Normalised, thermo-mechanically rolled or quenched and tempered(4)</td>
</tr>
<tr>
<td>F36</td>
<td></td>
<td>&gt;50 mm ≤ 100 mm</td>
<td>Normalised, thermo-mechanically rolled or quenched and tempered</td>
</tr>
</tbody>
</table>

Notes:
1. These conditions of supply and the requirements for impact tests are summarised in Table 3.2.14.2-2.
2. The frequency of impact tests is to be in accordance with 3.2.14.2 (b).
3. Subject to the special approval of the Register, sections in Grades A32, A36, D32 and D36 steels may be supplied in the as rolled condition provided satisfactory results are consistently obtained from Charpy V-notch impact tests. Similarly sections in Grades E32 and E36 steels may be supplied in the as rolled or controlled rolled condition. The frequency of impact tests is to be in accordance with 3.2.14.2(c).
4. Subject to the special approval of the Register, sections in Grades F32 and F36 steels may be supplied in the controlled rolled condition. The frequency of impact tests is to be in accordance with 3.2.14.3(c).

3.2.6 Mechanical Properties

3.2.6.1 For tensile test either the upper yield stress (ReH) or where ReH cannot be determined, the 0.2 percent proof stress (Rp 0.2) is to be determined and the material is considered to comply with the requirements if either value meets or exceeds the specified minimum value for yield strength (Re).

3.2.6.2 The results obtained from tensile tests are to comply with the appropriate requirements of Tables 3.2.6.2-1 and 3.2.6.2-2.
### Table 3.2.6.2-1
Mechanical properties for normal strength steels

<table>
<thead>
<tr>
<th>Grade</th>
<th>Yield Strength ReH (N/mm²) min</th>
<th>Tensile Strength Rm (N/mm²)</th>
<th>Elongation (5.65 (\sqrt{S_o}) A5 (%)</th>
<th>Test Temp °C</th>
<th>Impact Test Average Impact Energy (J) min</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>t ≤ 50 (mm)</td>
<td>50 &lt; t ≤ 70 (mm)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Long (3)</td>
<td>Trans (3)</td>
</tr>
<tr>
<td>A</td>
<td>235</td>
<td>400/520(1)</td>
<td>22(2)</td>
<td>+20</td>
<td>-</td>
</tr>
<tr>
<td>B</td>
<td></td>
<td></td>
<td></td>
<td>0</td>
<td>27(4)</td>
</tr>
<tr>
<td>D</td>
<td></td>
<td></td>
<td></td>
<td>-20</td>
<td>27</td>
</tr>
<tr>
<td>E</td>
<td></td>
<td></td>
<td></td>
<td>-40</td>
<td>27</td>
</tr>
</tbody>
</table>

Note:

(1) For all thicknesses of Grade A sections the upper limit for the specified tensile strength range may be exceeded at the discretion of the Register.

(2) For full thickness flat tensile test specimens with a width of 25 mm and a gauge length of 200 mm the elongation is to comply with the following minimum values:

<table>
<thead>
<tr>
<th>Thickness (mm)</th>
<th>14</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>19</th>
<th>20</th>
<th>21</th>
<th>22</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A32</td>
<td>315</td>
<td>440/570</td>
<td>22(1)</td>
<td>0</td>
<td>31(3)</td>
<td>22(3)</td>
<td>38</td>
<td>26</td>
</tr>
<tr>
<td>D32</td>
<td>315</td>
<td>440/570</td>
<td>22(1)</td>
<td>-20</td>
<td>31</td>
<td>22</td>
<td>38</td>
<td>26</td>
</tr>
<tr>
<td>E32</td>
<td>315</td>
<td>440/570</td>
<td>22(1)</td>
<td>-40</td>
<td>31</td>
<td>22</td>
<td>38</td>
<td>26</td>
</tr>
<tr>
<td>F32</td>
<td>315</td>
<td>440/570</td>
<td>22(1)</td>
<td>-60</td>
<td>31</td>
<td>22</td>
<td>38</td>
<td>26</td>
</tr>
<tr>
<td>A36</td>
<td>355</td>
<td>490/630</td>
<td>21(1)</td>
<td>0</td>
<td>34(3)</td>
<td>24(3)</td>
<td>41</td>
<td>27</td>
</tr>
<tr>
<td>D36</td>
<td>355</td>
<td>490/630</td>
<td>21(1)</td>
<td>-20</td>
<td>34</td>
<td>24</td>
<td>41</td>
<td>27</td>
</tr>
<tr>
<td>E36</td>
<td>355</td>
<td>490/630</td>
<td>21(1)</td>
<td>-40</td>
<td>34</td>
<td>24</td>
<td>41</td>
<td>27</td>
</tr>
<tr>
<td>F36</td>
<td>355</td>
<td>490/630</td>
<td>21(1)</td>
<td>-60</td>
<td>34</td>
<td>24</td>
<td>41</td>
<td>27</td>
</tr>
<tr>
<td>A40</td>
<td>390</td>
<td>510/660</td>
<td>20(1)</td>
<td>0</td>
<td>39</td>
<td>26</td>
<td>46</td>
<td>31</td>
</tr>
<tr>
<td>D40</td>
<td>390</td>
<td>510/660</td>
<td>20(1)</td>
<td>-20</td>
<td>39</td>
<td>26</td>
<td>46</td>
<td>31</td>
</tr>
<tr>
<td>E40</td>
<td>390</td>
<td>510/660</td>
<td>20(1)</td>
<td>-40</td>
<td>39</td>
<td>26</td>
<td>46</td>
<td>31</td>
</tr>
<tr>
<td>F40</td>
<td>390</td>
<td>510/660</td>
<td>20(1)</td>
<td>-60</td>
<td>39</td>
<td>26</td>
<td>46</td>
<td>31</td>
</tr>
</tbody>
</table>

Notes:

(1) For full thickness flat tensile test specimens with a width of 25 mm and a gauge length of 200 mm the elongation is to comply with the following minimum values:

<table>
<thead>
<tr>
<th>Thickness (mm)</th>
<th>Grade</th>
<th>&gt; 5</th>
<th>&gt; 10</th>
<th>&gt; 15</th>
<th>&gt; 20</th>
<th>&gt; 25</th>
<th>&gt; 30</th>
<th>&gt; 40</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elongation (%)</td>
<td>A32, D32, E32 &amp; F32</td>
<td>14</td>
<td>16</td>
<td>17</td>
<td>18</td>
<td>19</td>
<td>20</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>A36, D36, E36 &amp; F36</td>
<td>13</td>
<td>15</td>
<td>16</td>
<td>17</td>
<td>18</td>
<td>19</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>A40, D40, E40 &amp; F40</td>
<td>12</td>
<td>14</td>
<td>15</td>
<td>16</td>
<td>17</td>
<td>18</td>
<td>19</td>
</tr>
</tbody>
</table>

(2) See paragraph 3.2.6.3.

(3) For Grades A32 and A36 steels a relaxation in the number of impact tests for acceptance purposes may be permitted by special agreement with the Register provided that satisfactory results are obtained from occasional check tests.
3.2.6.3  Minimum average energy values are specified for Charpy V-notch impact test specimens taken in either the longitudinal or transverse directions (see 3.2.13.2). Generally only longitudinal test specimens need to be prepared and tested except for special applications where transverse test specimens may be required by the purchaser or the Register. Transverse test results are to be guaranteed by the supplier.

The tabulated values are for standard specimens 10 mm x 10 mm. For plate thickness less than 10 mm, impact test may be waived at the discretion of the Register or sub-size specimens as specified in Chapter 2.

3.2.6.4  The average value obtained from one set of three impact tests is to comply with the requirements given in Tables 3.2.6.2-1 and 3.2.6.2-2. One individual value only may be below the specified average value provided it is not less than 70% of that value.

3.2.6.5  Generally, impact tests are not required when the nominal plate thickness is less than 6 mm.

3.2.7  Surface quality

3.2.7.1  The steel is to be free from surface defects prejudicial to the use of the material for the intended application.

The finished material is to have a surface quality in accordance with a recognized standard such as EN 10163 parts 1, 2 and 3, or an equivalent standard accepted by the Register, unless otherwise specified in this section.

3.2.7.2  The responsibility for meeting the surface finish requirements rests with the manufacturer of the material, who is to take the necessary manufacturing precautions and is to inspect the products prior to delivery. At that stage, however, rolling or heat treatment scale may conceal surface discontinuities and defects. If, during the subsequent descaling or working operations, the material is found to be defective, the Register may require materials to be repaired or rejected.

3.2.7.2.1  The surface quality inspection method shall be in accordance with recognized national or international standards agreed between purchaser and manufacturer, accepted by the Register.

3.2.7.2.2  If agreed by the manufacturer and purchaser, steel may be ordered with improved surface finish over and above these requirements.

3.2.7.3  Acceptance Criteria

3.2.7.3.1  Imperfections

Imperfections of a harmless nature, for example pitting, rolled-in scale, indentations, roll marks, scratches and grooves, regarded as being inherent of the manufacturing process, are permissible irrespective of their number, provided the maximum permissible limits of Class A of EN 10163-2 or limits specified in a recognized equivalent standard accepted by the Register, are not exceeded and the remaining plate or wide flat thickness remains within the average allowable minus thickness tolerance specified in 3.2.9.

Total affected area with imperfection not exceeding the specified limits are not to exceed 15% of the total surface in question.

3.2.7.3.2  Defects

Affected areas with imperfections with a depth exceeding the limits of Class A of EN 10163-2 or the maximum permissible limits specified in a recognized equivalent standard accepted by the Register, shall be repaired irrespective of their number.

Cracks, injurious surface flaws, shells (overlapping material with non-metallic inclusion), sand patches, laminations and sharp edged seams (elongated defects) visually evident on surface and/or edge of plate are considered defects, which would impair the end use of the product and which require rejection or repair, irrespective of their size and number.

3.2.7.4  Repair

3.2.7.4.1  Grinding repair

Grinding may be applied provided all the conditions below are adhered to:

a) The nominal product thickness will not be reduced by more than 7% or 3 mm, whichever is the less.

b) Each single ground area does not exceed 0.25 m².

c) All ground areas do not exceed 2% of the total surface in question.

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

e) Ground areas lying opposite each other on both surfaces shall not decrease the product thickness by values exceeding the limits as stated under a).

Defects or unacceptable imperfections are to be completely removed by grinding and the remaining plate or wide flat thickness shall remain within the average allowable minus thickness tolerance specified in . The ground areas shall be a smooth transition to the surrounding surface of the product. Complete elimination of the defect is to be verified by magnetic particle or by liquid penetrant testing.

3.2.7.4.2  Welding repair

Weld repair procedures and the method are to be reported and be approved by the Register. Repair of defects such as unacceptable imperfections, cracks, shells or seams shall be followed by magnetic particle or liquid penetrant testing.

Local defects which cannot be repaired by grinding as stated in 3.2.7.4.1 may be repaired by welding with the agreement of the Register subject to the following conditions:

a) Any single welded area shall not exceed 0.125 m² and the sum of all areas shall not exceed 2% of the surface side in question.

b) The distance between two welded areas shall not be less than their average width.

c) The weld preparation shall not reduce the thickness of the product below 80% of the nominal thickness. For occasional defects with depths exceeding the 80% li-
mit, special consideration at the Surveyor’s discretion will be necessary.

d) If weld repair depth exceeds 3 mm, UT may be requested by the Register.
e) If required, UT shall be carried out in accordance with an approved procedure.
f) The repair shall be carried out by qualified welders using an approved procedure for the appropriate steel grade. The electrodes shall be of low hydrogen type and shall be dried in accordance with the manufacturer’s requirements and protected against rehumidification before and during welding.

3.2.7.5 The surface quality and condition requirement herein are not applied to products in forms of bars and tubulars, which will be subject to manufacturers’ conformance standards.

3.2.8. Internal soundness

3.2.8.1 If plates and wide flats are ordered with ultrasonic inspection, this is to be made in accordance with an accepted standard at the discretion of the Register.

3.2.8.2 Verification of internal soundness is the responsibility of the manufacturer. The acceptance of internal soundness by the Register’s surveyor shall not absolve the manufacturer from this responsibility.

3.2.9 Thickness tolerances

Unless otherwise agreed or specially required requirements for the thickness tolerances in this subsection are applicable.

3.2.9.1 Scope

3.2.9.1.1 These requirements apply to the tolerance on thickness of steel plates and wide flats with widths of 600 mm or greater (hereinafter referred to as: product or products) with thicknesses of 5 mm and over, covering the following steel grades:

a) Normal and higher strength hull structural steels according to 3.2.
b) High strength steels for welded structure according to 3.4.
c) Steels for machinery structures in accordance with the Rules of the Register.

The thickness tolerances for products below 5 mm are to be in accordance with a national or international standard, e.g. Class B of ISO 7452. However, the minus tolerance shall not exceed 0,3 mm.

Note: Tolerances for length, width, flatness and over thickness may be taken from national or international standards.

3.2.9.1.2 These requirements do not apply to products intended for the construction of lifting appliances which are subject to decision by the Register.

3.2.9.1.3 These requirements do not apply to products intended for the construction of boilers, pressure vessels and independent tanks, e.g. for the transportation of liquefied gases or chemicals.

3.2.9.2 Responsibility

3.2.9.2.1 The responsibility for verification and maintenance of the production within the required tolerances rests with the manufacturer. The Surveyor may require to witness some measurements.

3.2.9.2.2 The responsibility for storage and maintenance of the delivered product(s) with acceptable level of surface conditions rests with the shipyard before the products are used in fabrication.

3.2.9.3 Thickness tolerances

3.2.9.3.1 The tolerances on thickness of a given product are defined as:

- Minus tolerance is the lower limit of the acceptance range below the nominal thickness.
- Plus tolerance is the upper limit of the acceptance range above the nominal thickness.

Note: Nominal thickness is stated by the purchaser at the time of enquiry and order.

3.2.9.3.2 The minus tolerance on nominal thickness of products in accordance with Section 3.2 and Section 3.4 is 0,3 mm irrespective of nominal thickness.

3.2.9.3.3 The minus tolerances for products for machinery structures are to be in accordance with Table 3.2.9.3.3.

Table 3.2.9.3.3

<table>
<thead>
<tr>
<th>Nominal thickness (t) (mm)</th>
<th>Minus tolerance on nominal thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 ≤ t &lt; 5</td>
<td>-0,3</td>
</tr>
<tr>
<td>5 ≤ t &lt; 8</td>
<td>-0,4</td>
</tr>
<tr>
<td>8 ≤ t &lt; 15</td>
<td>-0,5</td>
</tr>
<tr>
<td>15 ≤ t &lt; 25</td>
<td>-0,6</td>
</tr>
<tr>
<td>25 ≤ t &lt; 40</td>
<td>-0,7</td>
</tr>
<tr>
<td>40 ≤ t &lt; 80</td>
<td>-0,9</td>
</tr>
<tr>
<td>80 ≤ t &lt; 150</td>
<td>-1,1</td>
</tr>
<tr>
<td>150 ≤ t &lt; 250</td>
<td>-1,2</td>
</tr>
<tr>
<td>t ≥ 250</td>
<td>-1,3</td>
</tr>
</tbody>
</table>

3.2.9.3.4 The tolerances on nominal thickness are not applicable to areas repaired by grinding. For areas repaired by grinding the 3.2.7.4 requirements are to be applied, unless stricter requirements as per a recognized standard are considered by the Register or purchaser.

3.2.9.3.5 The plus tolerances on nominal thickness are to be in accordance with a recognized national or international standard.
3.2.9.4 Average thickness

3.2.9.4.1 The average thickness of products is defined as the arithmetic mean of the measurements made in accordance with the requirements of 3.2.9.5.

3.2.9.4.2 The average thickness of products in accordance with Section 3.2 or Section 3.4 is not to be less than the nominal thickness.

3.2.9.5 Thickness measurements

3.2.9.5.1 The thickness is to be measured at locations of products as defined in 3.2.9.6.

3.2.9.5.2 Automated method or manual method is applied to the thickness measurements.

3.2.9.5.3 The procedure and the records of measurements are to be made available to the Surveyor and copies provided on request.

3.2.9.6 Thickness Measuring Locations

3.2.9.6.1 Scope of application

This section applies to the thickness measuring locations for the thickness tolerance and the average thickness of product.

3.2.9.6.2 Measuring locations

At least two lines among Line 1, Line 2 or Line 3 as shown in Figure 3.2.9.6.1, are to be selected for the thickness measurements and at least three points on each selected line as shown in Figure 3.2.9.6.1 are to be selected for thickness measurement. If more than three points are taken on each line the number of points shall be equal on each line.

Note: The measurement locations apply to a product rolled directly from one slab or steel ingot even if the product is to be later cut by the manufacturer. Examples of the original measurements relative to later cut products are shown in Figure 3.2.9.6.2. It is to be noted that the examples shown are not representative of all possible cutting scenarios.

For automated methods, the measuring points at sides are to be located not less than 10 mm but not greater than 300 mm from the transverse or longitudinal edges of the product.

For manual methods, the measuring points at sides are to be located not less than 10 mm but not greater than 100 mm from the transverse or longitudinal edges of the product.

3.2.10 Identification of Materials

3.2.10.1 The steelmaker is to adopt a system for the identification of ingots, slabs and finished pieces which will enable the material to be traced to its original cast.
3.2.10.2 The Surveyor is to be given full facilities for so tracing the material when required.

3.2.11 Testing and Inspection

3.2.11.1 Facilities for Inspection

The manufacturer is to afford the Surveyor all necessary facilities and access to all relevant parts of the works to enable him to verify that the approved process is adhered to, for the selection of test materials, and the witnessing of tests, as required by the Rules, and for verifying the accuracy of the testing equipment.

3.2.11.2 Testing Procedures

The prescribed tests and inspections are to be carried out at the place of manufacture before dispatch. The test specimens and procedures are to be in accordance with Chapter 2. All the test specimens are to be selected and stamped by the Surveyor and tested in his presence, unless otherwise agreed.

3.2.11.3 Through Thickness Tensile Tests

If plates and wide flats with thickness of 15 mm and over are ordered with through thickness properties, the through thickness tensile test in accordance with Section 3.9 is to be carried out.

3.2.11.4 Dimensions

Verification of dimensions is the responsibility of steel maker. The acceptance by the Register’s Surveyor shall not absolve the steel maker from this responsibility.

3.2.12 Test Material

3.2.12.1 Definitions

a) Piece: the term "piece" is understood to mean the rolled product from a single slab, billet or ingot if this is rolled directly into plates, sections or bars.
b) Batch: a number of similar pieces presented as a group for acceptance tests.

3.2.12.2 Test Samples

a) All material in a batch presented for acceptance tests is to be of the same product form e.g. plates, flats, sections, etc. from the same cast and in the same condition of supply.
b) The test samples are to be fully representative of the material and, where appropriate, are not to be cut from the material until heat treatment has been completed.
c) The test specimens are not to be separately heat treated in any way.
d) Unless otherwise agreed the test samples are to be taken from the following positions:
   - Plates and flats with a width >600 mm. The test samples are to be taken from one end at a position approximately midway between the axis in the direction of the rolling and the edge of the rolled product (see Fig.3.2.12.2-1). Unless otherwise agreed the tensile test specimens are to be prepared with their longitudinal axes transverse to the final direction of rolling.
   - Flats with a width < 600 mm, bulb flats and other sections. The test samples are to be taken from one end at a position approximately one third from the outer edge (see Figs. 3.2.12.2-2, 3.2.12.2-3 and 3.2.12.2-4) or in the case of small sections, as near as possible to this position. In the case of channels, beams or bulb angles, the test samples may alternatively be taken from a position approximately one quarter of the width from the web centre line or axis (see Fig. 3.2.12.2-3) The tensile test specimens may be prepared with their longitudinal axes either parallel or transverse to the final direct of rolling.
   - Bars and other similar products. The test samples are to be taken so that the longitudinal axes of the test specimens are parallel to the direction of rolling and are as near as possible to the following:
     - for non-cylindrical sections, one third of the half diagonal from the outside,
     - for cylindrical sections, at one third of the radius from the outside (see Fig. 3.2.12.2-6).

3.2.13 Mechanical Test specimens

3.2.13.1 Tensile Test Specimens

The dimensions of the tensile test specimens are to be in accordance with Chapter 2. Generally for plates, wide flats and sections flat test specimens of full product thickness are to be used. Round test specimens may be used when the product thickness exceeds 40 mm or for bars and other similar products. Alternatively for small sizes of bars, etc. test specimens may consist of a suitable length of the full cross section of the product.

3.2.13.2 Impact Test Specimens

The impact test specimens are to be of the Charpy V-notch type cut with their edge within 2 mm from the “as rolled” surface with their longitudinal axes either parallel (indicated “Long” in Table 3.2.6.2-1 & 3.2.6.2-2) or transverse (indicated “Trans” in Tables 3.2.6.2-1 & 3.2.6.2-2) to the final direction of rolling of the material. The notch is to be cut in a face of the test specimen which was originally perpendicular to the rolled surface. The position of the notch is not to be nearer than 25 mm to a flame cut or sheared edge (see also 3.2.6.3). Where the product thickness exceeds 40 mm, the impact test specimens are to be taken with their longitudinal axis at a quarter thickness position.
3.2.14 Number of Test Specimens

3.2.14.1 Number of Tensile Tests. For each batch presented, except where specially agreed by the Register, one tensile test is to be made from one piece unless the weight of finished material is greater than 50 tonnes or fraction thereof. Additionally tests are to be made for every variation of 10 mm in the thickness or diameter of products from the same cast.


   a) Except where otherwise specified or specially agreed by the Register, for each batch presented, at least one set of three Charpy V-notch test specimens is to be made from one piece unless the weight of finished material is greater than 50 tonnes, in which case one extra set of three test specimens is to be made from a different piece from each 50 tonnes or fraction thereof. When steel plates except for Grade A steel over 50 mm in thickness is supplied in the controlled rolled condition, the frequency of impact test is to be made from a different piece from each 25 tonnes or fraction thereof.

   b) For steel plates of grades A40 and D40 with thickness over 50mm in normalized or TM condition, one set of impact test specimens is to be taken from each batch of 50 tonnes or fraction thereof. For those in QT condition, one set of impact test specimens is to be taken from each length, as heat treated.

   c) When, subject to the special approval of the Register, material is supplied in the as rolled condition, the frequency of impact tests is to be increased to one set from each batch of 25 tonnes or fraction thereof. Similarly Grade A steel over 50 mm in thickness may be supplied in the as rolled condition. In such case one set of three Charpy V-notch test specimens is to be taken from each batch of 50 tonnes or fraction thereof.

   d) The piece selected for the preparation of the test specimens is to be the thickest in each batch.

3.2.14.3 Number of Impact Tests (Grades E, E32, E36, E40, F32, F36 and F40)
a) For steel plates supplied in the normalised or TM condition one set of impact test specimens is to be taken from each piece. For quenched and tempered steel plates one set of impact test specimens is to be taken from each length as heat treated.

b) For sections one of impact tests is to be taken from each batch of 25 tonnes or fraction thereof.

c) When, subject to the special approval of the Register, sections other than Grades E40 and F40 are supplied in the as rolled or controlled rolled condition, one set of impact tests is to be taken from each batch of 15 tonnes or fraction thereof.

d) For (b) and (c) above the piece selected for the preparation of the test specimens is to be the thickest in each batch.

Table 3.2.14.2-1
Required condition of supply and number of impact tests for normal strength steels

<table>
<thead>
<tr>
<th>Grade</th>
<th>Deoxidation Practice</th>
<th>Products</th>
<th>Condition of Supply (Batch for Impact Tests)(^{(1)(2)})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Thickness (mm)</td>
<td>10</td>
</tr>
<tr>
<td>A</td>
<td>Rimmed</td>
<td>Sections</td>
<td>A(-)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Plates</td>
<td>A(-)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>For t (\leq) 50 mm</td>
<td>Any method except rimmed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sections</td>
<td>A(-)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Plates</td>
<td>A(-)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>For t (&gt;) 50 mm</td>
<td>Killed</td>
</tr>
<tr>
<td>B</td>
<td>Killed</td>
<td>Plates</td>
<td>A(50)</td>
</tr>
<tr>
<td></td>
<td>Sections</td>
<td>Sections</td>
<td>A(50)</td>
</tr>
<tr>
<td>D</td>
<td>Sections</td>
<td>Plates</td>
<td>N(Each piece)</td>
</tr>
<tr>
<td></td>
<td>Killed and fine grain treated</td>
<td>Sections</td>
<td>N(25)</td>
</tr>
<tr>
<td>E</td>
<td>Killed and fine grain treated</td>
<td>Plates</td>
<td>N(Each piece)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sections</td>
<td>N(25)</td>
</tr>
</tbody>
</table>

Remarks:
(1) Condition of Supply
A- Any
N- Normalised Condition
CR- Controlled Rolled Condition
TM- Thermo-Mechanical rolling
AR*- As Rolled Condition subject to special approval of the Register
CR*- Controlled Rolled Condition subject to special approval of the Register
(2) Number of Impact Tests
One set of impact tests is to be taken from each batch of the “specified weight” in ( ) or fraction thereof.
(3) See Note (5) of Table 3.2.6.2-1
### Table 3.2.14.2-2
Required condition of supply and number of impact tests for higher strength steels

<table>
<thead>
<tr>
<th>Grade</th>
<th>Deoxidation Practice</th>
<th>Grain Refining Elements</th>
<th>Products</th>
<th>Condition of supply (Batch for Impact Tests)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Thickness (mm)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>A32</td>
<td>Killed and fine grain treated</td>
<td>Nb and/or V</td>
<td>Plates</td>
<td>A(50)</td>
</tr>
<tr>
<td>A36</td>
<td>Killed and fine grain treated</td>
<td>Al alone or with Ti</td>
<td>Plates</td>
<td>A(50)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sections</td>
<td>A(50)</td>
</tr>
<tr>
<td>A40</td>
<td>Killed and fine grain treated</td>
<td>Any</td>
<td>Plates</td>
<td>A(50)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sections</td>
<td>N(50), CR(50), TM(50)</td>
</tr>
<tr>
<td>D32</td>
<td>Killed and fine grain treated</td>
<td>Nb and/or V</td>
<td>Plates</td>
<td>A(50)</td>
</tr>
<tr>
<td>D36</td>
<td>Killed and fine grain treated</td>
<td>Al alone or with Ti</td>
<td>Plates</td>
<td>A(50)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sections</td>
<td>A(50)</td>
</tr>
<tr>
<td>D40</td>
<td>Killed and fine grain treated</td>
<td>Any</td>
<td>Plates</td>
<td>N(50), CR(50), TM(50)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sections</td>
<td>N(50), CR(50), TM(50)</td>
</tr>
<tr>
<td>E32</td>
<td>Killed and fine grain treated</td>
<td>Any</td>
<td>Plates</td>
<td>N(Each piece), TM(Each piece)</td>
</tr>
<tr>
<td>E36</td>
<td>Killed and fine grain treated</td>
<td>Any</td>
<td>Sections</td>
<td>N(25), TM(25), AR*(15), CR*(15)</td>
</tr>
<tr>
<td>E40</td>
<td>Killed and fine grain treated</td>
<td>Any</td>
<td>Plates</td>
<td>N(Each piece), TM(Each piece), QT(Each length as heat treated)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sections</td>
<td>N(25), TM(25), QT(25)</td>
</tr>
</tbody>
</table>
### Table

<table>
<thead>
<tr>
<th>Grade</th>
<th>Deoxidation Practice</th>
<th>Grain Refining Element</th>
<th>Products</th>
<th>Thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Plates</td>
<td>10</td>
</tr>
<tr>
<td>F32 F36</td>
<td>Killed and fine grain treated</td>
<td>Any</td>
<td>N(Each piece)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sections</td>
<td>N(25)</td>
</tr>
<tr>
<td>F40</td>
<td>Killed and fine grain treated</td>
<td>Any</td>
<td>Plates</td>
<td>N(Each piece)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sections</td>
<td>N(25)</td>
</tr>
</tbody>
</table>

#### Remarks:

1. **Condition of Supply**
   - A - Any
   - N - Normalised Condition
   - CR - Controlled Rolled Condition
   - TM - Thermo-Mechanical Rolling
   - QT - Quenched and tempered Condition
   - AR* - As Rolled Condition subject to the special approval of the Register
   - CR* - Controlled Rolled Condition subject to the special approval of the Register

2. **Number of Impact Tests**
   - One set of impact tests is to be taken from each batch of the “specified weight” in ( ) or fraction thereof.
   - For grades A32 and A36 steels a relaxation in the number of impact tests may be permitted. (See Note (3) of Table 3.2.6.2-2).

### 3.2.15 Retest procedures

#### 3.2.15.1 When the tensile test from the first piece selected in accordance with 3.2.14.1 fails to meet the requirements, re-test requirements for tensile test are to be in accordance with Chapter 2.

#### 3.2.15.2 If one or both of the additional tests referred to above are unsatisfactory, the piece is to be rejected, but the remaining material from the same batch may be accepted provided that two of the remaining pieces in the batch selected in the same way, are tested with satisfactory results. If unsatisfactory results are obtained from either of these two pieces then the batch of material is to be rejected.

#### 3.2.15.3 Re-test requirement for Charpy impact test are to be in accordance with Chapter 2.

#### 3.2.15.4 When the initial piece, representing a batch, gives unsatisfactory results from the additional Charpy V-notch impact tests referred to above, this piece is to be rejected but the remaining material in the batch may be accepted provided that two of the remaining pieces in the batch are tested with satisfactory results. If unsatisfactory results are obtained from either of these two pieces then the batch of material is to be rejected. The pieces selected for these additional tests are to be the thickest remaining in the batch.

#### 3.2.15.5 If any test specimen fails because of faulty preparation, visible defects or (in the case of tensile test) because of fracturing outside the range permitted for the appropriate gauge length, the defective test piece may, at the Surveyors discretion, be disregarded and replayed by an additional test piece of the same type.

#### 3.2.15.6 At the option of the steel maker, when a batch of material is rejected, the remaining pieces in the batch may be resubmitted individually for test and those pieces which give satisfactory results may be accepted.

#### 3.2.15.7 At the option of the steelmaker, rejected material may be resubmitted after heat treatment or reheat treatment, or may be resubmitted as another grade of steel and may then be accepted provided the required tests are satisfactory.

#### 3.2.15.8 In the event of any material proving unsatisfactory during subsequent working or fabrication, such material may be rejected, notwithstanding any previous satisfactory testing and/or certification.

### 3.2.16 Marking

#### 3.2.16.1 Every finished piece is to be clearly marked by the maker in at least one place with the Register’s brand and the following particulars:

   a) Unified identification mark for the grade steel (e.g. A, A36).

   b) Steels which have been specially approved by the Register and which differ from these requirements (see 3.2.1.4) are to have the letter “S” after the above identification mark (e.g. A36S, ES).
3.2.16.2 Steel plates that have complied with the requirements for corrosion resistant steel will be identified by adding a corrosion designation to the unified identification mark for the grade of steel.

The corrosion resistant steel is to be designated according to its area of application as follows:
- Lower surface of strength deck and surrounding structures; RCU
- Upper surface of inner bottom plating and surrounding structures; RCB
- For both strength deck and inner bottom plating; RCW

Example of designation: A36 TM RCB Z35

3.2.16.3 The above particulars, but excluding the manufacturer’s name or trade mark where this is embossed on finished products, are to be encircled with paint or otherwise marked so as to be easily recognisable.

3.2.16.4 Where a number of light materials are securely fastened together in bundles the manufacturer may, subject to the agreement of the Register, brand only the top piece of each bundle, or alternatively, a firmly fastened durable label containing the brand may be attached to each bundle.

3.2.16.5 In the event of any material bearing the Register’s brand failing to comply with the test requirements, the brand is to be unmistakably defaced by the manufacturer.

3.2.17 Documentation

3.2.17.1 The Surveyor is to be supplied with the number of copies as required by the Register, of the test certificates or shipping statements for all accepted materials. The Register may require separate documents of each grade of steel. These documents are to contain, in addition to the description, dimensions, etc., of the material, at least the following particulars:

a) Purchaser’s order number and if known the hull number for which the material is intended.
b) Identification of the cast and piece including, where appropriate, the test specimen number.
c) Identification of the steelworks.
d) Identification of the grade of steel.
e) Ladle analysis (for elements specified in tables 3.2.4.1-1 & 3.2.4.1-2).
f) For steel with a corrosion resistant steel designation the weight percentage of each element added or intentionally controlled for improving corrosion resistance.
g) Condition of supply when other than as rolled i.e. normalised, controlled rolled or thermomechanically rolled.
h) State if rimming steel has been supplied for grade A sections, up to 12.5 mm thick.
i) Test Results

3.2.17.2 Before the test certificates or shipping statements are signed by the Surveyor, the manufacturer is required to furnish him with a written declaration stating that the material has been made by an approved process and that it has been subjected to and has withstood satisfactory the required tests in the presence of the Surveyor or his authorised deputy. The name of the Register is to appear on the test certificate. The following form of declaration will be accepted if stamped or printed on each test certificate or shipping statement with the name of the steelworks and initialled for the makers by an authorised official:

“We hereby certify that the material has been made by an approved process and has been satisfactorily tested in accordance with the Rules of the Register”.

3.3 UNALLOYED STRUCTURAL STEELS FOR WELDED STRUCTURES

3.3.1 General

3.3.1.1 These requirements apply to flat products, sections and bars made from unalloyed steels with minimum nominal yield strengths up to and including 355 N/mm² which are to be used for welded structures, (e.g. in machinery manufacture).

3.3.1.2 Rolled bars for the manufacture of shafts, shanks, studs, bolts and other rotating parts are governed by Section 3.11–Hull and machinery steel forgings.

3.3.2 Suitable steels

The following steels may be used with the requirements laid down in the relevant standards:

3.3.2.1 Steels conforming to European Standard EN 10025, EN 10210 and EN 10219 grades as follows:
- S235: all grades,
  Note: The grade S235 JR according to EN 10025-2 are excluded from application.
- S275: all grades
- S355: all grades

3.3.2.2 Weldable fine-grained structural steels conforming to EN 10025-3, in the grades:
- S275 N, S 275 NL, S355 N, S355 NL (normalised or normalised rolled), and conforming to EN 10025-4 in the grades:
3.3.2.3 Other steels after their suitability has been determined by the Register, provided that they satisfy the following minimum requirements:

a) The chemical composition (%) of the ladle analysis shall not exceed the following limits values:

<table>
<thead>
<tr>
<th>C</th>
<th>Mn</th>
<th>Si</th>
<th>P</th>
<th>S</th>
<th>Cu</th>
<th>Cr</th>
<th>Ni</th>
<th>Mo</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.22</td>
<td>1.70</td>
<td>0.040</td>
<td>0.040</td>
<td>0.30</td>
<td>0.20</td>
<td>0.40</td>
<td>0.08</td>
<td></td>
</tr>
</tbody>
</table>

In addition, fine-grained treated structural steels shall have an adequate content of grain refining elements, e.g. Al, Nb, V or Ti.

b) The elongation A_5 shall be at least 20% in tests with longitudinal specimens and 18% in tests with transverse specimens.

c) For fine-grain treated structural steels, an impact energy of not less that 27 Joules (average value) shall be achieved in tests with longitudinal Charpy V-notch specimens at a testing temperature of:

- -20°C for products supplied in normalised, normalised rolled or thermomechanically rolled condition;
- 0°C for products supplied in as rolled condition.

3.3.3 Condition of supply and heat treatment

Plates and wide flats with a width of ≥ 600 mm made of fine-grained treated structural steels are to be supplied in normalised, normalised rolled or thermomechanically rolled condition. For all other products, the data in the standards apply, unless otherwise specified in the order.

3.3.4 Dimensions, dimensional and geometrical tolerances

Requirements specified in Section 3.2.9 – Thickness tolerances shall be applied.

3.3.5 Scope of testing

3.3.5.1 Test of chemical composition

The manufacturer shall determine the chemical composition of each heat and shall issue a relevant certificate.

3.3.5.2 Tensile test

The mechanical properties shall be verified by tensile test.

For the purpose of taking specimens, products of the same shape shall be formed according to heat and within the thickness ranges relevant to the yield strength into test batches of not more than 40 t.

A tensile test specimen shall be taken from the thickest item in the test batch. In the case of plates and wide flats with a width of ≥ 600 mm, this shall be positioned transverse to the rolling direction. In other products, the test specimen may lie transverse or parallel to the rolling direction.

Where plates are to be tested individually, this shall be specially stipulated in the order.

3.3.5.3 Notched bar impact test

All products made of fine grain treated steels shall be subjected to notched bar impact tests performed with longitudinal Charpy V-notch specimens at the test temperatures specified in the standards or in 3.3.2.3 c). Where, in the case of plates, individual testing has not been agreed, a set of test specimens shall be taken from the thickest piece in the test batch in accordance with 3.3.5.2.

Testing shall be performed for products with a thickness of ≥ 6 mm.

3.3.5.4 Testing of surface finish and dimensions

The surface finish and dimensions of all products shall be checked by the manufacturer. At the request of the Surveyor, the products shall then be submitted to him for final inspection.

3.4 HIGH-STRENGTH STEELS

3.4.1 High-strength steels for welded structures

3.4.1.1 Scope

3.4.1.1.1 These requirements apply to hot-rolled, fine-grain, weldable high strength structural steels, intended for use in marine and offshore structural applications. These requirements do not apply to steels intended for hull structure of commercial ships whose requirements are specified in 3.2.

3.4.1.1.2 Steels covered by the scope of these requirements are specified in yield strength levels of 420, 460, 500, 550, 620, 690, 890 and 960 N/mm². For each yield strength level grades A, D, E and F are specified, based on the impact test temperature, except for yield strength level of 890 and 960 N/mm² for which grade F is not applicable.

The full list of grades are:

<table>
<thead>
<tr>
<th>AH420</th>
<th>DH420</th>
<th>EH420</th>
<th>FH420</th>
</tr>
</thead>
<tbody>
<tr>
<td>AH460</td>
<td>DH460</td>
<td>EH460</td>
<td>FH460</td>
</tr>
<tr>
<td>AH500</td>
<td>DH500</td>
<td>EH500</td>
<td>FH500</td>
</tr>
<tr>
<td>AH550</td>
<td>DH550</td>
<td>EH550</td>
<td>FH550</td>
</tr>
<tr>
<td>AH620</td>
<td>DH620</td>
<td>EH620</td>
<td>FH620</td>
</tr>
<tr>
<td>AH690</td>
<td>DH690</td>
<td>EH690</td>
<td>FH690</td>
</tr>
<tr>
<td>AH890</td>
<td>DH890</td>
<td>EH890</td>
<td></td>
</tr>
<tr>
<td>AH960</td>
<td>DH960</td>
<td>EH960</td>
<td></td>
</tr>
</tbody>
</table>
mechanical controlled rolled (TM) or Quenched and Tempered (QT) condition.

Note:

TM is a generic delivery condition that may or may not include accelerated cooling, and may or may not include direct quenching followed by tempering after TM-rolling.

3.4.1.1.4 Product forms include plates, wide flats, sections, bars and seamless tubulars.

3.4.1.1.5 Steels with a thickness beyond the maximum thicknesses as given in Table 3.4.1.3 of section 3.4.1.5.3 may be approved at the discretion of the Register.

3.4.1.1.6 Steels differing in chemical composition, deoxidation practice, delivery condition and mechanical properties may be accepted, subject to the special approval of the Register. Such steels are to be given a special designation.

3.4.1.2 Approval

3.4.1.2.1 For applications subjected to Classification, all steels are to be manufactured at steel works which have been approved by the Register for the type and grade of steel which is being supplied. The procedure for approval is shown in Appendix A3.

3.4.1.2.2 It is the steelmaker’s responsibility to assure that effective quality, process and production controls during manufacturing are adhered to within the manufacturing specification. The manufacturing specification shall be submitted to the Register at the time of initial approval.

3.4.1.2.3 Where non-conformities arise, the manufacturer is to identify the root cause and establish countermeasures to prevent its recurrence. The non-conformities and the countermeasures are to be documented and reported to the Register.

3.4.1.2.4 When the semi-finished products were not manufactured by the approved manufacturer of the finish rolled and heat treated products, the manufacturer of the semi-finished product shall also be subject to approval by Register.

Note 1:
The attention of the users must be drawn to the fact that when fatigue loading is present, the effective fatigue strength of a welded joint of high strength steel may not be greater than that of a welded joint in normal strength steels.

Note 2:
Before subjecting steels produced by both thermomechanical rolling or quenched and tempered after rolling to further heating for forming or stress relieving, or using high heat input welding, special consideration must be given to the possibility of a consequent reduction in mechanical properties.

3.4.1.3 Method of Manufacture

3.4.1.3.1 Steel making process

3.4.1.3.1.1 The steel is to be manufactured, by the basic oxygen, basic electric arc furnace or by processes specially approved by the Register.

3.4.1.3.1.2 Vacuum degassing shall be used for any of the following:

a) All steels with enhanced through-thickness properties, and

b) All steels of grade H690, H890 and H960.

3.4.1.3.2 Deoxidation

3.4.1.3.2.1 The steel is to be fully killed.

3.4.1.3.3 Grain size

3.4.1.3.3.1 The steel is to be fine grain treated, and is to have a fine grain structure. The fine grain practice is to be as detailed in the manufacturing specification.

Note:
A fine grain structure has an equivalent index $\geq 6$ determined by micrographic examination in accordance with ISO 643 or alternative test method.

3.4.1.3.4 Nitrogen control

3.4.1.3.4.1 The steels shall contain nitrogen binding elements as detailed in the manufacturing specification. Also see note 4 in Table 3.4.1.1.

3.4.1.4 Chemical Composition

3.4.1.4.1 The chemical composition is to be determined by the steelmaker in an adequately equipped and competently staffed laboratory. The method of sampling is to follow that carried out for the initial approval tests, either from the ladle, the tundish or the mould in the case of continuous casting. The aim analysis is to be in accordance with the manufacturing specification. All the elements listed in Table 3.4.1.1 are to be reported.

3.4.1.4.2 Elements used for alloying, nitrogen binding, and fine grain treatment, and as well as the residual elements are to be as detailed in the manufacturing specification, e.g. when boron is deliberately added for enhancement of hardenability of the steels, the maximum content of the boron content shall not be higher than 0.005%; and the analysis result shall be reported.

3.4.1.4.3 The carbon equivalent value is to be calculated from the ladle analysis. Maximum values are specified in Table 3.4.1.2.

a) For all steel grades the following formula of IIW may be used:

$$\text{Ceq} = C + \frac{Mn}{6} + \frac{Cu + Mo + V}{5} + \frac{Ni + Cr}{13} \%$$

b) For steel grades H460 and higher, CET may be used instead of Ceq at the discretion of the manufacturer, and is to be calculated according to the following formula:

$$\text{CET} = C + \frac{Mn + Mo}{10} + \frac{Cr + Cu}{20} + \frac{Ni}{40} \%$$
30 RULES FOR THE CLASSIFICATION OF SHIPS

PART 25

Note:
The CET is included in the standard EN 1011-2:2001 used as one of the parameters for pre-heating temperature determination which is necessary for avoiding cold cracking.

c) For TM and QT steels with carbon content not more than 0.12%, the cold cracking susceptibility $P_{cm}$ for evaluating weldability may be used instead of carbon equivalent of $C_{eq}$ or $CET$ at manufacturer’s discretion and is to be calculated using the following formula:

$$P_{cm} = C + \frac{\text{Si}}{30} + \frac{\text{Mn}}{20} + \frac{\text{Cu}}{60} + \frac{\text{Ni}}{20} + \frac{\text{Mo}}{15} + \frac{\text{V}}{10} + 5B[\%]$$

Table 3.4.1.1
Chemical composition

<table>
<thead>
<tr>
<th>Steel grade</th>
<th>N/NR</th>
<th>Delivery condition</th>
<th>TM</th>
<th>QT</th>
</tr>
</thead>
<tbody>
<tr>
<td>AH420, DH420, AH460, DH460</td>
<td>EH440, EH460</td>
<td>AH420, DH420, AH460, DH460</td>
<td>AH420, DH420, AH460, DH460</td>
<td>AH420, DH420, AH460, DH460</td>
</tr>
</tbody>
</table>

Chemical composition:

<table>
<thead>
<tr>
<th>Element</th>
<th>N max (%)</th>
<th>Mn (%)</th>
<th>Si max (%)</th>
<th>P max (%)</th>
<th>S max (%)</th>
<th>Al total min (%)</th>
<th>Nb max (%)</th>
<th>V max (%)</th>
<th>Ti max (%)</th>
<th>Ni max (%)</th>
<th>Cu max (%)</th>
<th>Cr max (%)</th>
<th>Mo max (%)</th>
<th>N max (%)</th>
<th>O max (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C max.</td>
<td>0.20</td>
<td>0.18</td>
<td>0.16</td>
<td>0.14</td>
<td>0.18</td>
<td>0.60</td>
<td>0.50</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.30</td>
<td>0.50</td>
<td>0.20</td>
<td>N.A</td>
</tr>
<tr>
<td>Mn (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.0 – 1.70</td>
<td></td>
<td></td>
<td>1.0 – 1.70</td>
<td>1.70</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Si max.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.0 – 1.70</td>
<td></td>
<td></td>
<td>1.0 – 1.70</td>
<td>0.80</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P max</td>
<td>0.030</td>
<td>0.035</td>
<td>0.025</td>
<td>0.020</td>
<td>0.025</td>
<td>0.025</td>
<td>0.020</td>
<td>0.015</td>
<td>0.015</td>
<td>0.015</td>
<td>0.015</td>
<td>0.015</td>
<td>0.015</td>
<td>0.015</td>
<td></td>
</tr>
<tr>
<td>S max</td>
<td>0.025</td>
<td>0.020</td>
<td>0.015</td>
<td>0.010</td>
<td>0.015</td>
<td>0.015</td>
<td>0.015</td>
<td>0.015</td>
<td>0.015</td>
<td>0.015</td>
<td>0.015</td>
<td>0.015</td>
<td>0.015</td>
<td>0.015</td>
<td></td>
</tr>
<tr>
<td>Al total min</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>Nb max</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>V max</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
</tr>
<tr>
<td>Ti max</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>Ni max</td>
<td>0.80</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
</tr>
<tr>
<td>Cu max</td>
<td>0.55</td>
<td>0.55</td>
<td>0.55</td>
<td>0.55</td>
<td>0.55</td>
<td>0.55</td>
<td>0.55</td>
<td>0.55</td>
<td>0.55</td>
<td>0.55</td>
<td>0.55</td>
<td>0.55</td>
<td>0.55</td>
<td>0.55</td>
<td>0.55</td>
</tr>
<tr>
<td>Cr max</td>
<td>0.30</td>
<td>0.50</td>
<td>0.50</td>
<td>1.50</td>
<td>1.50</td>
<td>1.50</td>
<td>1.50</td>
<td>1.50</td>
<td>1.50</td>
<td>1.50</td>
<td>1.50</td>
<td>1.50</td>
<td>1.50</td>
<td>1.50</td>
<td>1.50</td>
</tr>
<tr>
<td>Mo max</td>
<td>0.10</td>
<td>0.50</td>
<td>0.70</td>
<td>0.70</td>
<td>0.70</td>
<td>0.70</td>
<td>0.70</td>
<td>0.70</td>
<td>0.70</td>
<td>0.70</td>
<td>0.70</td>
<td>0.70</td>
<td>0.70</td>
<td>0.70</td>
<td>0.70</td>
</tr>
<tr>
<td>N max</td>
<td>0.025</td>
<td>0.025</td>
<td>0.025</td>
<td>0.015</td>
<td>0.015</td>
<td>0.015</td>
<td>0.015</td>
<td>0.015</td>
<td>0.015</td>
<td>0.015</td>
<td>0.015</td>
<td>0.015</td>
<td>0.015</td>
<td>0.015</td>
<td>0.015</td>
</tr>
<tr>
<td>O max (ppm)</td>
<td>N.A</td>
<td>N.A</td>
<td>50</td>
<td>N.A</td>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes:
1) See section 3.4.1.5.1 for definition of delivery conditions.
2) The chemical composition is to be determined by ladle analysis and shall meet the approved manufacturing specification at the time of approval.
3) For sections the P and S content can be 0.005% higher than the value specified in the table.
4) The total aluminium to nitrogen ratio shall be a minimum of 2:1. When other nitrogen binding elements are used, the minimum Al value and Al/N ratio do not apply.
5) Total Nb+V+Ti ≤ 0.26% and Mo+Cr ≤ 0.65%, not applicable for QT steels.
6) Higher Ni content may be approved at the discretion of the Register.
7) The requirement on maximum Oxygen content is only applicable to DH890; EH890; DH960 and EH960.
N.A = Not applicable
### Table 3.4.1.2
Maximum Ceq, CET and Pcm values

<table>
<thead>
<tr>
<th>Steel grade and delivery condition</th>
<th>Carbon Equivalent (%)</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plates</td>
<td>Sections</td>
<td>Bars</td>
<td>Tubulars</td>
<td>all</td>
<td>all</td>
</tr>
<tr>
<td>t ≤ 50 [mm]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50 &lt; t ≤ 100 [mm]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100 &lt; t ≤ 250 [mm]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>t ≤ 50 [mm]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>t ≤ 250 or d ≤ 250 [mm]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>t ≤ 65 [mm]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ceq</td>
<td>CET</td>
<td>Pcm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Plates</td>
<td>Sections</td>
<td>Bars</td>
<td>Tubulars</td>
<td>all</td>
<td>all</td>
</tr>
<tr>
<td>H420N/NR</td>
<td>0.46</td>
<td>0.48</td>
<td>0.52</td>
<td>0.47</td>
<td>0.53</td>
<td>0.47</td>
</tr>
<tr>
<td>H420TM</td>
<td>0.43</td>
<td>0.45</td>
<td>0.47</td>
<td>0.44</td>
<td>N.A</td>
<td>N.A</td>
</tr>
<tr>
<td>H420QT</td>
<td>0.45</td>
<td>0.47</td>
<td>0.49</td>
<td>N.A</td>
<td>N.A</td>
<td>0.46</td>
</tr>
<tr>
<td>H460N/NR</td>
<td>0.50</td>
<td>0.52</td>
<td>0.54</td>
<td>0.51</td>
<td>0.55</td>
<td>0.51</td>
</tr>
<tr>
<td>H460TM</td>
<td>0.50</td>
<td>0.52</td>
<td>0.54</td>
<td>0.51</td>
<td>0.55</td>
<td>0.51</td>
</tr>
<tr>
<td>H460QT</td>
<td>0.47</td>
<td>0.48</td>
<td>0.48</td>
<td>N.A</td>
<td>N.A</td>
<td>0.48</td>
</tr>
<tr>
<td>H500N/NR</td>
<td>0.48</td>
<td>0.50</td>
<td>0.54</td>
<td>N.A</td>
<td>N.A</td>
<td>0.50</td>
</tr>
<tr>
<td>H500TM</td>
<td>0.48</td>
<td>0.50</td>
<td>0.54</td>
<td>N.A</td>
<td>N.A</td>
<td>0.50</td>
</tr>
<tr>
<td>H50QT</td>
<td>0.56</td>
<td>0.60</td>
<td>0.64</td>
<td>N.A</td>
<td>N.A</td>
<td>0.56</td>
</tr>
<tr>
<td>H52QT</td>
<td>0.50</td>
<td>0.52</td>
<td>N.A</td>
<td>N.A</td>
<td>N.A</td>
<td>0.34</td>
</tr>
<tr>
<td>H620QT</td>
<td>0.56</td>
<td>0.60</td>
<td>0.64</td>
<td>N.A</td>
<td>N.A</td>
<td>0.58</td>
</tr>
<tr>
<td>H690N/NR</td>
<td>0.56</td>
<td>N.A</td>
<td>N.A</td>
<td>N.A</td>
<td>N.A</td>
<td>0.36</td>
</tr>
<tr>
<td>H690QT</td>
<td>0.64</td>
<td>0.66</td>
<td>0.70</td>
<td>N.A</td>
<td>N.A</td>
<td>0.68</td>
</tr>
<tr>
<td>H890N/NR</td>
<td>0.60</td>
<td>N.A</td>
<td>N.A</td>
<td>N.A</td>
<td>N.A</td>
<td>0.38</td>
</tr>
<tr>
<td>H890QT</td>
<td>0.68</td>
<td>N.A</td>
<td>N.A</td>
<td>N.A</td>
<td>N.A</td>
<td>0.40</td>
</tr>
<tr>
<td>H960QT</td>
<td>0.75</td>
<td>N.A</td>
<td>N.A</td>
<td>N.A</td>
<td>N.A</td>
<td>0.40</td>
</tr>
</tbody>
</table>

Notes:
N.A = Not applicable

3.4.1.5 Delivery Condition - Rolling Process and Heat Treatment

3.4.1.5.1 Steel is to be delivered in accordance with the processes approved by the Register. These processes include:

- Normalized (N)/Normalized rolled (NR)
- Thermo-mechanical controlled rolled (TM)/with Accelerated cooling (TM+AcC)/with direct quenching followed by tempering (TM+DQ), or
- Quenched and Tempered condition (QT)

The definition of these delivery conditions are defined in 3.2.

Note:
Direct quenching after hot-rolling followed by tempering is considered equivalent to conventional quenching and tempering.

3.4.1.5.2 Rolling reduction ratio

3.4.1.5.2.1 The rolling reduction ratio of slab, billet, bloom or ingot should not be less than 3:1 unless agreed at the time of approval.

3.4.1.5.3 Thickness limits for approval

3.4.1.5.3.1 The maximum thickness of slab, billet or bloom from the continuous casting process shall be at the manufacturer’s discretion.

3.4.1.5.3.2 Maximum thickness of plates, sections, bars and tubulars over which a specific delivery condition is applicable are shown in Table 3.4.1.3.
### Table 3.4.1.3

<table>
<thead>
<tr>
<th>Delivery condition</th>
<th>Plates</th>
<th>Sections</th>
<th>Bars</th>
<th>Tubulars</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>250(^{2)})</td>
<td>50</td>
<td>250</td>
<td>65</td>
</tr>
<tr>
<td>NR</td>
<td>150</td>
<td>1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TM</td>
<td>150</td>
<td>50</td>
<td>N.A</td>
<td>N.A</td>
</tr>
<tr>
<td>QT</td>
<td>150(^{2)})</td>
<td>50</td>
<td>N.A</td>
<td>50</td>
</tr>
</tbody>
</table>

**Notes:**
1) The maximum thickness limits of sections, bars and tubulars produced by NR process route are less than those manufactured by N route, and shall be at the discretion of the Register.
2) Approval for N steels with thickness larger than 250 mm and QT steels with thickness larger than 150 mm is subject to the special consideration of the Register.

N.A = Not applicable

### 3.4.1.6 Mechanical Properties

Test specimens and test procedures for mechanical properties are in accordance with Chapter 2 and 3.2.

#### 3.4.1.6.1 Tensile test

**3.4.1.6.1.1** Test specimens are to be cut with their longitudinal axes transverse to the final direction of rolling, except in the case of sections, bars, tubulars and rolled flats with a finished width of 600 mm or less, where the tensile specimens may be taken in the longitudinal direction.

**3.4.1.6.1.2** Full thickness flat tensile specimens are to be prepared. The specimens are to be prepared in such a manner as to maintain the rolling scale at least at one side. When the capacity of the test machine is exceeded by the use of a full thickness specimen, sub-sized flat tensile specimens representing either the full thickness or half of the product thickness retaining one rolled surface are to be used. Alternatively, machined round test specimens may be used. The specimens are to be located at a position lying at a distance of \( t/4 \) from the surface and additionally at \( t/2 \) for thickness above 100 mm or as near as possible to these positions.

**3.4.1.6.1.3** The results of the tests are to comply with the appropriate requirements of Table 3.4.1.4. In the case of product forms other than plates and wide flats where longitudinal tests are agreed, the elongation values are to be 2 percentage units above those transverse requirements as listed in Table 3.4.1.4.

#### 3.4.1.6.2 Impact test

**3.4.1.6.2.1** The Charpy V-notch impact test specimens for plates and wide flats over 600 mm in width are to be taken with their axes transverse to the final rolling direction and the results should comply with the appropriate requirements for transverse direction of Table 3.4.1.4. For other product forms, the impact tests are to be in the longitudinal direction, the results of the tests are to comply with the appropriate requirements for longitudinal direction of Table 3.4.1.4.

**3.4.1.6.2.2** Sub-surface test specimens will be taken in such a way that one side is not further away than 2 mm from a rolled surface, however, for material with a thickness in excess of 50 mm, impact tests shall be taken at the quarter thickness (\( t/4 \)) location and mid-thickness (\( t/2 \)).

**3.4.1.6.2.3** Impact test for a nominal thickness less than 6 mm are normally not required.

#### 3.4.1.6.3 Test frequency

**3.4.1.6.3.1** Tensile test sample is to be randomly selected from each batch, as defined in 3.2, that is to be less than or equal to 25 tonnes, and to be from the same cast, in the same delivery condition and of the same thickness.

**3.4.1.6.3.2** Impact test

a) For steels plates in N/NR or TM condition test sample is to be taken from each piece.

b) For steels in QT condition test sample is to be taken from each individually heat treated part thereof.

c) For sections, bars and tubulars, test sample is to be taken from each batch of 25 tonnes or fraction thereof.

*Note 1:*

*If the mass of the finished material is greater than 25 tonnes, one set of tests from each 25 tonnes and/or fraction thereof is required. (e.g. for consignment of 60 tonnes would require 3 plates to be tested).*

*Note 2:*

*For continuous heat treated product special consideration may be given to the number and location of test specimens required by the manufacturer to be agreed by the Register.*
### Table 3.4.1.4
Tensile properties at ambient temperature for all steel grades

<table>
<thead>
<tr>
<th>Steel grade and delivery condition</th>
<th>Nominal thickness [mm] (^4)</th>
<th>Nominal thickness [mm] (^4)</th>
<th>Minimum yield strength (R_{eH}) [N/mm(^2)]</th>
<th>Ultimate tensile strength (R_{m}) [N/mm(^2)]</th>
<th>Minimum percentage elongation after fracture (L_0=5.65\sqrt{S_o} (^2) [%]</th>
<th>Charpy V-notch impact test</th>
<th>Test temp. [°C]</th>
<th>Minimum [Joules]</th>
</tr>
</thead>
<tbody>
<tr>
<td>H420N/NR H420TM H420QT</td>
<td>≥ 3 ≤ 50</td>
<td>&gt; 50 ≤ 100</td>
<td>&gt; 100 ≤ 250</td>
<td>≥ 3 ≤ 100</td>
<td>&gt; 100 ≤ 250</td>
<td>T</td>
<td>19</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>420 390 365</td>
<td>520-680 470-650</td>
<td>0 -20 -40 -60</td>
<td>28 42</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H460N/NR H460TM H460QT</td>
<td>≥ 3 ≤ 50</td>
<td>&gt; 50 ≤ 100</td>
<td>&gt; 100 ≤ 250</td>
<td>≥ 3 ≤ 100</td>
<td>&gt; 100 ≤ 250</td>
<td>T</td>
<td>17</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>460 430 390</td>
<td>540-720 500-710</td>
<td>0 -20 -40 -60</td>
<td>33 50</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H500TM H500QT</td>
<td>≥ 3 ≤ 50</td>
<td>&gt; 50 ≤ 100</td>
<td>&gt; 100 ≤ 250</td>
<td>≥ 3 ≤ 100</td>
<td>&gt; 100 ≤ 250</td>
<td>T</td>
<td>17</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>500 480 440</td>
<td>590-770 540-720</td>
<td>0 -20 -40 -60</td>
<td>37 55</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H5500TM H550QT</td>
<td>≥ 3 ≤ 50</td>
<td>&gt; 50 ≤ 100</td>
<td>&gt; 100 ≤ 250</td>
<td>≥ 3 ≤ 100</td>
<td>&gt; 100 ≤ 250</td>
<td>T</td>
<td>15</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>550 530 490</td>
<td>640-820 590-770</td>
<td>0 -20 -40 -60</td>
<td>41 62</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H620TM H620QT</td>
<td>≥ 3 ≤ 50</td>
<td>&gt; 50 ≤ 100</td>
<td>&gt; 100 ≤ 250</td>
<td>≥ 3 ≤ 100</td>
<td>&gt; 100 ≤ 250</td>
<td>T</td>
<td>14</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>620 580 560</td>
<td>700-890 650-830</td>
<td>0 -20 -40 -60</td>
<td>46 69</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H690TM H690QT</td>
<td>≥ 3 ≤ 50</td>
<td>&gt; 50 ≤ 100</td>
<td>&gt; 100 ≤ 250</td>
<td>≥ 3 ≤ 100</td>
<td>&gt; 100 ≤ 250</td>
<td>T</td>
<td>11</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>690 650 630</td>
<td>770-940 710-900</td>
<td>0 -20 -40 -60</td>
<td>46 69</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H890TM H890QT</td>
<td>≥ 3 ≤ 50</td>
<td>&gt; 50 ≤ 100</td>
<td>&gt; 100 ≤ 250</td>
<td>≥ 3 ≤ 100</td>
<td>&gt; 100 ≤ 250</td>
<td>T</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>890 830 N.A</td>
<td>940-1100 N.A</td>
<td>0 -20 -40</td>
<td>46 69</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H960QT</td>
<td>≥ 3 ≤ 50</td>
<td>&gt; 50 ≤ 100</td>
<td>&gt; 100 ≤ 250</td>
<td>≥ 3 ≤ 100</td>
<td>&gt; 100 ≤ 250</td>
<td>T</td>
<td>960 N.A N.A N.A</td>
<td>980-1150 N.A</td>
</tr>
</tbody>
</table>

**Notes:**

1) For tensile test either the upper yield stress \(R_{eH}\) or where \(R_{eH}\) cannot be determined, the 0.2 percent proof stress \(R_{p0.2}\) is to be determined and the material is considered to comply with the requirement if either value meets or exceeds the specified minimum value of yield strength.

2) For full thickness flat test specimens with a width of 25 mm and a gauge length of 200 mm the elongation is to comply with the minimum values shown in Table 3.4.1.5.

3) In the case that the tensile specimen is parallel to the final rolling direction, the test result shall comply with the requirement of elongation for longitudinal (L) direction.

4) For plates and sections for applications, such as racks in offshore platforms etc, where the design requires that tensile properties are maintained through the thickness, a decrease in the minimum specified tensile properties is not permitted with an increase in the thickness.

N.A = Not applicable
Table 3.4.1.5
Elongation Minimum Values for a Width of 25 mm and a 200 mm Gauge Length1

<table>
<thead>
<tr>
<th>Strength level</th>
<th>Thickness [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>t ≤ 10</td>
</tr>
<tr>
<td>H420</td>
<td>11</td>
</tr>
<tr>
<td>H460</td>
<td>11</td>
</tr>
<tr>
<td>H500</td>
<td>10</td>
</tr>
<tr>
<td>H550</td>
<td>10</td>
</tr>
<tr>
<td>H620</td>
<td>9</td>
</tr>
<tr>
<td>H690</td>
<td>9²</td>
</tr>
</tbody>
</table>

Notes:
1) The tabulated elongation minimum values are the requirements for testing specimen in transverse direction. H890 and 960 specimens and specimens which are not included in this table shall be proportional specimens with a gauge length of $L_0=5.65\sqrt{S_0}$.
2) For H690 plates with thickness ≤ 20 mm, round specimen in accordance with Chapter 2 may be used instead of the flat tensile specimen. The minimum elongation for testing specimen in transverse direction is 14%.

N.A = Not applicable

3.4.1.6.4 Traceability
Traceability of test material, specimen sampling and test procedures including test equipment with respect to mechanical properties testing, is to be in accordance with 3.2.

3.4.1.6.5 Re-test procedures
Re-test procedures for tensile tests and Charpy impact tests are to be in accordance with Chapter 2.

3.4.1.6.6 Through thickness tensile test
3.4.1.6.6.1 For steels designated with improved through thickness properties, through thickness tensile tests are to be performed in accordance with 3.9 - Steel plates and wide flats with specified minimum through thickness properties (“Z” quality).
3.4.1.6.6.2 Subject to the discretion of the Register, through thickness tensile strength may be required to be not less than 80% of the specified minimum tensile strength.

3.4.1.7 Tolerances
Unless otherwise agreed or specially required, the thickness tolerances in 3.2.9 are applicable.

3.4.1.8 Surface Quality
3.4.1.8.1 All materials are to be free from cracks, injurious surface flaws, injurious laminations and similar defects.
3.4.1.8.2 The surface quality inspection method shall be in accordance with recognised national or international standards agreed between purchaser and manufacturer.

a) Welding repair procedures and the method for reporting repairs are to be approved by the Register.

b) Where repair by grinding is carried out then the remaining plate thickness below the ground area must be within the allowable under thickness tolerance.

3.4.1.8.3 Surface finish requirement shall be in accordance with the relevant requirements in 3.2.

3.4.1.8.4 Surface inspection is the responsibility of the manufacturer. The acceptance by the Register’s Surveyor of material later found to be defective shall not absolve the manufacturer of this responsibility.

3.4.1.9 Internal Soundness
3.4.1.9.1 Verification of internal soundness is the responsibility of the manufacturer. The acceptance by the Register’s Surveyor shall not absolve the manufacturer of this responsibility.

3.4.1.9.2 Ultrasonic examination
3.4.1.9.2.1 If required by the Register, ultrasonic examination should be carried out in accordance with 3.2 for the requirement of internal soundness, and is to be performed in accordance with an approved standard.

3.4.1.10 Stress relieving heat treatment and other heat treatments
3.4.1.10.1 Steels approved by the procedures given in Appendix A3 with respect to Heat Treatment are suitable for stress relieving heat treatment such as post-weld heat treatment and stress relieving heat treatment after cold forming for the purpose of reducing the risk of brittle fracture, increasing the fatigue lifetime and dimensional stability for machining.
Note:
Products can be susceptible to deterioration in mechanical strength and toughness if they are subjected to incorrect post-weld heat treatment procedures or other processes involving heating such as flame straightening, rerolling, etc. where the heating temperature and the holding time exceed the limits given by the manufacturer.

3.4.1.11 Facilities for Inspection

3.4.1.11.1 Testing is to be carried out under the witness of the Surveyor, or an authorised deputy, in order to verify whether the test results meet the specified requirements.

3.4.1.11.2 The manufacturer is to afford the Surveyor all necessary facilities and access to all relevant parts of the steel works to enable him to verify the approved process is adhered to, for the selection of test materials, and the witnessing of tests, as required by this section. Also for verifying the accuracy of the testing, calibration of inspection equipment and traceability of materials.

3.4.1.12 Identification of Materials

3.4.1.12.1 The manufacturer is to adopt a system for the identification of ingots, slabs, billet or bloom and finished products, which will enable the material to be traced to its original cast. The Surveyor is to be given full facilities for so tracing the material when required.

3.4.1.13 Branding

3.4.1.13.1 Each finished piece is to be clearly marked by the manufacturer with the following particulars:

a) Register’s brand mark
b) Unified identification mark for the grade of steel (e.g. EH620)
c) Name or initials to identify the steelworks
d) Cast number/Heat number, plate number or equivalent identification mark
e) Delivery condition (N/NR, TM/TM+AcC/TM+DQ or Q&T)

The entire markings are to be encircled with paint or otherwise marked so as to be easily recognised. Steels which have been specially approved by the Register and which differ from these requirements (see 3.4.1.1.6) are to have the letter “S” after the identification mark (e.g. EH620S)

3.4.1.14 Documentation of Inspection Tests

3.4.1.14.1 The Surveyor is to be supplied with two copies, of the test certificates or shipping statements for all accepted materials. In addition to the description, dimensions, etc., of the material, the following particulars are to be included:

a) Purchaser’s order number
b) Identification of the cast and piece
c) Manufacturer’s identification
d) Identification of the grade of steel
e) Chemical analysis, Ceq, CET or Pcm value
f) Delivery condition with heat treatment temperatures
g) Mechanical properties test results, including traceable test identification
h) Surface quality and inspection results
i) UT result, where applicable

3.4.1.14.2 Before the test certificates are signed by the Surveyor, the steelmaker is required to provide a written declaration stating that the material has been made by an approved process, and that it has been subjected to and has withstood satisfactorily the required tests in the presence of the Surveyor, or an authorised deputy. The following form of declaration will be accepted if stamped or printed on each test certificate with the name of the steelworks and signed by an authorised 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 Rules of the Register”.

3.4.2 Application of YP47 Steel plates

3.4.2.1 Application

3.4.2.1.1 Steel plates designated as YP47, refer to steel plates with a specified minimum yield point of 460 N/mm². The scope of application is defined in 3.4.2.1.2 and 3.4.2.2.

3.4.2.1.2 The YP47 steel can be applied to longitudinal structural members in the upper deck region of container carriers (such as hatch side coaming, hatch coaming top and the attached longitudinals). Special consideration is to be given to the application of YP47 steel plate for other hull structures.

This requirements defines grade YP47, its approval requirements, its certification requirements, welding consumables requirements and requirements for welding procedure qualification.

3.4.2.1.3 In the case where YP47 steel is applied as brittle crack arrest steel required by the Rules, Part 2 - Hull - Chapter 1.4.6 Requirements for use of extremely thick steel plates in container ships, the brittle crack arrest properties shall be in accordance with 3.4.2.3.2.

3.4.2.1.4 Brittle fracture toughness of welded joints is to comply with Section 3.2, with the Rules, Part 26 - Welding - Chapter 1.4 Welding procedure tests and this chapter.

3.4.2.1.5 Unless otherwise specified in these requirements, Section 3.2 is to be followed.

3.4.2.2 Thickness

3.4.2.2.1 These requirements apply to steel plates in thickness greater than 50 mm and not greater than 100 mm intended for hatch coamings and upper decks of container ships.

3.4.2.2.2 For steel plates outside of this thickness range, special consideration is to be given by the Register.

3.4.2.3 Material specifications

3.4.2.3.1 Material specifications for YP47 steel plates are defined in Table 3.4.2.3-1 and Table 3.4.2.3-2.
Table 3.4.2.3-1

Conditions of supply, grade and mechanical properties for YP47 steel plates

<table>
<thead>
<tr>
<th>Supply condition</th>
<th>Grade</th>
<th>Mechanical properties</th>
<th>Impact test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Yield Strength (N/mm²)</td>
<td>Tensile Strength (N/mm²)</td>
</tr>
<tr>
<td>TMCP*</td>
<td>EH47</td>
<td>460</td>
<td>570/720</td>
</tr>
</tbody>
</table>

Note:
- t - thickness (mm)
- Other conditions of supply are to be in accordance with the Register’s procedures.

Table 3.4.2.3-2

Chemical compositions for YP47 steel plates

<table>
<thead>
<tr>
<th>Chemical composition</th>
<th>Ceq (1)</th>
<th>Pcm (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>As approved by the Register</td>
<td>≤ 0,49%</td>
<td>≤ 0,49%</td>
</tr>
</tbody>
</table>

Note:
(1) The carbon equivalent Ceq value is to be calculated from the ladle analysis using the following formula:

\[ Ceq = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15} \%
\]

(2) Cold cracking susceptibility is to be calculated using the following formula:

\[ Pcm = C + \frac{Si}{30} + \frac{Mn}{20} + \frac{Cu}{20} + \frac{Ni}{60} + \frac{Cr}{20} + \frac{Mo}{15} + \frac{V}{10} + 5B[\%] \]

The extent of testing is to be one set of three specimens taken from each piece defined in 3.2.12.1.

3.4.2.3.2 For the purpose of this UR, brittle crack arrest steel is defined as steel plate with measured crack arrest properties at manufacturing approval stage, \( K_{ca} \) at -10 degree C ≥ 6,000 N/mm²² or other methods based on the determination of Crack Arrest Temperature (CAT).

NOTE:
1. The Crack Arrest Fracture Toughness \( K_{ca} \) is to be determined by the ESSO Test shown in Appendix D or other alternative method. Crack Arrest Temperature (CAT) may also be determined by the Double Tension Wide Plate Test or equivalent. The use of small scale test parameters such as the Nil Ductility Test Temperature (NDTT) may be considered provided that mathematical relationships of NDTT to \( K_{ca} \) or CAT can be shown to be valid.
2. 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 is to be specifically agreed with the Register.

3.4.2.4 Manufacturing approval test

3.4.2.4.1 General

Approval test items, test methods and acceptance criteria not specified in this document are to be in accordance with the Register’s procedures.

3.4.2.4.2 Approval range

One test product with the maximum thickness to be approved is to be selected provided the approved target chemical composition range remains unchanged.

3.4.2.4.3 Base Metal test

a) Charpy V-notch Impact Tests

Generally Charpy V-notch impact testing is to be carried out in accordance with Section 3.2. Test samples are to be taken from the plate corresponding to the top of the ingot, unless otherwise agreed. In the case of continuous castings, test samples are to be taken from a randomly selected plate.
The location of the test sample is to be at the square cut end of the plate, approximately one quarter width from an edge, as shown Fig.3.4.2.4.3.

Samples are to be taken with respect to the principal rolling direction of the plate at locations representing the top and bottom of the plate as follows:

- Longitudinal Charpy V-notch impact tests - Top and bottom,
- Transverse Charpy V-notch impact tests - Top only,
- Strain aged longitudinal Charpy V-notch impact test - Top only.

Charpy V-notch impact tests are required from both the quarter and mid thickness locations of the test samples. One set of 3 Charpy V-notch impact specimens is required for each impact test. The Charpy V-notch impact test temperature is to be -40°C.

In addition to the determination of the energy value, the lateral expansion and the percentage crystallinity are also to be reported.

The strain aged samples are to be strained to 5% followed by heating to 250°C for 1 hour prior to testing. Additionally at each location, Charpy V-notch impact tests are to be carried out with appropriate temperature intervals to properly define the full transition range.

Figure 3.4.2.4.3

Plates and flats

b) Brittle fracture initiation test
Deep notch test or Crack Tip Opening Displacement (CTOD) test is to be carried out and the result is to be reported. Test method is to be in accordance with the Register’s practice.

c) Naval Research Laboratory (NRL) drop weight test
The test method is to comply with ASTM E208 or equivalent method. Nil Ductility Test Temperature (NDTT) is to be reported for reference and may be used in the qualification of production test methods.

d) Brittle crack arrest test

Standard ESSO test described in Appendix D or other alternative test (e.g. double tension test etc.) is to be carried out in order to obtain the brittle crack arrest toughness for reference.

3.4.2.4 Weldability test

a) Charpy V-notch Impact Test
Charpy V-notch impact tests are to be taken at a position of 1/4 thickness from the plate surface on the face side of the weld with the notch perpendicular to the plate surface.

One set of the specimens transverse to the weld is to be taken with the notch located at the fusion line and at a distance 2.5 and minimum 20 mm from the fusion line. The fusion boundary is to be identified by etching the specimens with a suitable reagent.

One additional set of the specimens is to be taken from the root side of the weld with the notch located at the same position and at the same depth as for the face side. The impact test temperature is -40°C. Additionally at each location, impact tests are to be carried out with appropriate temperature intervals to properly define the full transition range.

b) Y- shape weld crack test (Hydrogen crack test)
The test method is to be in accordance with recognized national standards such as KS B0870, JIS Z 3158 or GB 4675.1. Acceptance criteria are to be in accordance with each society’s practice.

c) Brittle fracture initiation test
Deep notch test or CTOD test is to be carried out. Test method and results are to be considered appropriate by the Register.

3.4.2.5 Welding works

3.4.2.5.1 Welder
Welders engaged in YP47 welding work are to possess welder’s qualifications specified in the Register’s procedures.

3.4.2.5.2 Short bead
Short bead length for tack and repairs of welds by welding are not to be less than 50mm.

In the case where Pcm is less than or equal to 0.19, 25mm of short bead length may be adopted with approval of the Register.

3.4.2.5.3 Preheating
Preheating is to be 50°C or over when air temperature is 5°C or below.
In the case where $P_{cm}$ is less than or equal to 0.19, air temperature of 0°C or below may be adopted with approval of the Register.

### 3.4.2.5.4 Welding consumable

Specifications of welding consumables for YP47 steel plates are to be in accordance with Table 3.4.2.5.4-1. Consumable tests for butt weld assemblies are to be in accordance with Table 3.4.2.5.4-2.

#### Table 3.4.2.5.4-1

<table>
<thead>
<tr>
<th>Mechanical Properties</th>
<th>Impact test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield Strength $(N/mm^2)$ min.</td>
<td>Test Temp. $(°C)$</td>
</tr>
<tr>
<td>460</td>
<td>-20</td>
</tr>
</tbody>
</table>

#### Table 3.4.2.5.4-2

<table>
<thead>
<tr>
<th>Tensile Strength $(N/mm^2)$</th>
<th>Bend test ratio: $D/t$</th>
<th>Charpy V-notch impact tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>570-720</td>
<td>4</td>
<td>Test Temp. $(°C)$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Downhand, horizontal-vertical, overhead</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-20</td>
</tr>
</tbody>
</table>

### 3.4.2.5.5 Others

Special care is to be paid to the final welding so that harmful defects do not remain.

Jig mountings are to be completely removed with no defects in general, otherwise the treatment of the mounting is to be accepted by each Classification Society.

### 3.4.2.6 Welding Procedure Qualification Test

#### 3.4.2.6.1 General

Approval test items, test methods and acceptance criteria not specified in this paragraph are to be in accordance with the Register’s procedures.

#### 3.4.2.6.2 Approval range

The Rules, Part 26 - Welding - Chapter 1.4 Welding procedure test is to be followed for approval range.

#### 3.4.2.6.3 Impact test

The Rules, Part 26 - Welding - Chapter 1.4 Welding procedure test is to be followed for impact test. 64J at -20°C is to be satisfied.

### 3.4.2.6.4 Hardness

HV10, as defined in the Rules, Part 26 - Welding - Chapter 1.4 Welding procedure test, is to be not more than 380. Measurement points are to include mid-thickness position in addition to the points required by the Rules, Part 26 - Welding - Chapter 1.4 Welding procedure test.

### 3.4.2.6.5 Tensile test

Tensile strength in transverse tensile test is to be not less than 570N/mm².

### 3.4.2.6.6 Brittle fracture initiation test

Deep notch test or CTOD test may be required. Test method and acceptance criteria are to be considered appropriate by the Register.
3.5 HIGH-TEMPERATURE STEELS

3.5.1 General

3.5.1.1 These requirements apply to flat products made from high temperature ferritic steels, which are intended for the manufacture of steam boilers, pressure vessels, heat exchangers and process equipment.

3.5.2 Suitable steel grades

The materials listed below may be used:

3.5.2.1 Flat products made of steels used for pressure vessels conforming to EN 10028-2 “Non-alloy and alloy steels with specified elevated temperature properties”.

3.5.2.2 Flat products made of steels used for pressure vessels conforming to EN 10028-3 “Weldable fine grain steels, normalized”.

3.5.2.3 Flat products made of other steels, provided that their suitability for the intended purpose and their properties have been proved by the Register. For this purpose the following requirements are to be satisfied:

a) The elongation (A) shall have the minimum values which characterise the grade of steel, as specified in the manufacturer's specification approved by the Register, but shall not be less than 16%.

b) The impact energy shall meet or exceed the requirements of EN 10028-2 and -3 respectively for flat products of the same strength. In the case of plates to be used for shell rings and heads, the manufacturer and the steel user shall ensure that the values required for the final condition can be complied with.

c) Proof of weldability shall be furnished by the manufacturer. Details of preheating, temperature control during welding and heat treatment after welding shall be furnished by the manufacturer.

d) The yield strength at elevated temperature and, where necessary, the long-time rupture stress properties at elevated temperature shall be verified by the manufacturer, if they are different from required in EN 10028-2 and -3.

3.5.2.4 For plates to be used for shell rings and heads, the following additional requirements apply:

For steels for welded boiler drums, the impact energy shall be 31 J at ± 0°C in tests performed on the finished component, if in the case of plate thickness ≥ 50 mm the yield strength of these steels is ≥ 310 N/mm² at room temperature. This energy value is an average for three individual tests with transverse Charpy V-notch specimens, in which none of the individual values may be more than 15% lower than the stated average of 31 J. The stated impact energy value at ± 0°C is a minimum requirement. In addition, the individual steels shall exhibit their characteristic impact energies.

3.5.2.5 Plates to be manufactured into fire tubes shall exhibit adequate formability - elongation (A) ≥ 20% at 20°C.

3.5.3 Condition of supply and heat treatment

The products shall be delivered in the heat-treated conditions specified in the standards and/or in the manufacturer’s specification approved by the Register, unless they are to be further processed at elevated temperature.

3.5.4 Dimensions, dimensional and geometrical tolerances

Requirements of Section 3.2.9 - Thickness tolerances shall be applied.

3.5.5 Scope of testing

3.5.5.1 Test of chemical composition

The manufacturer shall determine the chemical composition of each heat and issue a relevant certificate.

3.5.5.2 Tensile test

The mechanical properties shall be verified by tensile testing. Test specimens shall be taken from the products transverse to the direction of rolling in the following quantity:

a) For sheet and plate, the specimens shall be taken as follows:
   - unalloyed steel sheet ≤ 50 mm thick: one specimen from one end of each rolled length;
   - unalloyed steel plate > 50 mm thick: one specimen from one end if the rolled length is ≤ 15 m, one specimen from each end if the rolled length is > 15 m;
   - alloy steels: one specimen from one end if the rolled length is ≤ 7 m, one specimen from each end if the rolled length is > 7 m.

b) For sheets made from hot-rolled wide strip, at least one specimen shall be taken from the outer end of each coil.

3.5.5.3 Tensile test at elevated temperature

The 0.2% proof stress is to be verified at elevated temperature. A tensile test at elevated temperature shall be performed for each heat. The test temperature shall be 300°C, unless no other temperature is specified in the order.

3.5.5.4 Notched bar impact test

All products with thicknesses ≥ 6 mm shall be impact tested using Charpy V-notch specimens at the test temperatures of 0°C. The specimens shall be taken from the product transverse to the direction of rolling. The number of sets (each of 3 specimens) required for this purpose shall be determined in the same way as the number of tensile test specimens prescribed in 3.5.5.2.
For other steels as per 3.5.2.3, the test temperature will be stipulated in the Register’s certificate.

3.5.5 Testing of surface finish and dimensions
The surface finish and dimensions of all products shall be checked by the manufacturer. The products shall also be submitted to the Surveyor for final inspection; as far as possible, the undersides of the products shall be inspected at the same time.

3.5.5.6 Non-destructive Testing
Where specified in the order or required in special cases, e.g. in the case of products subject to requirements in the thickness direction in accordance with Section 3.9, an ultrasonic test shall be carried out in accordance with 3.2.10.4.

3.5.5.7 Marking of products
The manufacturer shall mark the products in the prescribed manner, see EN 10028-1. In the case of plates which are not supplied in bundles, the marking shall be applied 200 to 400 mm from the bottom end in such a way that, looked at from the bottom end of the plate, the characters are upright and therefore indicate the direction of rolling.

3.5.6 Strength parameters for calculations
The strength parameters for calculations are:

3.5.6.1 For flat products conforming to EN 10028-2 and -3, the values are stated in these standards.

3.5.6.2 For flat products made of other steels as per 3.5.2.4, the values approved by the Register.

3.5.6.3 The strength parameters indicated in the above standards for 100°C are valid up to 120°C. In the other ranges, the values are to be determined by linear interpolation between the stated values, e.g. for 180°C between 150°C and 200°C, (rounding up is not allowed).

3.6 STEELS TOUGH AT SUB-ZERO TEMPERATURES

3.6.1 General
These rules apply to flat products made from:
- fine-grained structural steels,
- high strength, quenched and tempered fine-grained structural steels,
- nickel alloy steels which are tough at low temperatures
- austenitic steels
intended for the fabrication of cargo tanks and process pressure vessels for carrying liquefied gases.

3.6.1.2 Steels conforming to these rules shall be approved by the Register for the intended purpose and design temperature. To this end, the steels listed under 3.6.1.1 shall be subjected to an approval test by the Register. The Register shall decide on a case to case basis on the need for an approval test on austenitic steels and other special structural steels.

3.6.2 Suitable steel grades
The following steels may be used considering the minimum design temperatures stated in Table 3.6.2 provided that they satisfy the additional requirements stipulated in these Rules:

3.6.2.1 Weldable, fine-grained structural steels conforming to EN 10028-3.

3.6.2.2 Fine-grained structural steels with nominal yield strengths above 355 N/mm² in accordance with En 10028-3, -5 and -6.

3.6.2.3 Stainless, austenitic steels conforming to EN 10028-7, provided that they are suitable for the intended design temperature.

3.6.2.4 Other weldable steels conforming to other standards or to material specifications of the manufacturer or the purchaser, after initial testing of product suitability by the Register.

3.6.3 Approval test
3.6.3.1 On the subject of approval of materials, the material manufacturer or tank manufacturer shall provide the Register with a material specification containing all the particulars needed to evaluate the material. The specification shall give the minimum particulars as follows:
- material designation/standard,
- material manufacturer,
- recommended values for chemical composition,
- mechanical properties,
- intended minimum design temperature,
- range of product thicknesses,
- delivery condition,
- associated standards or specifications, e.g. for tolerances, surface finish, freedom of defects,
- heat treatments,
- working method.

3.6.3.2 By means of an approval test, the material manufacturer shall demonstrate that the material is suitable for intended minimum design temperature, the cargo carried and the intended method of processing, especially if this involves welding.

The scope of approval test is set down by the Register on a case by case basis. It shall include notch impact and drop weight tests in the appropriate temperature range, and for quenched and tempered steels with nominal yield strength of 620 and 690 N/mm² it shall also include fracture mechanics tests on the base metal.
### Table 3.6.2
**Minimum design temperatures for steels tough at sub-zero temperatures**

<table>
<thead>
<tr>
<th>Grade</th>
<th>Standard/standard designation</th>
<th>Minimum design temperature [°C]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normalized, TM rolled and fine-grained structural steels with nominal yield strengths above 355 N/mm²</td>
<td>e.g. according to EN 10028-3, -5 or -6 and to Section 3.4</td>
<td>0</td>
</tr>
<tr>
<td>Fine grained structural steels with nominal yield strengths up to 355 N/mm²</td>
<td>e.g. according to En 10028-3, -5 or -6</td>
<td>-45&lt;sup&gt;1)&lt;/sup&gt;</td>
</tr>
<tr>
<td>Nickel alloy steels containing: 0.5% Ni, 1.5% Ni, 3.5% Ni, 5% Ni, 9% Ni</td>
<td>Steels according to En 10028-4 11 Mn Ni 5-3, 13 Mn Ni 6-3 15 Ni Mn 6 12 Ni 14 X 12 Ni 5 X 7 Ni 9, X 8 Ni 9</td>
<td>-55, -60&lt;sup&gt;2)&lt;/sup&gt;, -90&lt;sup&gt;2)&lt;/sup&gt; -105&lt;sup&gt;2)&lt;/sup&gt;, -165</td>
</tr>
<tr>
<td>Austenitic steels</td>
<td>e.g. steels according to EN 10028-7 1.4306 (AISI 304 L) 1.4404 (AISI 316 L) 1.4541 (AISI 321) 1.4550 (AISI 347)</td>
<td>-165</td>
</tr>
</tbody>
</table>

1) The *Register* reserve the right to approve a lower design temperature (max. -55°C) if suitable properties are demonstrated during approval testing.
2) A lower design temperature may be approved for steels for steels containing 1.5%, 3.5% and 5% nickel if the steels are quenched and tempered. In these cases, the test temperatures will be specially stipulated by the *Register*.

### 3.6.4 Limits to use

For fabrication of cargo tanks and process pressure vessels, the limit values for the lowest design temperatures as per Table 3.6.2 shall apply.

### 3.6.5 Condition of supply and heat treatment

All products shall be supplied in the heat treated conditions specified during the approval test and/or in the standards or material specifications.

### 3.6.6 Dimensions and dimensional tolerances

For plates for parts of the tanks or vessel shell including the end plates and domes, the minimum thickness shall be the nominal thickness prescribed in the order specification. Plates, strips and wide flats which do not form part of the shell may be supplied with the minus tolerances stated in Table 3.6.8.3.3.

### 3.6.7 Freedom from defects and repair of surface defects

The provisions specified in 3.2.7 are applicable. Surface defects may generally be removed only by grinding, which shall not at any point reduce the thickness below the prescribed minimum. Where defects are to be repaired by welding, this shall be preceded by a welding procedure test, and the conditions for welding shall then be established.

### 3.6.8 Requirements applicable to the material

#### 3.6.8.1 Chemical composition

The chemical composition shall conform to the data in the recognized standard or the material specification approved by the *Register*.

On the subject of the evaluation of the weldability of high-strength, quenched and tempered fine-grained structural steels, sensitivity to cold-cracking is to be determined from the ladle analysis in accordance with the following formula:

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

The boundary value shall be specified when approval is given for the material.

#### 3.6.8.2 Mechanical properties

The requirements applicable to the mechanical properties which are stated in the recognized standard or the approved material specification shall be verified during testing.

#### 3.6.8.3 Impact energy

The required impact energy values specified in Table 3.6.8.3 and Table 3.6.9.4 respectively for the steel grade concerned must be achieved in tests on Charpy V-notch specimens at the prescribed test temperatures. This requirement applies to comparable steels conforming to the standards or specifications, irrespective of the values stated therein.
Table 3.6.8.3
Impact energy requirements for steels tough at sub-zero temperatures

<table>
<thead>
<tr>
<th>Steel designation</th>
<th>Product thickness [mm]</th>
<th>Notched bar impact test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Test temperature [°C]</td>
</tr>
<tr>
<td>Fine-grained structural steels with yield strengths $R_{eH} \geq 355$ N/mm$^2$</td>
<td>$\leq 40$</td>
<td>-20</td>
</tr>
<tr>
<td>Fine-grained structural steels, nickel alloy steel containing 0.5% nickel</td>
<td>$\leq 25^{(1)}$</td>
<td>5K below minimum design temperature, not higher than -20°C</td>
</tr>
<tr>
<td>Nickel alloy steels containing: 1.5% Ni</td>
<td>$\leq 25^{(1)}$</td>
<td>-65</td>
</tr>
<tr>
<td>3.5% Ni</td>
<td></td>
<td>-95</td>
</tr>
<tr>
<td>5% N</td>
<td></td>
<td>-110 (-196)$^{(4)}$</td>
</tr>
<tr>
<td>9% Ni</td>
<td></td>
<td>-196</td>
</tr>
<tr>
<td>Austenitic steels</td>
<td>$\leq 50$</td>
<td>-196</td>
</tr>
</tbody>
</table>

1) Average value of 3 specimens (figures in brackets are minimum individual values).
2) The following test temperatures are applicable to product thickness above 25 mm:

<table>
<thead>
<tr>
<th>Product thickness [mm]</th>
<th>Test temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>$&gt; 25 \leq 30$</td>
<td>10 K</td>
</tr>
<tr>
<td>$&gt; 30 \leq 35$</td>
<td>15 K</td>
</tr>
<tr>
<td>$&gt; 35 \leq 40$</td>
<td>20 K</td>
</tr>
</tbody>
</table>

For steels intended for tanks and structural components of tanks with product thicknesses above 25 mm which are subjected to stress-relief heat treatment after welding it is sufficient to apply a test temperature 5K below the design temperature but not higher than -20°C.

For stress-relief heat-treated tank reinforcements and similar welded parts, the test temperature may not be higher than that specified for the thickness of the adjoining shell plate.

3) Where, in the case of nickel alloy steels containing 1.5% Ni, 3.5% and 5% Ni, the product exceeds 25 mm, the test temperatures shall be determined in accordance with the data given in footnote 2. They shall not, however, be higher than those shown in the Table.

For 9% nickel steel over 25 mm thick, the requirements shall be specially agreed with the Register.

4) Where 5% nickel steel is tested and approved for a minimum design temperature of -165°C, the notched bar impact test shall be performed at a test temperature of -196°C.

3.6.8.4 Brittle fracture behaviour

When subjected to Pellini’s drop weight test at a test temperature 5K below the design temperature (but no higher than -20°C), ferritic steels shall display a “no break performance”.

3.6.8.5 Resistance of austenitic grades to intercrystalline corrosion

In the condition in which they are supplied, austenitic steels shall be resistant to intercrystalline corrosion. Where the materials undergo welding without subsequent heat treatment (solution annealing), only those grades of steel may be used which are corrosion - resistant in this condition, e.g. Ti or Nb stabilized steels or steels with carbon contents of $C \leq 0.03\%$.

3.6.9 Scope of testing

3.6.9.1 Test of chemical composition

The manufacturer shall determine the chemical composition of each heat and shall issue a relevant certificate.

3.6.9.2 Tensile test

All products shall be subjected to the tensile test. For this purpose, specimens shall be taken transverse to the direction of rolling in the case of plate, hot-rolled wide strip and wide flats with a width of $\geq 600$ mm. For all other products they may be taken transverse or parallel to the rolling direction.

The number of specimens shall be determined as follows:

a) normalised and TM-rolled plates: one specimen from one end of each heat-
3.6.9.3 Notched bar impact test

All products with thicknesses of ≥ 6 mm shall be subjected to the notched bar impact test performed on Charpy V-notch specimens at the test temperature specified in Table 3.6.8.3 and Table 3.6.9.3 respectively. In the case of plates and wide flats with a width of ≥ 600 mm the specimens shall be taken transverse to the direction of rolling.

For all other products they may be taken parallel or transverse to the rolling direction. The number of sets (each comprising 3 specimens) required shall be determined in the same way as the number of tensile specimens prescribed in 3.6.9.2.

Where the thickness of the products precludes the preparation of specimens with the standard dimensions (10 x 10), specimens measuring 7.5 x 10 mm or 5 x 10 mm shall be used wherever possible. These specimens are subject to the requirements stated in Table 3.6.9.3.

Table 3.6.9.3

<table>
<thead>
<tr>
<th>Necessary impact energy to Table 3.6.8.3 (standard specimens)</th>
<th>Necessary impact energy KV with specimens measuring 7,5 x 10 mm</th>
<th>7,5 x 10 mm</th>
<th>5 x 10 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>27 (19)</td>
<td>22</td>
<td>16</td>
<td>18</td>
</tr>
<tr>
<td>41 (29)</td>
<td>34</td>
<td>24</td>
<td>27</td>
</tr>
</tbody>
</table>

1) Average value of 3 specimens; figures in booklets are minimum individual values.

3.6.9.4 Drop weight test

Products made from high-strength, quenched and tempered fine-grained structural steels and steels designed for a minimum design temperature of less than -50°C (with the exception of austenitic steels) are to be tested per heat by means of a drop weight test.

For the drop weight test, at least 2 specimens shall be taken from the thickest item from each heat and tested at a temperature of 5 K below the minimum design temperature. The test shall only be performed on products with a thickness is > 16 mm. It is to be conducted in accordance with a recognized standard, e.g. Steel-iron test specification 1325, EN 10274 or ASTM E-208 (see also 2.7.5).

3.6.9.5 Test of resistance to intercrystalline corrosion

Wherever necessary or prescribed in the order, the resistance of austenitic steels to inter-crystalline corrosion shall be tested.

3.6.9.6 Test of surface finish and dimensions

The surface finish and dimensions of all products shall be checked by the manufacturer. They shall also be submitted to the Surveyor or for final testing and in the case of flat products the underside shall also be inspected wherever possible.

3.6.9.7 Non-destructive tests

The manufacturer shall carry out an ultrasonic test in accordance with the accepted standard at the discretion of the Register on the following products and shall certify the result:

a) plates made from high-strength, quenched and tempered fine-grained structural steels;

b) plates which are loaded in the thickness direction,

The purchaser shall indicate these requirements in his order documents.

Special arrangements are to be made for the testing of rolled sections for the equator rings of spherical tanks.

Ultrasonic testing is to be carried out according to EN 10160 or as stated in Steel-Iron Supply Specifications SEL 072) as follows in Table 3.6.9.7:

Test grid ≤200 mm or in lines 100 mm apart.
Table 3.6.9.7
Ultrasonic testing

<table>
<thead>
<tr>
<th>Test Type</th>
<th>SEL 072</th>
<th>EN 10160</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface test</td>
<td>Class 3, Table 1</td>
<td>S1</td>
</tr>
<tr>
<td>Marginal zone test</td>
<td>Class 1, Table 2</td>
<td>E3</td>
</tr>
</tbody>
</table>

Zone for longitudinal, circumferential and connection welds over width equal to the thickness of the plate, but not less than 50 mm in accordance with Class 1, Table 2 according to SEL 072 and quality class E3 according to EN 10160 respectively.

Areas for the connection of supporting brackets, lifting lugs and floating securing devices 100% in accordance with Class 0, Table 1 according to SEL 072 and quality class S3 according to EN 10160 respectively.

A non-destructive test shall be performed on products other than mentioned in 3.6.9.7 if this is specified at the time of the order or called for by the Register in special cases.

3.7 STAINLESS STEELS

3.7.1 General

These requirements are applicable to flat products, sections and bars made of stainless steels which are intended for the fabrication of cargo tanks of chemical tankers, pressure vessels and other vessels, for which chemical stability in relation to the cargo or operating fluid is required and also for sleeves of rudderstocks, rudder pintles, propeller shafts etc. which are required to be seawater resistant.

3.7.2 Selection of steels

3.7.2.1 Steels shall be selected in accordance with the operator’s list of cargoes, which provides information on the nature of the substances to be transported or stored.

3.7.2.2 Furthermore, steels shall be selected in such a way that also depending upon their further processing, e.g. by welding, the required chemical stability in relation to the respective cargo or operating fluid is ensured.

3.7.2.3 In the light of 3.7.2.1 and 3.7.2.2 above, suitable steels may be selected e.g. in accordance with EN 10088 relating to stainless steels, where the products are not required to be supplied in accordance with a specification which has been examined by the Register.

3.7.2.4 The Register reserves the right to demand an approval test for the grade of steel in question.

3.7.3 Condition of supply and heat treatment

All products shall be presented in the heat-treated condition appropriate to the material, i.e. ferritic steels shall be annealed or quenched and tempered, while austenitic and austenitic-ferritic steels shall be solution-treated.

3.7.4 Dimensional tolerances

Unless otherwise stipulated in the order specification, plates are to be supplied in accordance with 3.2.9.3.2 (permitted thickness tolerance -0.3mm). For all other products the values stated in the relevant standards shall apply.

3.7.5 General conditions of products

The requirements specified in 3.2.7.3 shall be applied. Surface defects may generally only be repaired by grinding. After grinding the relevant minus tolerances shall not be exceeded, at any point.

3.7.6 Requirements applicable to material properties

3.7.6.1 Chemical composition

The limit values for the chemical composition stated in the standards or in the specifications authorised by the Register shall apply.

For welded structures which cannot be heat treated after welding, only steels which are resistant to intercrystalline corrosion in this condition may be used, e.g. Ti or Nb stabilized austenitic steels or steels with carbon contents of $C \leq 0.03\%$.

3.7.6.2 Mechanical properties

The requirements applicable to the mechanical properties which are stated in the recognized standard or the approved material specification shall be verified during testing.

3.7.6.3 Impact energy

The requirements applicable to the impact energy which are stated in the recognized standard or the approved material specification shall be satisfied.

3.7.7 Testing and scope of tests

The following tests shall be performed:

3.7.7.1 Test of chemical composition

The manufacturer shall determine the chemical composition of each heat and issue the relevant certificate.

3.7.7.2 Testing of resistance to intercrystalline corrosion

All products shall be tested for resistance to inter-crystalline corrosion. For this purpose, at least 2 specimens shall be taken from each heat. The test is to be performed in accordance with ISO 3651-2 or DIN 50914 on specimens in the following conditions:

a) Stabilized steels and steels with a carbon content $\leq 0.03\%$; sensitized (annealed at 700$^{\circ}$C for 30 minutes and quenched in water);
b) All other steels: in the condition in which they are supplied.

3.7.7.3 Tensile test

At least one tensile test specimen shall be taken from each test batch and tested. A test batch comprises:

a) plates > 20 mm thick: the rolled length;

b) plates ≤ 20 mm thick: max 40 rolled plates of approximately the same thickness (deviation max. 20%) originating from the same heat and the same heat treatment batch with a total weight not exceeding 30 t;

c) strip and plates taken therefrom: one specimen each from the beginning and the end of the coil;

d) all other product shapes: 5000 kg for products of the same shape originating from the same heat and the same heat treatment batch.

In the case of plates and wide flats with a width of ≥ 600 mm, the specimens shall lie in the transverse direction. For all other product shapes they may lie in the longitudinal or transverse directions.

3.7.7.4 Notched bar impact test

Unless otherwise required by the Register or stipulated in the order, a notched bar impact test with Charpy V-notch specimens is required for

a) flat products with a thickness > 20 mm;

b) rods and bars with diameters or thicknesses > 50 mm;

c) flat products made of austenitic-ferritic steels with thicknesses ≥ 6 mm.

If the products are used for operating temperatures below -10°C, the impact test temperature shall be agreed with the Register.

3.7.7.5 Testing of surface finish and dimensions

The surface finish and dimensions of all products shall be checked by the manufacturer. The products shall also be submitted to the Surveyor for final testing. In the case of flat products, the underside shall also be inspected as far as possible.

3.7.7.6 Testing for use of correct material

The manufacturer shall test his products before delivery by appropriate methods as to whether the correct material has been used and shall confirm this in the acceptance test certificate.

3.7.7.7 Other tests

If there are special requirements regarding resistance to pitting or crevice corrosion, appropriate corrosion tests shall be performed, e.g. to ASTM-G48. The scope of these tests will be determined by the Register from case to case.

3.8 CLAD PLATES

3.8.1 General

These requirements are applicable to steel plates clad with cladding materials made of stainless steels and intended for the manufacture of containers and tanks, e.g. for chemical tankers. It may be agreed to apply these rules to plate clad with other materials, e.g. aluminium or copper - nickel alloys (for steel/aluminium transition joints see Section 5.3).

3.8.2 Suitability of cladding process

The manufacturer shall demonstrate by means of an initial test of product suitability that the clad products satisfy the requirements stated in 3.8.8 and the required properties of the base material are preserved after cladding.

3.8.3 Suitable materials

Steels conforming to Section 3.2. to Section 3.3 and Section 3.5 shall be used as base materials. The stainless steels specified in Section 3.7 and other materials approved by the Register for the purpose may be used as cladding materials.

3.8.4 Method of manufacture and condition of supply

3.8.4.1 Cladding may be performed by rolling or explosive cladding or by a combination of the two methods.

3.8.4.2 Plates clad with austenitic materials shall normally be supplied in rolled condition. Where heat treatment is required in special cases, this is governed by the base material. However, the treatment shall not impair either the chemical stability or the bonding of the cladding material. The type of heat treatment shall be notified to the Register.

3.8.5 Dimensions and tolerances

3.8.5.1 The nominal thickness of the cladding material shall be at least 2 mm. Where no closer thickness tolerances are specified in the order, the minus tolerances for the thickness shall be as shown in the Table 3.8.5.1.

<table>
<thead>
<tr>
<th>Nominal thickness [mm]</th>
<th>Minus tolerance [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 2,0 &lt; 2,5</td>
<td>-0,20</td>
</tr>
<tr>
<td>≥ 2,5 &lt; 3,0</td>
<td>-0,25</td>
</tr>
<tr>
<td>≥ 3,0 &lt; 3,5</td>
<td>-0,35</td>
</tr>
<tr>
<td>≥ 3,5 &lt; 4,0</td>
<td>-0,45</td>
</tr>
<tr>
<td>≥4,0</td>
<td>-0,50</td>
</tr>
</tbody>
</table>
3.8.5.2 The tolerances for the base materials shall be governed by the requirements for the respective steel grades and product shapes.

3.8.6 Surface finish

3.8.6.1 The cladding materials shall have a smooth surface consistent with their purpose. The surface shall be free from scale, impurities, annealing colour and such defects as may impair the manufacturing processes applied to the material, its application or its chemical stability. The surface finish of the base material shall comply with 3.2.7.3.

3.8.6.2 On the cladding material, the total surface area of all defects, with the exception of shallow defects as per 3.8.7.1, shall not exceed 20% of the surface area of the cladding.

3.8.7 Repair of defects

3.8.7.1 Shallow defects in the cladding material, e.g. impressions, grooves and scratches, shall be removed by grinding within the tolerance specified in 3.8.5.

3.8.7.2 In general points where bonding has not occurred up to an area of 50 cm² may be tolerated, except where the purchaser requires that certain areas of the plate be repaired.

3.8.7.3 Deep defects in the cladding material which cannot be removed by grinding and lack of bonding in excess of 50 cm² may be repaired by welding provided that the defects are isolated and separated from each other, do not exceed 1200 cm² in area and do not total more than 5% of the clad surface. Welding shall be subjected to the following rules:

a) All welds must be made by qualified welders using a technique approved by the Register.

b) The welds shall be free from cracks, lack of fusion, undercuts, slag and other defects liable to impair the characteristics of the cladding.

c) After welding, the repaired defect shall be ground flush with the plate. Welding shall be followed by heat treatment if this was specified by the procedure approval test or if called for in the order.

d) After final machining, the plates shall be submitted to the Surveyor for final testing and a suitable non-destructive test technique, e.g. dye penetrant inspection, shall be used to prove that the repairs are free from defects.

e) For each repair by weld, the manufacturer shall give the Surveyor a report stating the dimensions and location of the defects, the details of the welding technique used, nature of any heat treatment applied and the results of the test.

3.8.8 Requirements applicable to material

The clad steels shall satisfy the following requirements:

3.8.8.1 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.

3.8.8.2 Shear strength

The bond between the base and cladding materials shall be adequate to ensure that the cladding material cannot "break" away from the base material when proper manufacturing processes or service loads are applied. In the case of cladding materials with a tensile strength of <280 N/mm², the shear strength shall be at least 50% of the minimum tensile strength of the cladding material and for all other cladding materials it shall be not less than 140 N/mm², irrespective of the direction of testing, unless otherwise agreed in the order.

3.8.8.3 Bonding

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. For clad steels which are severely stressed during processing, e.g. in the manufacture of heads, or while in use, e.g. in tubesheets, it may be necessary for the purchaser to impose more stringent requirements.

3.8.8.4 Mechanical properties

When subjected to the tensile test, the clad plate must satisfy at least the following requirements:

$$\sigma_{pl} = \frac{\sigma_G \times S_G + \sigma_A \times S_A}{S_{pl}}$$

where:

- $\sigma$ [N/mm²] - specified minimum value of tensile strength or yield strength or 0.2% proof stress,

- $S$ [mm] - nominal thickness,

Indices:

- $G$ - base material
- $A$ - cladding material
- $pl$ - clad steel

If the tensile test gives a lower value than that calculated by the formula, the requirements applicable to the base material may be verified by means of specimens from which the cladding material has been removed by machining.

The elongation specified for the base material concerned shall be verified by tests performed on clad specimens.

3.8.8.5 Technological properties

When subjected to the side bend test, the clad plate shall be capable of being bent through 180° over a mandrel with a diameter equal to four times the thickness of
the specimen without separation of the cladding material or formation of incipient cracks. Larger bending mandrel diameters may be agreed for other cladding materials, e.g. aluminium.

3.8.8.6 Impact energy
The requirements applicable to the base material shall be capable of being satisfied after cladding has been carried out.

3.8.8.7 Resistance to intercrystalline corrosion
For austenitic and austenitic-ferritic cladding materials, the requirements to resistance to inter-crystalline corrosion applicable to the relevant grade of steel shall be satisfied.

3.8.9 Testing
The scope of tests and the number and location of the test specimens are determined by the base material. The following tests are to be performed:

3.8.9.1 Test of chemical composition
The manufacturer must determine the chemical composition of each heat of base and cladding material and shall issue a relevant certificate.

3.8.9.2 Test of resistance to intercrystalline corrosion
In the case of austenitic and austenitic-ferritic cladding materials, the resistance to intercrystalline corrosion shall be verified for each test batch. For this purpose, those plates may be grouped together into a test batch which have been clad in the same manufacturing cycle with cladding materials originating from the same heat. Under test, the clad side must be subjected to tensile stress.

3.8.9.3 Tensile test
The tensile test shall be performed on a transverse specimen from each test batch. Unless otherwise agreed, the cladding material shall be left on the test specimen. The gauge marks shall be applied to the base material side.

3.8.9.4 Shear test
From each test batch a specimen shall be taken with its axis transverse to the rolling direction and this shall be subjected to the shear test. The test shall be performed in accordance with a recognized standard (e.g. DIN 50162). The dimensions of the test specimen and the test arrangement are shown in Figure 3.8.9.4.

3.8.9.5 Side bend test
From each test batch a specimen shall be taken with its axis transverse to the rolling direction and this shall be subjected to the side bend test. The dimensions of the test specimen and the test arrangement are shown in Figure 3.8.9.5. Where the product thickness exceeds 80 mm, the specimens may be reduced to 80 mm by machining the base material side.

3.8.9.6 Notched bar impact test
The notched bar impact test shall be performed in cases where it is specified for the base material. The number of specimens, their orientation and the test temperature are subject to the same conditions as apply to the base material.

3.8.9.7 Test of surface finish and dimensions
The surface finish and dimensions of all plates shall be checked by the manufacturer and the thickness of the cladding shall be measured at the edges and in the middle of the plate. All plates shall be submitted to the Surveyor for final testing and verification of the dimensions.
3.8.9.8 Non-destructive testing

To ascertain the quality of the bond between the base and cladding materials, the manufacturer shall carry out 100% ultrasonic testing of the surfaces and edges of all plates.

3.8.10 Marking

All plates are to be marked as follows:

- Manufacturer's mark
- Abbreviated steel grade designation or material number of base and cladding material
- Heat numbers of base and cladding material
- Thickness of base and cladding material
- Specimen No.

3.9 STEEL PLATES AND WIDE FLATS WITH SPECIFIED MINIMUM THROUGH THICKNESS PROPERTIES (“Z” QUALITY)

3.9.1 Application

These requirements supplement those given in Section 3.2 and Section 3.4 for material with a thickness greater than or equal to 15mm and intended to have a specified minimum ductility in the through thickness or “Z” direction (Figure 3.9.1.1). Products with a thickness less than 15mm may be included at the discretion of the Register.

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

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

![Figure 3.9.1.1](Schematic of testing directions)

3.9.2 Manufacture

3.9.2.1 All the materials are to be manufactured at works approved by the Register for "Z" quality steels.

The approval should follow the procedure given in Section 3.2 Appendix A but take into account the improved steelmaking techniques of calcium treatment, vacuum degassing and argon stirring as well as the control of centreline segregation during continuous casting.

Note:

See the standard EN 10164, quality class Z-35.

3.9.2.2 Freedom from Defects

All products must be free from defects liable to impair the required characteristics in the thickness direction, e.g. laminations, major non-metallic inclusions, flakes and segregation.

In addition, when subjected to ultrasonic testing products must satisfy the class 2 test requirements laid down in Iron and steel supply conditions 072, or comparable requirements to another standard.

Note:

Iron and steel supply conditions 072, specifies the following class 2 test requirements for the general ultrasonic test:

- Minimum significant flaw size: 0.5 cm²
- Maximum permissible flaw size: 1.0 cm²
- Permissible incidence of flaws in relation to area:
  - locally: up to 30/m²
  - in relation to total plate area: up to 15/m²
  - Maximum permissible length of significant flaws:
    - parallel to edge (edge testing): 4 cm
    - Permissible incidence of flaws (edge testing): up to 5/m.

3.9.3 Chemical composition

In addition to the requirements of the appropriate steel specification Section 3.2 or Section 3.4, the maximum sulphur content is to be 0.008% determined by the ladle analysis.

3.9.4 Test procedure

In addition to the requirements of the appropriate steel specification Section 3.2 or Section 3.4, preparation of specimens and testing procedures are to be as follows:

3.9.4.1 Test sampling

For plates and wide flats, one test sample is to be taken close to the longitudinal centreline of one end of each rolled piece, representing the batch. See Table 3.9.4.1 and Figure 3.9.4.2.
Table 3.9.4.1
Batch size dependent on product and sulphur content

<table>
<thead>
<tr>
<th>Product</th>
<th>Product S &gt; 0.005 %</th>
<th>Product S ≤ 0.005 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plates</td>
<td>Maximum 50 t of products of the same cast, thickness and heat treatment</td>
<td>Each piece (parent plate)</td>
</tr>
<tr>
<td>Wide flats of nominal thickness ≤ 25 mm</td>
<td>Maximum 10 t of products of the same cast, thickness and heat treatment</td>
<td>Maximum 50 t of products of the same cast, thickness and heat treatment</td>
</tr>
<tr>
<td>Wide flats of nominal thickness &gt; 25 mm</td>
<td>Maximum 20 t of products of the same cast, thickness and heat treatment</td>
<td>Maximum 50 t of products of the same cast, thickness and heat treatment</td>
</tr>
</tbody>
</table>

3.9.4.2 Number of tensile test specimens

The test sample must be large enough to accommodate the preparation of 6 specimens. 3 test specimens are to be prepared while the rest of the sample remains for possible re-testing.

3.9.4.3 Tensile test specimen dimensions

Round test specimens including built-up type by welding are to be prepared in accordance with a recognised national standard.

3.9.4.4 Tensile test results

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

The minimum average value for the reduction of area of at least 3 tensile test specimens, taken in the through thickness direction, must be that shown for the appropriate grade given in Table 3.9.4.2. Only one individual value may be below the minimum average but not less than minimum individual value shown for the appropriate grade. See Figure 3.9.4.3.

Table 3.9.4.2
Reduction of area acceptance values

<table>
<thead>
<tr>
<th>Grade</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>

3.9.4.5 Re-testing procedure

Figure 3.9.4.3 shows the three cases where a re-testing situation is permitted. In these instances, three more tensile tests are to be taken from the remaining test sample.

The average of all 6 tensile tests is to be greater than the required minimum average, with no greater than two results below the minimum average.

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

3.9.5 Ultrasonic tests

Ultrasonic testing is required and is to be performed in accordance with either EN 10160 Level S1/E1 or ASTM A 578 Level C.

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

3.9.6 Marking

Products complying with these requirements are to be marked in accordance with the appropriate steel requirement Section 3.2 or Section 3.4 and in addition, with the notation Z25 or Z35 added to the material grade designation, e.g. CRS-E36Z25 or CRS-E36Z35.

3.9.7 Certification

The following information is required to be included on the certificate, in addition to the appropriate steel requirement given in Section 3.2 or Section 3.4:

a) Through thickness reduction in area (%)
b) steel grade with Z25 or Z35 notation.
3.10 STEEL PIPES

3.10.1 General

3.10.1.1 Scope

3.10.1.1.1 The requirements, contained in 3.10.1 to be observed in the manufacture of seamless and welded steel pipes apply in conjunction with the following individual requirements 3.10.2 to 3.10.5.

The scope of these requirements embraces all pipes used in the construction of steam boilers, pressure vessels and equipment as well as for pipelines, accumulators and pressure cylinders.

As regard steel pipes for structural applications, Sections 3.2, 3.3, 3.4 and 3.7 shall apply respectively.

Pipes which are individually manufactured and welded, such as masts, crane posts, pressure vessel shells et. shall also comply with Part 26 – Welding.

3.10.1.1.2 Pipes conforming to national or international standards or to manufacturer's specifications may be approved provided that their properties are equivalent to the properties stipulated in these Rules or where special approval has been granted for their use. References to standardized materials whose use is permitted are contained in the following individual Rules.

3.10.1.1.3 Pipes conforming to these Rules may be designated either in accordance with the relevant standards or with the symbols shown in the Tables. In the latter case, pipes made of carbon and carbon-manganese steels shall be identified by their minimum tensile strength and, where applicable, by the added letter V denoting high-temperature steel or N denoting steel tough at sub-zero temperatures, while alloy pipes, with the exception of the austenitic grades, shall be identified by the symbols denoting their alloy content.

3.10.1.2 Requirements to be met by pipe manufacturer

3.10.1.2.1 Pipe manufacturer shall be approved by the Register. In addition, where welded pipes are manufactured, the characteristics and the required quality of the welded seam shall be subject to preliminary proof in the form of a procedure approval test the extent of which shall be determined by the Register on a case to case basis.

The Register reserve the right to demand that a test of suitability be carried out in the case of seamless pipes also where these have to meet special requirements, e.g. in respect of their impact energy at low temperatures or their high-temperature strength characteristics.

3.10.1.3 Manufacturing process, condition of supply

3.10.1.3.1 Pipe steels shall be made by basic oxygen steelmaking processes, in an electric furnace or by other methods approved by the Register. Unless otherwise specified, the steels shall be killed.

3.10.1.3.2 Seamless pipes may be manufactured by hot or cold rolling (cold pilger rolling), by hot pressing or by hot and cold drawing.

3.10.1.3.3 Welded ferritic steel pipes may be manufactured by electrical induction or resistance pressure welding or by fusion welding of strips and plates and may be subjected to hot or cold reduction. For austenitic steels tough at sub-zero temperatures and austenitic stainless steels, only fusion welding processes may be used. The manufacturing process and the testing must ensure a weld quality factor of v=1,0.

3.10.1.3.4 All pipes shall be supplied in a properly heat treated condition over their whole length, as specified in the 3.10.2 up to 3.10.5 of this Section.

3.10.1.4 General characteristics of pipes

3.10.1.4.1 Pipes may not display any cracks. Defects liable to have more than an insignificant effect on the use or further treatment of the pipes may be removed by grinding within the minimum permissible wall thickness. Repair welds are not allowed. This rule may be waived in the case of the seams of fusion-welded pipes.

3.10.1.4.2 Pipes shall have a smooth inside and outside surface consistent with the method of manufacture. Minor depressions or shallow longitudinal grooves due to the manufacturing process may be tolerated provided that they do not impair the serviceability of the pipes and the wall thickness remains within the permitted tolerances.

3.10.1.4.3 The upset metal on the outside of pressure welded pipes shall be removed. In pipes having a bore of 20 mm or more, the height of the upset metal on the inside shall not exceed 0,3 mm.

3.10.1.4.4 On fusion-welded pipes, the inside and outside weld reinforcement shall not exceed a value of 1+0,1 x seam width [mm].

3.10.1.5 Dimensions, dimensional and geometrical tolerances

The dimensions and the dimensional and geometrical tolerances of the pipes must comply with the requirements specified in the standards. The relevant standards shall be stated in the order and made known to the Surveyor. The ends of pipes must be cut off perpendicular to the pipe axis and shall be free from burrs. Apart from pipes which are delivered in coils, all pipes shall appear straight to the eye.

3.10.1.6 Integrity of pipes

All pipes shall be leakproof at the specified test pressures.

3.10.1.7 General requirements applicable to the material quality

3.10.1.7.1 Chemical composition

The chemical composition of the pipe material (heat analysis) shall conform to the values specified in Tables contained in this Part of the Rules or, where applicable, values in the relevant standards.
3.10.1.7.2 Weldability

Pipes in accordance with these Rules must be weldable by established workshop methods. Wherever necessary, appropriate measures to safeguard quality shall be taken e.g. preheating and/or subsequent heat treatments.

3.10.1.7.3 Mechanical properties

The tensile strength, yield strength or proof stress, elongation and, where required, the 0.2% or 1% proof stress at elevated temperatures and the impact energy must conform to the Tables contained in this Part of the Rules or, where applicable, in the relevant standards. Irrespective of the provisions contained in the standards, pipes made of steels tough at sub-zero temperatures must at least meet the values specified in 3.10.4 of these Section for the impact energy at the prescribed test temperature.

3.10.1.7.4 Technological properties

Pipes must meet the requirements for the ring test specified in 3.10.1.8.5.

3.10.1.8 General instructions for testing

3.10.1.8.1 Test of chemical composition

The pipe manufacturer and, where appropriate, the manufacturer of the starting material in the case of welded pipes shall verify the composition of each heat and submit the relevant certificates to the Surveyor.

All the elements affecting compliance with the required characteristics shall be specified in the certificates.

A product analysis shall be performed if there is any doubt about the composition of pipes submitted for testing.

3.10.1.8.2 Test of mechanical properties

a) For testing, pipes shall be grouped by steel grades and dimensions (alloy steel pipes also by heats) into test batches of 100 pipes for outside diameters ≤500 mm and into 50 pipes for outside diameters >500 mm. Residual quantities of up to 50 pipes may be evenly allocated to the various test batches. Where welded pipes are concerned, a pipe is considered to be a cut length of not more than 30 m.

b) For the performance of the tensile tests, two pipes each shall be taken from the first two test batches and one pipe each from every subsequent batch. Where a consignment comprises only 10 pipes or less, it shall be sufficient to take one pipe. Normally, longitudinal test specimens shall be taken from the sample pipes. Where the diameter is 200 mm or more, test specimens may also be taken transverse to the pipe axis. From welded pipes additionally test specimens are to be taken transversely to the welded seam. The weld reinforcement shall be machined off over the gauge length.

3.10.1.8.3 Determination of the 0.2 % proof stress at elevated temperatures

Where pipes are designed for use at elevated temperatures on the basis of their high-temperature strength characteristics, the 0.2% or 1% proof stress shall be proved by a hot tensile test performed on one test specimen per heat and per pipe size. The test shall be performed at the temperature which approximates most closely to the level of the operating temperature, rounded off to the nearest 50°C.

The test may be dispensed with in case of pipes to recognized standards, the high-temperature mechanical properties of which are regarded as proven.

3.10.1.8.4 Notched bar impact test

Where this test is specified for the individual types of pipe, the number of sets of specimens and the position of the specimens shall be determined in the same way as the tensile test specimens called for in 3.10.1.8.2. The test shall be performed on Charpy V-notch specimens. In case of pipes with wall thickness above 30 mm, the longitudinal axis of the specimen is to be located in a distance of 1/4 of the pipe wall from the outer surface or as close as possible to this location.

3.10.1.8.5 Technological tests

a) The pipes selected for testing shall be subjected to one of the ring tests specified in Table 3.10.1.8.5-1, provided that the wall thickness of the pipe does not exceed 40 mm. For the performance of the tests, see Section 2.8.

The number of test specimens depends on the application of pipes and is stipulated in the following parts of these Rules.

b) In the ring flattening test, the prescribed distance between the plates H is calculated by applying the following formula:

$$ H = \frac{1 + C}{C + \frac{a}{D}} $$

where:

- $H$ [mm] - distance between the plates;
- $a$ [mm] - nominal wall thickness;
- $D$ [mm] - outside diameter of pipe;
- $C$ - constant determined by the steel grade (see the provisions relating to technological tests contained in the following parts of the Rules).

Where ring specimens of welded pipes are tested, the weld must be set at 90° to the direction of the compressive load.

c) In the ring expanding test, the change in the diameter of the specimen expanded to the point of fracture shall be at least equal to the percentages shown in Table 3.10.1.8.5-2, depending on the material.

d) When the ring tensile test is applied to specimens of welded pipes, the weld shall be set at 90° to the direction of the tensile load.
e) In the drift expanding test applied to the austenitic steel pipes a 20% expansion shall be achieved. Where pipes are made of other steels, the requirements of the other relevant standards shall be achieved.

<table>
<thead>
<tr>
<th>Outside diameter of pipe [mm]</th>
<th>Nominal wall thickness t [mm]</th>
<th>Types of ring test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>t &lt; 2</td>
<td>ring flattening test$^{1,3}$</td>
</tr>
<tr>
<td>≤ 21,3</td>
<td>2 ≤ t ≤ 16</td>
<td>ring flattening test$^{1,3}$</td>
</tr>
<tr>
<td>&gt; 21,3 ≤ 146</td>
<td>≥ 0,7</td>
<td>ring expanding test$^{1,3}$</td>
</tr>
<tr>
<td>&gt; 146</td>
<td>≥ 0,7</td>
<td>ring tensile test$^{2}$</td>
</tr>
</tbody>
</table>

1) The drift expanding test may also be applied to welded pipes.
2) Instead of the ring tensile test, the flattening test is applied to pipes with bores of 100 mm.
3) The drift expanding test is applied to seamless and welded pipes in compliance with EN 10305-1 and -2 respectively.

### Table 3.10.1.8.5-2

<table>
<thead>
<tr>
<th>Pipe material</th>
<th>Minimum expansion [%] for ID/OD ratios of</th>
</tr>
</thead>
<tbody>
<tr>
<td>C and CMn steels</td>
<td>≥0,9 ≥0,8 &gt;0,9 ≥0,7 &gt;0,7 ≥0,6 &gt;0,6 ≥0,5 &gt;0,5</td>
</tr>
<tr>
<td>Mo, CrMo and Ni steels</td>
<td>8 10 12 20 25 30 30 30</td>
</tr>
<tr>
<td>Austenitic steels</td>
<td>30</td>
</tr>
</tbody>
</table>

3.10.1.8.6 Test of surface finish and dimensions

The finish of the inside and outside surface of each pipe shall be inspected by the manufacturer. The diameters and wall thicknesses shall also be measured. The pipes shall then be submitted to the Surveyor for final testing.

3.10.1.8.7 Non-destructive tests

a) The pipes shall be subjected to non-destructive tests of the extent specified in 3.10.2, 3.10.3, 3.10.4 and 3.10.5. Where tests of greater scope are prescribed in the order or in the relevant standards or specifications, these requirements shall be complied with.

b) Other test specifications require special approval by the Register.

c) The test equipment used for the continuous inspection of pipes shall be regularly calibrated using pipes with artificial defects. The efficiency of the equipment must be demonstrated to the Surveyor.

3.10.1.8.8 Tightness test

a) All pipes shall be tested for leaks by the manufacturer by applying the internal pressure test or, where the Register has given its consent, by a suitable non-destructive testing method, e.g. eddy current or stray flux techniques.

b) The internal pressure test shall normally be performed at a standard hydraulic test pressure of 80 bar. Where pipes are intended for an operating pressure of ≤ 25 bar, the test pressure may be reduced to a standard value of 50 bar. 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 after agreement with the Surveyor.

c) Where a non-destructive method of testing is to be used instead of the internal hydraulic pressure test, it shall be able to cover the whole circumference of the pipe. In addition, the method of testing must conform to a recognized standard (e.g. EN 10246) or to an approved test specification. The efficiency of the method shall be initially demonstrated to the Register.

3.10.1.8.9 Re-tests in the event of failure of specimens

If the requirements are not met by specimens subjected to tensile, ring or notched bar impact tests or if, in the notched bar impact test, one individual value falls below 70% of the stipulated average value, then, before the unit testing quantity is rejected, the procedure for retests described Section 2.9 in may be applied.

3.10.1.9 Marking of pipes

3.10.1.9.1 The manufacturer shall mark each pipe as follows in at least one position about 300 mm from the end:

a) short designation or material number of the steel grade,
b) manufacturer’s mark,
c) additionally, the heat number or heat code.

3.10.1.9.2 Markings shall be applied with punches. Pipes with sensitive surfaces or small wall thicknesses which may be damaged by punches shall be marked by another method, e.g. by the coloured imprint, electrical engraving or rubber stamps.

3.10.1.10 Certificates

3.10.1.10.1 For each consignment the manufacturer shall furnish the Surveyor with a certificate containing the following details:

a) purchaser and order number,
b) newbuilding and project number respectively, where known,
c) quantity, dimensions and weight of delivered pipes,
d) strength category or pipe grade,
e) steel grade or material specification,
f) method of pipe manufacture,
g) heat numbers,
i) chemical composition of the heat,
j) condition in which supplied or heat treatment applied,
k) marking,
l) results of material testing.

3.10.1.10.2 The manufacturer shall also certify that all the pipes have been successfully tightness tested and, where applicable, have successfully undergone a non-destructive test and a test of resistance to intercrystalline corrosion.

3.10.1.10.3 If the steels of which the pipes are made are not produced in the pipe works, a steelmaker’s certificate shall be handed to the Surveyor indicating the numbers and analyses of the heats. The steelmaker shall have been approved for the grades concerned. In case of doubt, the Surveyor shall be given facilities for carrying out a check.

3.10.2 Unalloyed steel pipes

3.10.2.1 General

3.10.2.1.1 The requirements are applicable to seamless and welded carbon steel and carbon-manganese steel pipes for use in pressure vessels, process equipment, pipelines and pressure cylinders. Pipes conforming to this Part of the Rules are intended for use at normal ambient temperatures. In general for these applications, pipe grades according to Table 3.10.2.1.1 are to be used.

If the pipes are intended for the manufacture of hydraulic cylinders exposed to low service temperatures, a minimum impact energy of 41 J is to be proven on longitudinal ISO-V specimens, which may lead to the application of steels tough at sub-zero temperatures.

### Table 3.10.2.1.1

<table>
<thead>
<tr>
<th>Strength category or pipe grade to Table 3.10.2.3.2</th>
<th>Corresponding pipe grade to EN 10216-1(^1) or EN 10217-1(^1)</th>
<th>Corresponding pipe grade to EN 10216-3(^1) or EN 10217-3(^2)</th>
<th>EN 10305-1</th>
<th>EN 10305-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>360</td>
<td>P235TR2</td>
<td>E235+N</td>
<td>E235+N</td>
<td></td>
</tr>
<tr>
<td>410</td>
<td>P265TR2</td>
<td>P275NL1</td>
<td>E275+N</td>
<td></td>
</tr>
<tr>
<td>490</td>
<td>P355N</td>
<td>E355+N</td>
<td>E355+N</td>
<td></td>
</tr>
</tbody>
</table>

1) seamless
2) welded

3.10.2.1.2 Pipes conforming to this Part of the Rules may be used for the cargo and processing equipment of gas tankers provided that the relevant design temperatures are not below 0°C.

3.10.2.2 Heat treatment

The pipes shall be in proper heat-treated condition. This is generally to be achieved by normalizing.

Subsequent heat treatment need not be applied to hot-formed pipes if the hot forming operation ensures a corresponding structure of sufficient uniformity.
3.10.2.3 Requirements applicable to materials quality

3.10.2.3.1 Chemical composition

The chemical composition of the pipe steels shall conform to the data given in Table 3.10.2.3.1 or, where appropriate, in the relevant standards or specifications.

3.10.2.3.2 Mechanical properties

The required values of tensile strength, yield strength and elongation specified in Table 3.10.2.3.2 or, where appropriate, in the relevant standards or specifications must be met under test at room temperature.

3.10.2.4 Testing and scope of test

3.10.2.4.1 Test of chemical composition

The manufacturer must determine the chemical composition of each heat in accordance with 3.10.1.8.1.

3.10.2.4.2 Tensile test

Specimens of the sample pipes selected in accordance with 3.10.1.8.2 shall be subjected to the tensile test.

3.10.2.4.3 Technological test

a) Pipes with longitudinal weld seams and seamless pipes of grade 490 are to be examined according to one of the ring tests specified in 3.10.1.8.5, namely two pipes of one test batch. Apart from that for fusion-welded pipes a weld seam bend test in accordance with Part 26 – Welding may be carried out, applying a bending mandrel diameter of 3t.

b) To calculate the distance between the thrust plates in the ring flattening test, the following values shall be assigned to the constant C in the formula given in 3.10.1.8.5 b):

Pipes of strength category 360: C = 0.09
Other pipe grades: C = 0.07.

3.10.2.4.4 Notched bar impact test

On the pipes selected in accordance with 3.10.1.8.2, the notched bar impact test shall be performed on transverse Charpy V-notch specimens if the outside diameter is ≥200 mm. If the outside diameter is <200, longitudinal specimens may be used.

---

Table 3.10.2.3.1

<table>
<thead>
<tr>
<th>Strength category or pipe grade</th>
<th>Chemical composition [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C&lt;sub&gt;max&lt;/sub&gt;</td>
</tr>
<tr>
<td>360</td>
<td>0,17</td>
</tr>
<tr>
<td>410</td>
<td>0,21</td>
</tr>
<tr>
<td>490</td>
<td>0,22</td>
</tr>
</tbody>
</table>

1) This requirement does not apply if the steel contains a sufficient fraction of other nitrogen absorbing elements, which is to be specified.

Table 3.10.2.3.2

<table>
<thead>
<tr>
<th>Strength category or pipe grade</th>
<th>Tensile strength R&lt;sub&gt;m&lt;/sub&gt; [N/mm&lt;sup&gt;2&lt;/sup&gt;]</th>
<th>Yield strength R&lt;sub&gt;yf&lt;/sub&gt; [N/mm&lt;sup&gt;2&lt;/sup&gt;]</th>
<th>Elongation A [%]</th>
<th>Impact energy KV&lt;sup&gt;1)&lt;/sup&gt; [J]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>long.</td>
<td>trans.</td>
<td>long.</td>
<td>trans.</td>
</tr>
<tr>
<td>360</td>
<td>360-500</td>
<td></td>
<td>235</td>
<td>25</td>
</tr>
<tr>
<td>410</td>
<td>410-570</td>
<td></td>
<td>255</td>
<td>21</td>
</tr>
<tr>
<td>490</td>
<td>490-650</td>
<td></td>
<td>310</td>
<td>19</td>
</tr>
</tbody>
</table>

1) For pipes with a wall thickness > 10 mm.
3.10.2.4.5 Test of surface finish and dimensions

The test of surface finish and dimensions shall be performed in accordance with 3.10.1.8.6.

3.10.2.4.6 Non-destructive tests

All pipes shall be subjected by the manufacturer to a non-destructive test over their whole length in accordance with EN 10246 (see 3.10.1.8.7).

a) Non-destructive testing of seamless pipes

The pipes shall be subjected to a non-destructive test for detection of longitudinal defects according to EN 10246-7, acceptance category U2, subcategory C or EN 10246-5, acceptance category F2. Areas in way of pipe ends which have not been tested automatically, shall be subjected either to a manual or semi-automatic ultrasonic test in accordance with EN 10246-7, acceptance category U2, subcategory C or shall be cut off.

b) Non-destructive testing of pressure-welded pipes

Pipe grade 360 and 410:

The weld seam of pipe grades 360 and 410 shall be tested over its entire length according to either EN 10246-3, acceptance category E3 or EN 10246-5, acceptance category F3 or EN 10246-7, acceptance category U3, subcategory C or EN 10246-8, acceptance category U3, if applicable.

Areas in way of pipe ends which have not been tested automatically, shall be subjected either to a manual or semi-automatic ultrasonic test in accordance with EN 10246-8, acceptance category U3 or shall be cut off.

Pipe grade 490:

Pipes of grade 490 shall be subjected to an ultrasonic test for detection of longitudinal defects according to EN 10246-7, acceptance category U2 or EN 10246-10, image quality category R2.

Areas of the weld seam in way of pipe ends which have not been tested automatically, shall be subjected either to a manual or semi-automatic ultrasonic test or to radiographic testing as specified above or shall be cut off.

The base material is to be tested according to EN 10246-15, acceptance category U2.

The pipe ends have to be tested in accordance with EN 10246-17. Laminations in circumferential direction of more than 6 mm length are not permitted within the last 25 mm pipe length at each end.

Plate or strip edges adjacent to the weld seam are to be tested within a 15 mm wide zone along the weld seam in accordance with EN 10246-15 or EN 10246-16, acceptance category U2 in each case.

c) Non-destructive testing of fusion-welded pipes

Pipe grade 360 and 410:

The weld seam of SAW pipe grades 360 and 410 shall be tested either according to EN 10246-9, acceptance category U3 or EN 10246-10, image quality category R2.

Areas in way of pipe ends which have not been tested automatically, shall be subjected either to a manual or semi-automatic ultrasonic test in accordance with EN 10246-9, acceptance category U3, or shall be examined by means of radiographic testing according to EN 10246-10, image quality class R2 or shall be cut off.

Pipe grade 490:

The weld seam of pipes of grade 490 shall be tested over its entire length according to EN 10246-9, acceptance category U2 or EN 10246-10, image quality class R2.

Areas of the weld seam in way of pipe ends which have not been tested automatically, shall be subjected either to a manual or semi-automatic ultrasonic test or to radiographic testing as specified above or shall be cut off.

The base material is to be tested according to EN 10246-15, acceptance category U2.

The pipe ends have to be tested in accordance with EN 10246-17. Laminations in circumferential direction of more than 6 mm length are not permitted within the last 25 mm pipe length at each end.

Plate or strip edges adjacent to the weld seam are to be tested within a 15 mm wide zone along the weld seam in accordance with EN 10246-15 or EN 10246-16, acceptance category U2 in each case.

3.10.2.4.7 Tightness test

All pipes shall be tightness tested by the manufacturer in accordance with 3.10.1.8.8.

3.10.3 High-temperature steel pipes

3.10.3.1 General

3.10.3.1.1 These Rules are applicable to seamless and welded pipes made of carbon steel, carbon-manganese steel, Mo steel and CrMo steel and intended for steam boilers, pressure vessels, process equipment and pipelines. Pipes conforming to these Rules are intended for application at both ambient and elevated temperatures.

For these applications, standardized pipe grades are generally to be used. The appropriate pipe grades are shown in Table 3.10.3.1.1.

3.10.3.2 Heat treatment

Pipes shall be properly heat treated as follows:

a) carbon steel, carbon-manganese steel and 0,3 Mo steel pipes:
   - normalized;

b) pipes made of 1 Cr 0,5 Mo and 2,25 Cr 1 Mo steels:
   - quenched and tempered.
Subsequent heat treatment need not be applied to hot formed pipes covered by a) if the hot forming operation ensures a corresponding structure of sufficient uniformity. Under these conditions, tempering may be sufficient for the alloy pipes covered by b).

Table 3.10.3.1.1
Standardized pipes made of high-temperature steel grades

<table>
<thead>
<tr>
<th>Strength category or pipe grade</th>
<th>Corresponding pipe grade to</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>EN 10216-2</td>
</tr>
<tr>
<td>360</td>
<td>P235GH</td>
</tr>
<tr>
<td>410</td>
<td>P265GH</td>
</tr>
<tr>
<td>460</td>
<td>-</td>
</tr>
<tr>
<td>510</td>
<td>20MnNb6</td>
</tr>
<tr>
<td>0,3Mo</td>
<td>16Mo3</td>
</tr>
<tr>
<td>1Cr05Mo</td>
<td>13CrMo4-5</td>
</tr>
<tr>
<td>2,25Cr1Mo</td>
<td>10CrMo9-10</td>
</tr>
</tbody>
</table>

3.10.3.3 Requirements applicable to material

3.10.3.3.1 Chemical composition
The chemical composition must conform to the values given in the relevant standards or specifications.

3.10.3.3.2 Mechanical properties
The required values of tensile strength, yield strength and elongation specified in the relevant standards or specifications must be met under test at room temperature.

3.10.3.3.3 Technological properties
When subjected to the ring tests, the pipes shall display a capacity for deformation which meets the requirements specified in 3.10.1.8.5.

3.10.3.3.4 Impact energy
The pipes shall at least satisfy the impact energy requirements specified in the relevant standards or specifications.

3.10.3.3.5 High-temperature characteristics
The 0,2% proof stress at elevated temperatures shall satisfy the requirements specified in the relevant standards or specifications.

3.10.3.3.6 Dimensional tolerances for collectors
Seamless collector pipes and collectors with inside diameters ≤600 mm are subject to the following dimensional tolerances:

a) on the inner or outer clear width ±1,0% where the outer clear width is ≤225 mm, or ±1,5% where the outer clear width is >225 mm,
b) 0% to +25% on the wall thickness,
c) the lateral curvature of square pipes shall be as shown in Fig.3.10.3.3.6.

![Figure 3.10.3.3.6](image)

Tolerance on the lateral curvature of square pipes
In square pipes, the inner corner radius \( r \) in relation to the wall thickness \( s \) shall be at least:

\[ r \geq \frac{s}{3} \geq 8 \text{ mm} \]

3.10.3.4 Testing and scope of tests
The following tests are to be performed:

3.10.3.4.1 Test of chemical composition
The manufacturer must determine the chemical composition of each heat in accordance with 3.10.1.8.1.

3.10.3.4.2 Tensile test
Specimens of the sample pipes selected in accordance with 3.10.1.8.2 shall be subjected to the tensile test.

3.10.3.4.3 Technological test
a) The pipes, namely two pipes of one test batch, shall undergo one of the ring tests specified in 3.10.1.8.5.
For fusion-welded pipes a weld seam bend test in accordance with Part 26 – Welding is to be carried out, applying a bending mandrel diameter of 3t.

b) To calculate the distance between the thrust plates in the ring flattening test, the following values shall be assigned to the constant C in the formula given in 3.10.1.8.5 b):

- Pipes of strength category 360: C = 0.09
- Other pipe grades: C = 0.07

3.10.3.4.4 Notched bar impact test

The test is to be carried out at room temperature on the sample pipes selected in accordance with 3.10.1.8.2, using transverse Charpy V-notch specimens if the outside diameter is ≥ 200 mm. If the outside diameter is < 200 mm, longitudinal specimens may be used.

3.10.3.4.5 High-temperature tensile test

Where stipulated in 3.10.1.8.3 or in the order, the 0.2% proof stress shall be determined by a high-temperature tensile test.

3.10.3.4.6 Test of surface finish and dimensions

The test of surface finish and dimensions shall be performed in accordance with 3.10.1.8.6.

3.10.3.4.7 Non-destructive tests

All pipes shall be subjected by the manufacturer to a non-destructive test according to EN 10246 over their whole length and cross section (see 3.10.1.8.7).

a) Non-destructive testing of seamless and pressure-welded pipes:

The pipes shall be subjected to a non-destructive test for detection of longitudinal defects according to EN 10246-7, acceptance category U2, subcategory C. Areas in way of pipe ends which have not been tested automatically, shall be subjected either to a manual or semi-automatic ultrasonic test or shall be examined by means of radiographic testing according to the procedures specified above or shall be cut off.

b) Non-destructive testing of fusion-welded pipes:

The weld seam of the pipes shall be tested over its entire length according to either EN 10246-9, acceptance category U2 or EN 10246-10, image quality class R2. Areas in way of pipe ends which have not been tested automatically, shall be subjected either to a manual or semi-automatic ultrasonic test or shall be examined by means of radiographic testing according to the procedures specified above or shall be cut off.

The base material is to be tested according to EN 10246-15, acceptance category U2.

The pipe ends have to be tested in accordance with EN 10246-17. Laminations in circumferential direction of more than 6 mm length are not permitted within the last 25 mm pipe length at each end.

Plate or strip edges adjacent to the weld seam are to be tested within a 15 mm wide zone along the weld seam in accordance with EN 10246-15 or EN 10246-16, acceptance category U2 in each case.

3.10.3.4.8 Tightness test

All pipes shall be tightness tested by the manufacturer in accordance with 3.10.1.8.8.

3.10.4 Pipes tough at sub-zero temperatures

3.10.4.1 General

3.10.4.1.1 These requirements are applicable to seamless or welded pipes made of carbon steel, carbon-manganese steel, nickel alloy steel or austenitic steel tough at sub-zero temperatures and with wall thicknesses up to 25 mm, which are intended for the cargo and processing equipment of gas tankers with design temperatures below 0°C.

For these applications, suitable standardised steel grades may also be used provided that they meet the requirements stated in this Part of the Rules, including especially those relating to impact energy at sub-zero temperatures. For the appropriate pipe grades see Table 3.10.4.1.1.

3.10.4.1.2 Where the wall thickness of the pipes exceeds 25 mm, the requirements are subject to special agreement with the Register.

3.10.4.1.3 If the pipes are used for cargo and processing equipment on gas tankers, the minimum design temperatures specified in Table 3.10.4.1.3, are applicable.

<table>
<thead>
<tr>
<th>Table 3.10.4.1.3 Minimum design temperatures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strength category or pipe grade</td>
</tr>
<tr>
<td>---------------------------------</td>
</tr>
<tr>
<td>360 T</td>
</tr>
<tr>
<td>390 T</td>
</tr>
<tr>
<td>490 T</td>
</tr>
<tr>
<td>0,5 Ni</td>
</tr>
<tr>
<td>3,5 Ni</td>
</tr>
<tr>
<td>9 Ni</td>
</tr>
<tr>
<td>Austenitic pipes</td>
</tr>
</tbody>
</table>

<sup>1)</sup> Only applicable if the required impact energy has been demonstrated at the time of the approval tests.
Table 3.10.4.1.1
Comparably suitable pipe grades of steels tough at sub-zero temperatures according to standard

<table>
<thead>
<tr>
<th>Strength category or pipe grade</th>
<th>Corresponding pipe grade to EN 10216-3(1) or DIN 17458(2)</th>
<th>DIN 17457(2)</th>
<th>ISO 9329-3(1) or ISO 9330-3(2)</th>
<th>ISO 9329-4(1) or ISO 9330-6(2)</th>
<th>ASTM(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>360 T</td>
<td>P215NL</td>
<td>P265NL</td>
<td>P255NL1</td>
<td>PL25</td>
<td></td>
</tr>
<tr>
<td>390 T</td>
<td>P265NL</td>
<td>P275NL1</td>
<td>P255NL2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>490 T</td>
<td>P355NL1</td>
<td>P355NL2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0,5Ni</td>
<td>13MnNi6-3</td>
<td>13MnNi6-3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3,5Ni</td>
<td>12Ni14</td>
<td>12Ni14</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9Ni</td>
<td>X10Ni9</td>
<td>X10NiMn9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.4306</td>
<td>X2CrNi19-11</td>
<td>X2CrNi18-10</td>
<td>TP 304 L</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.4404</td>
<td>X2CrNiMo17-13-2</td>
<td>X2CrNiMo17-12</td>
<td>TP 316 L</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.4541</td>
<td>X6CrNiTi18-10</td>
<td>X6CrNiTi18-10</td>
<td>TP 321</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.4550</td>
<td>X6CrNiNbn18-10</td>
<td>X6CrNiNbn18-10</td>
<td>TP 347</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.4571</td>
<td>X6CrNiMoTi17-12</td>
<td>X6CrNiMoTi17-12</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1) Seamless pipes
2) Welded pipes
3) The notched bar impact energies according to Table 3.10.4.3.3 are to be demonstrated.

3.10.4.2 Heat treatment

Depending on the selected material, the pipes shall be supplied in one of the heat treated conditions specified in Table 3.10.4.2.

For austenitic pipes, the heat treatment may be followed by cold drawing entailing small degrees of deformation, provided that the required characteristics can be maintained.

Welded austenitic pipes may be delivered in the welded state without post-weld heat treatment 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. In addition, any scale, residual slag and temper colours on the inner and outer surfaces shall be carefully removed, e.g. by pickling, grinding or sand blasting.

Table 3.10.4.2
Heat treatment of steel pipes tough at sub-zero temperatures

<table>
<thead>
<tr>
<th>Strength category or pipe grade</th>
<th>Type of heat treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>360 T</td>
<td>Normalized or quenched and tempered</td>
</tr>
<tr>
<td>390 T</td>
<td>Normalized</td>
</tr>
<tr>
<td>490 T</td>
<td>Normalized and tempered or quenched and tempered</td>
</tr>
<tr>
<td>0,5 Ni</td>
<td>Double normalized and tempered or quenched and tempered</td>
</tr>
<tr>
<td>3,5 Ni</td>
<td></td>
</tr>
<tr>
<td>9 Ni</td>
<td></td>
</tr>
<tr>
<td>Seamless austenitic pipes</td>
<td>Solution annealed and quenched</td>
</tr>
<tr>
<td>Welded austenitic pipes</td>
<td>Solution annealed and quenched or in the welded condition</td>
</tr>
</tbody>
</table>

3.10.4.3 Requirements applicable to material

3.10.4.3.1 Chemical composition

The chemical composition of the pipe steels shall conform to the data in Table 3.10.4.3.1 or, where appropriate to the other relevant standards or specifications.

3.10.4.3.2 Resistance of austenitic pipe grades to intercrystalline corrosion

Austenitic steel pipes shall be resistant to intercrystalline corrosion. Where welding is not followed by further heat treatment (quenching), only those pipe grades may be used which are corrosion-resistant in the welded condition, e.g. steels stabilized with Ti or Nb or steels with carbon contents of $C \leq 0.03\%$ (see Table 3.10.4.3.1).

3.10.4.3.3 Mechanical properties

The values for tensile strength, yield strength or $0.2\%$ or $1\%$ proof stress and elongation specified in Table 3.10.4.3.3 or, where appropriate, in the other relevant standards or specifications must be satisfied under test at room temperature.

3.10.4.3.4 Technological properties

In the technological ring tests, the pipes shall exhibit a capacity for deformation which satisfies the requirements stated in 3.10.1.8.5.

3.10.4.3.5 Low-temperature impact energy

The required impact energy values specified in Table 3.10.4.3.3 for the pipe grade concerned shall be met at the prescribed test temperatures. This requirement is also applicable to comparable pipe grades conforming to the stand-
ards or specifications, irrespective of the values specified therein.

3.10.4.4 Testing and scope of tests

The following tests are to be performed:

3.10.4.4.1 Test of chemical composition

The chemical composition of each heat shall be determined by the pipe manufacturer, or, where appropriate in the case of welded pipes, by the manufacturer of the starting material in accordance with 3.10.1.8.1.

3.10.4.4.2 Test of resistance to intercrystalline corrosion

a) The resistance to inter-crystalline corrosion shall be tested on austenitic steel pipes where this is called for in the order or where the pipes are made of materials which do not meet the requirements in respect of the limited carbon content or sufficient stabilisation with titanium or niobium (see 3.10.4.3.2).

b) The testing of resistance to intercrystalline corrosion shall be performed in accordance with ISO 3651-2 on at least two samples per heat. The test specimens must be treated as follows:

- Steels with C ≤ 0,03% and stabilized steels are to undergo sensitising heat treatment (700°C, 30 min. water quench).
- All other grades of steel must be in the condition in which they are supplied.

3.10.4.4.3 Tensile test

The tensile test shall be performed on the sample pipes selected in accordance with 3.10.1.8.2.

3.10.4.4.4 Technological tests

The pipes shall undergo one of the technological ring tests as specified in Table 3.10.1.8.5-1. For the performance of the test, specimens shall be taken from one end of two pipes of a test batch.

To calculate the distance between the plates to be used in the ring flattening test, the values according to Table 3.10.4.4.4 shall be assigned to the constant C in the formula given in 3.10.1.8.5 b).

<table>
<thead>
<tr>
<th>Strength category or pipe grade</th>
<th>Constant C</th>
</tr>
</thead>
<tbody>
<tr>
<td>360 T</td>
<td>0,09</td>
</tr>
<tr>
<td>390 T and 490 T</td>
<td>0,07</td>
</tr>
<tr>
<td>0,5 Ni</td>
<td>0,07</td>
</tr>
<tr>
<td>3,5 Ni</td>
<td>0,08</td>
</tr>
<tr>
<td>9 Ni</td>
<td>0,06</td>
</tr>
<tr>
<td>Austenitic pipes</td>
<td>0,10</td>
</tr>
</tbody>
</table>

3.10.4.4.5 Notched bar impact test

On pipes with wall thicknesses ≥ 6mm, the notched bar impact test shall be performed on Charpy V-notch specimens taken from each sample pipe selected in accordance with 3.10.1.8.2.

If the dimensions of the pipe are such that test specimens can be taken without straightening, these shall be taken transverse to the pipe axis. In such cases 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.

In all other cases the specimens shall be taken parallel to the pipe axis.

If the wall thickness of the pipe does not allow the preparation of specimens with the standard dimensions (10x10 mm), specimens measuring 7,5x10 mm or 5x10 mm shall be used.

The requirements applicable to these specimens as compared with the standard specimens are shown in Table 3.10.4.4.5.

3.10.4.4.6 Test of surface finish and dimensions

The test of surface finish and dimensions shall be performed in accordance with 3.10.1.8.6.

3.10.4.4.7 Non-destructive tests

All pipes shall be subjected by the manufacturer to a non-destructive test according to EN 10246 over their whole length and cross section (see 3.10.1.8.7).

a) Non-destructive testing of seamless and pressure-welded pipes:

The pipes shall be subjected to a non-destructive test for detection of longitudinal defects according to EN 10246-7, acceptance category U2, subcategory C or EN 10246-5 (only for ferromagnetic pipe grades), acceptance category F2. Areas in way of pipe ends which have not been tested automatically, shall be subjected either to a manual or semi-automatic ultrasonic test according to EN 10246-7, acceptance category U2, subcategory C or shall be cut off.

b) Non-destructive testing of fusion-welded pipes:

The weld seam of the pipes shall be tested over its entire length according to either EN 10246-9, acceptance category U2 or EN 10246-10, image quality class R2. Areas in way of pipe ends which have not been tested automatically, shall be subjected either to a manual or semi-automatic ultrasonic test or shall be examined by means of radiographic testing according to the procedures specified above or shall be cut off.

The base material is to be tested according to EN 10246-15, acceptance category U2.
The pipe ends have to be tested in accordance with EN 10246-17. Laminations in circumferential direction of more than 6 mm length are not permitted within the last 25 mm pipe length at each end.

Plate or strip edges adjacent to the weld seam are to be tested within a 15 mm wide zone along the weld seam in accordance with EN 10246-15 or EN 10246-16, acceptance category U2 in each case.

3.10.4.4.8 Tightness test

All pipes shall be tightness tested by the manufacturer in accordance with 3.10.1.8.8.

### Table 3.10.4.3.1

<table>
<thead>
<tr>
<th>Strength category</th>
<th>Chemical composition [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>or pipe grade</td>
<td>C_max</td>
</tr>
<tr>
<td>360 T</td>
<td>0,16</td>
</tr>
<tr>
<td>390 T</td>
<td>0,16</td>
</tr>
<tr>
<td>490 T</td>
<td>0,18</td>
</tr>
<tr>
<td>0,5 Ni</td>
<td>0,16</td>
</tr>
<tr>
<td>3,5 Ni</td>
<td>0,15</td>
</tr>
<tr>
<td>9Ni</td>
<td>0,13</td>
</tr>
<tr>
<td>1.4306</td>
<td>0,030</td>
</tr>
<tr>
<td>1.4404</td>
<td>0,030</td>
</tr>
<tr>
<td>1.4541</td>
<td>0,08</td>
</tr>
<tr>
<td>1.4550</td>
<td>0,08</td>
</tr>
<tr>
<td>1.4571</td>
<td>0,08</td>
</tr>
</tbody>
</table>

1) Al may be wholly or partly replaced by other fine grain elements.
2) Residual elements: Cu ≤ 0,20; total Cr+Cu+Mo ≤ 0,45%
3) Residual elements: Nb ≤ 0,05; Cu ≤ 0,15; V ≤ 0,05; total ≤ 0,30

### Table 3.10.4.3.3

<table>
<thead>
<tr>
<th>Strength category or pipe grade</th>
<th>Tensile strength $R_m$ [N/mm²]</th>
<th>Proof stress $R_{p0,2}$/$R_{p1,0}$</th>
<th>Elongation $A$ [%]</th>
<th>Notched bar impact test (Impact energy KV)$^{(1)}$ Test temp. [°C]</th>
<th>long.</th>
<th>trans.</th>
<th>[J]</th>
</tr>
</thead>
<tbody>
<tr>
<td>360 T</td>
<td>360-490</td>
<td>255</td>
<td>25</td>
<td>23</td>
<td>5K below design temperature, min. -20°C</td>
<td>24</td>
<td>22</td>
</tr>
<tr>
<td>390 T</td>
<td>390-510</td>
<td>275</td>
<td>24</td>
<td>22</td>
<td>-80</td>
<td>-95</td>
<td>22</td>
</tr>
<tr>
<td>490 T</td>
<td>490-630</td>
<td>355</td>
<td>24</td>
<td>20</td>
<td>-196</td>
<td>-196</td>
<td>20</td>
</tr>
<tr>
<td>0,5 Ni</td>
<td>490-610</td>
<td>255</td>
<td>22</td>
<td>20</td>
<td>-</td>
<td>-</td>
<td>41</td>
</tr>
<tr>
<td>3,5 Ni</td>
<td>440-620</td>
<td>355</td>
<td>22</td>
<td>20</td>
<td>-</td>
<td>-</td>
<td>27</td>
</tr>
<tr>
<td>9Ni</td>
<td>690-840</td>
<td>510</td>
<td>20</td>
<td>18</td>
<td>-</td>
<td>-</td>
<td>41(29)</td>
</tr>
<tr>
<td>1.4306</td>
<td>480-680</td>
<td>215</td>
<td>40</td>
<td>35</td>
<td>-</td>
<td>-</td>
<td>27(19)</td>
</tr>
<tr>
<td>1.4404</td>
<td>490-690</td>
<td>225</td>
<td>40</td>
<td>35</td>
<td>-</td>
<td>-</td>
<td>27(19)</td>
</tr>
<tr>
<td>1.4541</td>
<td>510-710</td>
<td>235</td>
<td>35</td>
<td>30</td>
<td>-</td>
<td>-</td>
<td>27(19)</td>
</tr>
<tr>
<td>1.4550</td>
<td>510-740</td>
<td>240</td>
<td>35</td>
<td>30</td>
<td>-</td>
<td>-</td>
<td>27(19)</td>
</tr>
<tr>
<td>1.4571</td>
<td>510-710</td>
<td>245</td>
<td>35</td>
<td>30</td>
<td>-</td>
<td>-</td>
<td>27(19)</td>
</tr>
</tbody>
</table>

1) $R_{p0,2}$ or $R_{p1,0}$ applies to ferritic steels, $R_{p1,0}$ to austenitic steels.
2) Average value of 3 specimens; the values in brackets are the individual minima.
Table 3.10.4.4.5
Impact energy for specimens of reduced size

<table>
<thead>
<tr>
<th>Required impact energy(^1) indicated in Table 3.10.4.3.3 (standard specimens)</th>
<th>Required impact energy with specimens measuring</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7.5 x 10 mm</td>
</tr>
<tr>
<td>27(19)</td>
<td>22</td>
</tr>
<tr>
<td>41(29)</td>
<td>34</td>
</tr>
</tbody>
</table>

3.10.5 Stainless steel pipes

3.10.5.1 General

3.10.5.1.1 These requirements are applicable to seamless and welded austenitic and austenitic-ferritic stainless steel pipes to be used for the cargo and processing equipment on chemical tankers and for other lines, vessels and equipment, where chemical stability is required. Suitable pipe grades conforming to international or national standards and to established and recognized specifications together with the austenitic pipe grades specified in Part 3.10.4, Table 3.10.4.3.1, are appropriate to these applications subject to the following conditions relating to manufacture and testing.

3.10.5.1.2 Pipe grades shall be so selected with regard to subsequent manufacturing operations, e.g. welding, that they possess the chemical stability demanded by the intended application.

3.10.5.2 Heat treatment

The pipes shall be supplied in solution-annealed and quenched condition, although welded pipes may also be supplied without post-weld heat treatment provided that they continue to possess the required chemical stability in this condition and that the conditions stated in 3.10.4.2 are complied with.

3.10.5.3 Requirements applicable to the material

3.10.5.3.1 Chemical composition

The chemical composition of the pipe steels shall conform to recognized standards or specifications.

3.10.5.3.2 Resistance to intercrystalline corrosion

In the condition in which they are supplied, the pipes must be resistant to intercrystalline corrosion.

Where the welding is not to be followed by heat treatment (solution annealing), only those pipe grades may be used which are corrosion-resistant in the welded condition, e.g. steels stabilized with Ti or Nb or steels with carbon contents of C ≤ 0.03%.

3.10.5.3.3 Mechanical properties

The required values of tensile strength, 1% proof stress and elongation shall be satisfied in tests at room temperature in accordance with the standard or the recognized specification.

3.10.5.3.4 Technological properties

In the technological ring tests, the pipes shall exhibit a capacity for deformation which satisfies the requirements stated in 3.10.1.8.5.

3.10.5.3.5 High-temperature characteristics

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.

3.10.5.3.6 Impact energy

The required impact energy values shall be satisfied in tests at room temperature in accordance with the relevant standards or the recognized specification.

3.10.5.4 Testing and scope of tests

The following tests are to be performed:

3.10.5.4.1 Test of chemical composition

The chemical composition of each heat shall be determined by the pipe manufacturer, or, where appropriate in the case of welded pipes by the manufacturer of the starting material in accordance with 3.10.1.8.1.

3.10.5.4.2 Test of resistance to intercrystalline corrosion

Depending on the application and grade of the pipes, a test of resistance to intercrystalline corrosion shall be performed on the following pipes:

a) pipes for use on chemical tankers irrespective of the grade of material;

b) pipes which do not meet the requirements in respect of stabilisation or limited carbon content specified in 3.10.5.3.2;

c) pipes made of stabilized steels or steels with limited carbon contents intended for applications not covered, where such test-
ing is specially prescribed in view of the anticipated corrosive attack.

The test conditions shall be as prescribed in 3.10.4.4.2 b).

3.10.5.4.3 Tensile test

The tensile test shall be performed on specimens of the sample pipes selected in accordance with 3.10.1.8.2.

3.10.5.4.4 Technological tests

Unless more extensive testing is prescribed in the standards, one of the technological ring tests specified in Table 3.10.1.8.5-1, shall be performed on one end of 2% of the pipes. To calculate the distance between the plates to be used in the ring flattening test, a value of 0,10 shall be assigned to the constant C in the formula given in 3.10.1.8.5 b).

3.10.5.4.5 High temperature tensile test

Where called for in 3.10.1.8.3 or stipulated in the order, the 0,2% or 1% proof stress shall be determined by a high-temperature tensile test.

3.10.5.4.6 Test of surface finish and dimensions

The pipes shall be subjected to the test of surface finish and dimensions in accordance with 3.10.1.8.6.

3.10.5.4.7 Non-destructive tests

All pipes shall be subjected by the manufacturer to non-destructive testing over their entire length according to EN 10246. The pipes shall be subjected to a non-destructive test in order to detect longitudinal defects according to EN 10246-7, acceptance category U2, subcategory C. Areas in way of pipe ends which have not been tested automatically, shall be subjected either to a manual or semi-automatic ultrasonic test according to EN 10246-6, acceptance category U2, subcategory C or shall be cut of.

3.10.5.4.8 Tightness test

All pipes shall be tightness tested by the manufacturer in accordance with 3.10.1.8.8.

3.11 HULL AND MACHINERY STEEL FORGINGS

3.11.1 Scope

3.11.1.1 These requirements are applicable to steel forgings, intended for hull and machinery applications, such as rudder stocks, pintles, propeller shafts, crankshafts, connecting rods, piston rods, gearing, etc. Where relevant, these requirements are also applicable to material for forging stock and to rolled bars, intended to be machined into components of simple shape.

3.11.1.2 These requirements are applicable only to steel forgings, where the design and acceptance tests are related to mechanical properties at ambient temperature. For other applications, additional requirements may be necessary, especially when the forgings are intended for service at low or elevated temperatures.

3.11.1.3 Alternatively, forgings which comply with national or proprietary specifications may be accepted provided such specifications give reasonable equivalence to these requirements or are otherwise specially approved or required by the Register.

3.11.2 Manufacture

3.11.2.1 Forgings are to be made at a manufacturer, approved by the Register.

3.11.2.2 The steel used in the manufacture of forgings is to be made by a process approved by the Register.

3.11.2.3 Adequate top and bottom discards are to be made to ensure freedom from piping and harmful segregation in the finished forgings.

3.11.2.4 The plastic deformation is to be such as to ensure soundness, uniformity of structure and satisfactory mechanical properties after heat treatment. The reduction ratio is to be calculated with reference to the average cross-sectional area of the cast material. Where the cast material is initially upset, this reference area may be taken as the average cross-sectional area after this operation. Unless otherwise approved, the total reduction ratio is to be at least:

- for forgings made from ingots or from forged blooms or billets, 3 : 1 where L > D and 1.5 : 1 where L ≤ D
- for forgings made from rolled products, 4 : 1 where L > D and 2 : 1 where L ≤ D
- for forgings made by upsetting, the length after upsetting is to be not more than one-third of the length before upsetting or, in 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

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

3.11.2.5 For crankshafts, where grain flow is required in the most favourable direction having regard to the mode of stressing in service, the proposed method of manufacture may require special approval by the Register. In such cases, tests may be required to demonstrate that a satisfactory structure and grain flow are obtained.

3.11.2.6 The shaping of forgings or rolled slabs and billets by flame cutting, scarfing or arc-air gouging is to be undertaken in accordance with recognized good practice and, unless otherwise approved, is to be carried out before the final heat treatment. Preheating is to be employed when necessitated by the composition and/or thickness of the steel.

For certain components, subsequent machining of all flame cut surfaces may be required.

3.11.2.7 When two or more forgings are joined by welding to from a composite component, the proposed welding procedure specification is to be submitted for approval.
Welding procedure qualification tests may be required by the Register.

3.11.3 Quality of forgings

3.11.3.1 All forgings are to be free from surface or internal defects which would be prejudicial to their proper application in service.

3.11.4 Chemical composition

3.11.4.1 All forgings are to be made from killed steel and the chemical composition is to be appropriate for the type of steel, dimensions and required mechanical properties of the forgings being manufactured.

3.11.4.2 The chemical composition of each heat is to be determined by the manufacturer on a sample taken preferably during the pouring of the heat. When multiple heats are tapped into a common ladle, the ladle analysis shall apply.

3.11.4.3 The chemical composition is to comply with the overall limits given in Tables 3.11.4.3.1 and 3.11.4.3.2, or where applicable, the requirements of the approved specification.

3.11.4.4 At the option of the manufacturer, suitable grain refining elements such as aluminium, niobium or vanadium may be added. The content of such elements is to be reported.

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

Table 3.11.4.3.1
Chemical composition limits$^1$ for hull steel forgings$^6$

<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$^3$</th>
<th>Total residuals</th>
</tr>
</thead>
<tbody>
<tr>
<td>C, C-Mn</td>
<td>0.23$^5$</td>
<td>0.45</td>
<td>0.30-1.50</td>
<td>0.035</td>
<td>0.035</td>
<td>0.30$^6$</td>
<td>0.15$^6$</td>
<td>0.40$^6$</td>
<td>0.30</td>
<td>0.85</td>
</tr>
<tr>
<td>Alloy</td>
<td>0.45</td>
<td>0.45</td>
<td>0.30-1.50</td>
<td>0.035</td>
<td>0.035</td>
<td>0.30$^5$</td>
<td>0.15$^5$</td>
<td>0.40$^5$</td>
<td>0.30</td>
<td>-</td>
</tr>
</tbody>
</table>

1) Composition in percentage mass by mass maximum unless shown as a range.
2) The carbon content may increased above this level provided that the carbon equivalent (Ceq) is not more than 0.41% calculated using the following formula:

\[
Ceq = C + \frac{\text{Mn}}{50} + \frac{\text{Cr} + \text{Mo} + \text{V}}{5} + \frac{\text{Ni} + \text{Cu}}{15} \%
\]

3) The carbon content of C and C-Mn steel forgings not intended for welded construction may be 0.65 maximum.
4) Elements are considered as residual elements.
5) Specification is to be submitted for approval.
6) Rudder stocks and pintles should be of weldable quality.

Table 3.11.4.3.2
Chemical composition limits$^1$ machinery steel forgings

<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$^3$</th>
<th>Total residuals</th>
</tr>
</thead>
<tbody>
<tr>
<td>C, C-Mn</td>
<td>0.65$^3$</td>
<td>0.45</td>
<td>0.30-1.50</td>
<td>0.035</td>
<td>0.035</td>
<td>0.30$^3$</td>
<td>0.15$^3$</td>
<td>0.40$^3$</td>
<td>0.30</td>
<td>0.85</td>
</tr>
<tr>
<td>Alloy</td>
<td>0.45</td>
<td>0.45</td>
<td>0.30-1.00</td>
<td>0.035</td>
<td>0.035</td>
<td>Min 0.40$^3$</td>
<td>Min 0.15$^3$</td>
<td>Min 0.40$^3$</td>
<td>0.30</td>
<td>-</td>
</tr>
</tbody>
</table>

1) Composition in percentage mass by mass maximum unless shown as a range or a minimum.
2) The carbon content of C and C-Mn steel forgings intended for welded construction is to be 0.23 maximum. The carbon content may increased above this level provided that the carbon equivalent (Ceq) is not more than 0.41%.
3) Elements are considered as residual elements unless shown as a minimum.
4) Where alloy steel forgings are intended for welded constructions, the proposed chemical composition is subject to approval by the Register.
5) One or more of the elements is to comply with the minimum content.

3.11.5 Heat treatment (including surface hardening and straightening)

3.11.5.1 At an appropriate stage of manufacture, after completion of all hot working operations, forgings are to be suitably heat treated to refine the grain structure and to obtain the required mechanical properties.

3.11.5.2 Except as provided in 3.11.5.7 and 3.11.5.8 forgings are to be supplied in one of the following conditions:

a) Carbon and carbon-manganese steel

b) Alloy steel

Fully annealed
Normalized
Normalized and tempered
Quenched and tempered
Quenched and tempered

For all types of steel the tempering temperature is to be not less than 550°C. Where forgings for gearing are not intended for surface hardening, lower tempering temperature may be allowed.

3.11.5.3 Alternatively, alloy steel forgings may be supplied in the normalized and tempered condition, in which case
the specified mechanical properties are to be agreed with the Register.

3.11.5.4 Heat treatment is to be carried out in properly constructed furnaces which are efficiently maintained and have adequate means for control and recording of temperature. The furnace dimensions are to be such as to allow the whole furnace charge to be uniformly heated to the necessary temperature. In the case of very large forgings alternative methods of heat treatment will be specially considered by the Register.

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

3.11.5.5 If for any reasons a forging is subsequently heated for further hot working, the forging is to be reheat treated.

3.11.5.6 Where it is intended to surface harden forgings, full details of the proposed procedure and specification are to be submitted for the approval of the Register. For the purposes of this approval, the manufacture may be required to demonstrate by test that the proposed procedure gives a uniform surface layer of the required hardness and depth and that it does not impair the soundness and properties of the steel.

3.11.5.7 Where induction hardening or nitriding is to be carried out, forgings are to be heat treated at an appropriate stage to a condition suitable for this subsequent surface hardening.

3.11.5.8 Where carburizing is to be carried out, forgings are to be heat treated at an appropriate stage (generally either by full annealing or by normalizing and tempering) to a condition suitable for subsequent machining and carburizing.

3.11.5.9 If a forging is locally reheated or any straightening operation is performed after the final heat treatment consideration is to be given to a subsequent stress relieving heat treatment.

3.11.5.10 The forge is to maintain records of heat treatment identifying the furnace used, furnace charge, date, temperature and time at temperature. The records are to be presented to the Surveyor on request.

3.11.6 Mechanical tests

3.11.6.1 Test material, sufficient for the required test and for possible re-testing purposes, is to be provided with a cross-sectional area of not less than that part of the forging which it represents. This test material is to be integral with each forging except as provided in 3.11.6.7 and 3.11.6.10. Where batch testing is permitted according to 3.11.6.10, the test material may alternatively be a production part or separately forged. Separately forged test material is to have a reduction ratio similar to that used for the forgings represented.

3.11.6.2 For the purpose of these requirements a set of test is to consist of one tensile test specimen and, when required, these Charpy V-notch impact test specimens.

3.11.6.3 Test specimens are normally to be cut with their axes either mainly paralleled (longitudinal test) or mainly tangential (tangential test) to the principal axial direction of each product.

3.11.6.4 Unless otherwise agreed, the longitudinal axis of test specimens is to be positioned as follows:

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

3.11.6.5 Except as provided in 3.11.6.10 the number and direction of tests is to be as follows.

- Hull components such as rudder stocks, pintles etc. General machinery components such as shafting, connecting rods, etc.

One set of tests is to be taken from the end of each forging in a longitudinal direction except that, at the discretion of the manufacturer, the alternative directions or positions as shown in Fig. 3.11.6.5.1, 3.11.6.5.2 and 3.11.6.5.3 may be used. Where a forging exceeds both 4 tonnes in mass and 3 m in length, one set of tests is to be taken from each end. These limits refer to the "as forged" mass and length but excluding the test material.

- Pinions

Where the finished machined diameter of the toothed portion exceeds 200 mm one set of tests is to be taken from each forging in a tangential direction adjacent to the toothed portion (test position B in Fig. 3.11.6.5.4). The dimensions preclude the preparation of tests from this position; tests in a tangential direction are to be taken from the end of the journal (test position C in Fig. 3.11.6.5.4). If however, the journal diameter is 200 mm or less the tests are to be taken in a longitudinal direction (test position A in Fig. 3.11.6.5.4). Where the finished length of the toothed portion exceed 1.25 m, one set of tests is to be taken from each end.

- Small pinions

Where the finished machined diameter of the toothed portion is 200 mm or less one set of tests is to be taken in a longitudinal direction (test position A in Fig. 3.11.6.5.4).

- Gear wheels

One set of tests is to be taken from each forging in a tangential direction (test position A or B in Fig. 3.11.6.5.5).

- Gear wheel rims (made by expanding)

One set of tests is to be taken from each forging in a tangential direction (test position A or B in Fig. 3.11.6.5.6). Where the finished diameter exceeds 2.5 m or the mass (as heat treated excluding test material) exceeds 3 tonnes, two sets of tests are to be taken from diametrically opposite
positions (test positions A and B in Fig. 3.11.6.5.6). The mechanical properties for longitudinal test are to be applied.

f) **Pinion sleeves**
One set of tests is to be taken from each forging in a tangential direction (test position A or B in Fig. 3.11.6.5.7). Where the finished length exceeds 1.25 m one set of tests is to be taken from each end.

g) **Crankwebs**
One set of tests is to be taken from each forging in a tangential direction.

h) **Solid open die forged crankshafts**
One set of tests is to be taken in a longitudinal direction from the driving shaft end of each forging (test position A in Fig. 3.11.6.5.8).

Where the mass (at heat treated but excluding test material) exceeds 3 tonnes, test in a longitudinal direction are to be taken from each end (test position A and B in Fig. 3.11.6.5.8). Where, however, the crankthrows are formed by machining or flame cutting, the second set of tests is to be taken in a tangential direction from material removed from the crankthrow at the end opposite the driving shaft end (test position C in Fig. 3.11.6.5.8).

---

**Figure 3.11.6.5.1**
Plain shaft

**Figure 3.11.6.5.2**
Flanged shaft

**Figure 3.11.6.5.3**
Flanged shaft with collar
L = length of toothed portion
D = diameter of toothed portion
d = journal diameter

Figure 3.11.6.5.4
Pinion

Figure 3.11.6.5.5
Gear wheel

Figure 3.11.6.5.6
Gear rim (made by expanding)
3.11.6.6 For closed die crankshaft forgings and crankshaft forgings where the method of manufacture has been specially approved in accordance with 3.11.2.7, the number and positions of test specimens is to be agreed with the Register, having regard to the method of manufacture employed.

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

3.11.6.8 Except for components which are to be carburized or for hollow forgings where the ends are to be subsequently closed, test material is not to be cut from a forging until all heat treatment has been completed.

3.11.6.9 When forgings are to be carburized, sufficient test material is to be provided for both preliminary tests at the forge and for final tests after completion of carburizing.

For this purpose duplicate sets of test material are to be taken from positions as detailed in 3.11.6.5, except that irrespective of the dimensions or mass of the forging, tests are required from one position only and, in the case of forgings with integral journals, are to be cut in a longitudinal direction.

This test material is to be machined to a diameter of \(D/4\) or 60 mm, whichever is less, where \(D\) is the finished diameter of the toothed portion.

For preliminary tests at the forge one set of test material is to 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 is to be blank carburized and heat treated along with the forgings which they represent.

At the discretion of the forgemaster or gear manufacture test samples of larger cross section may be either carburized or blank carburized, but these are to be machined to the required diameter prior to the final quenching and tempering heat treatment.

Alternative procedures for testing of forgings which are to be carburized may be specially agreed with the Register.

3.11.6.10 Normalized forgings with mass up to 1000 kg each and quenched and tempered forgings, with mass up to 500 kg each, may be batch tested. A batch is to consist of forgings of similar shape and dimensions, made from the same heat of steel, heat treated in the same furnace charge and with a total mass not exceeding 6 tonnes for normalized forgings and 3 tonnes for quenched and tempered forgings, respectively.

3.11.6.11 A batch testing procedure may also be used for hot rolled bars. A batch is to consist of either:

- 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.

3.11.6.12 The preparation of test specimens and the procedures used for mechanical testing are to comply with the relevant requirements of Chapter 2. Unless otherwise agreed, all tests are to be carried out in the presence of the Surveyor.

3.11.7 Mechanical properties

3.11.7.1 Tables 3.11.7.1.3 and 3.11.7.1.4 give the minimum requirements for yield stress, elongation, reduction of area and impact test energy values corresponding to different strength levels but it is not intended that these should necessarily be regarded as specific grades. Where it is proposed to use a steel with a specified minimum tensile strength intermediate to those given, corresponding minimum values for the other properties may be obtained by interpolation.

3.11.7.2 Forgings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Tables 3.11.7.1.3 or 3.11.7.1.4, but subject to any additional requirements of the relevant construction Rules.

3.11.7.3 The mechanical properties are to comply with the requirements of Tables 3.11.7.1.3 or 3.11.7.1.4 appropriate to the specified minimum tensile strength or, where applicable, the requirements of the approved specification.

3.11.7.4 At the discretion of Register, hardness tests may be required on the following:

- Gear forgings after completion of heat treatment and prior to machining the gear teeth. The hardness is to be determined at four positions equally spaced around the circumference of the surface where teeth will subsequently be cut. Where the finished diameter of the toothed portion exceeds 2.5 m, the above number of test positions is to be increased to eight. Where the width of a gear wheel forging exceeds 1.25 m, the hardness is to be determined at eight positions at each end of the forging.

- Small crankshaft and gear forgings which have been batch tested. In such cases at least one hardness test is to be carried out on each forging.

The results of hardness test are to be reported and, for information purposes, typical Brinell hardness values are given in Table 3.11.7.1.4.

3.11.7.5 Hardness tests may also be required on forgings which have been induction hardened, nitrided or carburized. For gear forgings these tests are to be carried out on the teeth after, where applicable, they have been ground to the finished profile. The results of such tests are to comply with the approved specifications (see 3.11.5.6).

3.11.7.6 Re-test requirements for Charpy impact test are to be in accordance with Chapter 2.

3.11.7.7 Re-test requirements for tensile tests are to be in accordance with Chapter 2.

3.11.7.8 The additional tests detailed in 3.11.7.6 and 3.11.7.7 are to be taken, preferably from material adjacent to the original tests, but alternatively from another test position or sample representative of the forging or batch of forgings.

3.11.7.9 At the option of the manufacturer, when a forging or a batch of forgings has failed to meet the test requirements, it may be reheat treated and re-submitted for acceptance tests.

### Table 3.11.7.1.3

**Mechanical properties for hull steel forgings**

<table>
<thead>
<tr>
<th>Steel type</th>
<th>Tensile strength¹</th>
<th>Yield stress</th>
<th>Elongation</th>
<th>Reduction of area</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rm min. N/mm²</td>
<td>Re min. N/mm²</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>C and C-Mn</td>
<td>400</td>
<td>200</td>
<td>26</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>440</td>
<td>220</td>
<td>24</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>480</td>
<td>240</td>
<td>22</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>520</td>
<td>260</td>
<td>21</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>560</td>
<td>280</td>
<td>20</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>600</td>
<td>300</td>
<td>18</td>
<td>13</td>
</tr>
<tr>
<td>Alloy</td>
<td>550</td>
<td>350</td>
<td>20</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>600</td>
<td>400</td>
<td>18</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>650</td>
<td>450</td>
<td>17</td>
<td>12</td>
</tr>
</tbody>
</table>

1) The following ranges for tensile strength may be additionally specified:

- specified minimum tensile strength: $< 600$ N/mm² $\geq 600$ N/mm²
- tensile strength range: $120$ N/mm² $150$ N/mm²
Table 3.11.7.1.4
Mechanical properties for machinery steel forgings2)

<table>
<thead>
<tr>
<th>Steel type</th>
<th>Tensile strength1) Rm min. N/mm²</th>
<th>Yield stress Re min. N/mm²</th>
<th>Elongation A5 min. %</th>
<th>Reduction of area Z min. %</th>
<th>Hardness3) (Brinell)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C and C-Mn</td>
<td>400</td>
<td>200</td>
<td>26</td>
<td>19</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>440</td>
<td>220</td>
<td>24</td>
<td>18</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>480</td>
<td>240</td>
<td>22</td>
<td>16</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>520</td>
<td>260</td>
<td>21</td>
<td>15</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>560</td>
<td>280</td>
<td>20</td>
<td>14</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>600</td>
<td>300</td>
<td>18</td>
<td>13</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>640</td>
<td>320</td>
<td>17</td>
<td>12</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>680</td>
<td>340</td>
<td>16</td>
<td>12</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>720</td>
<td>360</td>
<td>15</td>
<td>11</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>760</td>
<td>380</td>
<td>14</td>
<td>10</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>800</td>
<td>400</td>
<td>13</td>
<td>9</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>900</td>
<td>420</td>
<td>12</td>
<td>8</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>1000</td>
<td>450</td>
<td>11</td>
<td>7</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>1100</td>
<td>480</td>
<td>10</td>
<td>6</td>
<td>35</td>
</tr>
</tbody>
</table>

1) The following ranges for tensile strength may be additionally specified:
   - specified minimum tensile strength: < 900 N/mm²
   - specified minimum tensile strength: ≥ 900 N/mm²
   - tensile strength range: 150 N/mm² ≤ 200 N/mm²
2) For propeller shafts intended for ships with ice class notation except the lowest one, Charpy V-notch impact testing is to be carried out for all steel types at -10°C and the average energy value is to be minimum 27 J (longitudinal test). One individual value may be less than required average value provided that it is not less than 70% of this average value.
3) The hardness values are typical and are given for information purposes only.

3.11.8 Inspection

3.11.8.1 Before acceptance, all forgings are to be presented to the Surveyor for visual examination. Where applicable, this is to include the examination of internal surfaces and bores. Unless otherwise agreed the verification of dimensions is the responsibility of the manufacturer.

3.11.8.2 When required by the relevant construction Rules, or by approved procedure for welded composite components (see 3.11.2.7) appropriate non-destructive testing is also to be carried out before acceptance and the results are to be reported by the manufacturer.

The extent of testing and acceptance criteria are to be agreed with the Register. IACS Recommendation No. 68 is regarded as an example of an acceptable standard.

3.11.8.3 When required by the conditions of approval for surface hardened forgings (3.11.5.6 refers) additional test samples are to be processed at the same time as the forgings which they represent. These test samples are subsequently to be sectioned in order to determine the hardness, shape and depth of the locally hardened zone and which are to comply with the requirements of the approved specification.

3.11.8.4 In the event of any forging proving defective during subsequent machining or testing, it is to be rejected notwithstanding any previous certification.

3.11.9 Rectification of defective forgings

3.11.9.1 Defects may be removed by grinding or chipping and grinding provided the component dimensions are acceptable. The resulting grooves are to have a bottom radius of approximately three times the groove depth and are to be blended into the surrounding surface so as to avoid any sharp contours. Complete elimination of the defective material is to be verified by magnetic particle testing or liquid penetrant testing.

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

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

3.11.10 Identification of forgings

3.11.10.1 The manufacturer is to adopt a system of identification which will enable all finished forgings to be traced to the original cast and the Surveyor is to be given full facilities for so tracing the forgings when required.
3.11.10.2 Before acceptance, all forgings which have been tested and inspected with satisfactory results are to be clearly marked by the manufacturer. At the discretion of Register any of the following particulars may be required:

- Steel quality.
- Identification number, cast number or other marking which will enable the full history of the forging to be traced.
- Manufacturer's name or trade mark.
- The Register Society's name, initials or symbol.
- Abbreviated name of the Register local office.
- Personal stamp of Surveyor responsible for inspection.

3.11.10.3 Where small forgings are manufactured in large numbers, modified arrangements for identification may be specially agreed with the Register.

3.11 Certification

3.11.11 The manufacturer is to provide the required type of inspection certificate giving the following particulars for each forging or batch of forgings which has been accepted:

- Purchaser's name and other number.
- Description of forgings and steel quality.
- Identification number.
- Steelmaking process, cast number and chemical analysis of ladle sample.
- Results of mechanical tests.
- Results of non-destructive tests, where applicable.
- Details of heat treatment, including temperature and holding times.

3.12 HULL AND MACHINERY STEEL CASTINGS

3.12.1 Scope

3.12.1.1 These requirements are applicable to steel castings intended for hull and machinery applications such as stern frames, rudder frames, crankshafts, turbine castings, bedplates, etc.

3.12.1.2 These requirements are applicable only to steel castings where the design and acceptance tests are related to mechanical properties at ambient temperature. For other applications, additional requirements may be necessary, especially when the casting are intended for service at low or elevated temperatures.

3.12.1.3 Alternatively, castings which comply with national or proprietary specifications may be accepted provided such specifications give reasonable equivalence to these requirements or are otherwise specially approved or required by the Register.

3.12.1.4 Specific requirements are not given for alloy steel castings and where the use of such materials is proposed full details of the chemical composition, heat treatment, mechanical properties, testing, inspections and rectification are to be submitted for approval of Register.

3.12.2 Manufacture

3.12.2.1 Castings are to be made at a manufacturer approved by the Register.

3.12.2.2 The steel is to be manufactured by a process, approved by the Register.

3.12.2.3 All flame cutting, scarfing or arc-air gouging to remove surplus metal is to be undertaken in accordance with recognized good practice and is to be carried out before the final heat treatment. Preheating is to be employed when necessitated by the chemical composition and/or thickness of the castings. If necessary, the affected areas are to be either machined or ground smooth.

3.12.2.4 For certain components including steel castings subjected to surface hardening process, the proposed method of manufacture may require special approval by the Register.

3.12.2.5 When two or more castings are joined by welding to from a composite component, the proposed welding procedure is to be submitted for approval. Welding procedure qualification tests may be required by the Register.

3.12.3 Quality of castings

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

3.12.4 Chemical composition

3.12.4.1 All castings are to be made from killed steel and the chemical composition is to be appropriate for the type of steel and the mechanical properties specified for the castings.

3.12.4.1.1 The chemical composition of each heat is to be determined by manufacturer on a sample taken preferably during the pouring of the heat. When multiple heats are tapped into a common ladle, the ladle analysis shall apply.

3.12.4.2 For carbon and carbon-manganese steel castings the chemical composition is to comply with the overall limits given in Table 3.12.4.2.1 or, where applicable, the requirements of the approved specification.

3.12.4.3 Unless otherwise required suitable grain refining elements such as aluminium may be used at the discretion of the manufacturer. The content of such elements is to be reported.
### Table 3.12.4.2.1
Chemical composition limits for hull and machinery steel castings (%)

<table>
<thead>
<tr>
<th>Steel type</th>
<th>Applications</th>
<th>C (max.)</th>
<th>Si (max.)</th>
<th>Mn</th>
<th>S (max.)</th>
<th>P (max.)</th>
<th>Residual elements (max.)</th>
<th>Total residuals (max.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C, C-Mn</td>
<td>Castings for non-welded construction</td>
<td>0.40</td>
<td>0.60</td>
<td>0.50-1.60</td>
<td>0.040</td>
<td>0.040</td>
<td>0.30</td>
<td>0.30</td>
</tr>
<tr>
<td></td>
<td>Castings for welded construction</td>
<td>0.23</td>
<td>0.60</td>
<td>1.60 max.</td>
<td>0.040</td>
<td>0.040</td>
<td>0.30</td>
<td>0.30</td>
</tr>
</tbody>
</table>

### 3.12.5 Heat treatment (including straightening)

#### 3.12.5.1 Castings are to be supplied in one of the following conditions:
- Fully annealed
- Normalized
- Normalized and tempered
  - The tempering temperature is to be not less than 550°C.

#### 3.12.5.2 Castings for components such as crankshafts and engine bedplates, where dimensional stability and freedom from internal stresses are important, are to be given a stress relief heat treatment. This is to be carried out at a temperature of not less than 550°C followed by furnace cooling to 300°C or lower.

#### 3.12.5.3 Heat treatment is to be carried out in properly constructed furnaces which are efficiently maintained and have adequate means for control and recording of temperature. The furnace dimensions are to be such as to allow the whole casting to be uniformly heated to the necessary temperature. In the case of very large castings alternative methods for heat treatment will be specially considered by the Register. Sufficient thermocouples are to be connected to the furnace charge to measure and record that its temperature is adequately uniform unless the temperature uniformity of the furnace is verified at regular intervals.

#### 3.12.5.4 If a casting is locally reheated or any straightening operation is performed after the final heat treatment, a subsequent stress relieving heat treatment may be required in order to avoid the possibility of harmful residual stresses.

#### 3.12.5.5 The foundry is to maintain records of heat treatment identifying the furnace used, furnace charge date, temperature and time at temperature. The records are to be presented to the Surveyor on request.

### 3.12.6 Mechanical tests

#### 3.12.6.1 Test material, sufficient for the required tests and for possible re-testing purposes is to be provided for each casting or batch of castings.

#### 3.12.6.2 At least one test sample is to be provided for each casting. Unless otherwise agreed these test samples are to be either integrally cast or gated to the castings and are to have a thickness of not less than 30 mm.

#### 3.12.6.3 Where the casting is of complex design or where the finished mass exceeds 10 tonnes, two test samples are to be provided. Where large castings are made from two or more casts, which are not mixed in a ladle prior to pouring, two or more test samples are to be provided corresponding to the number of casts involved. These are to be integrally cast at locations as widely separated as possible.

#### 3.12.6.4 For castings where the method of manufacture has been specially approved by the Register in accordance with 3.12.2.4, the number and position of test samples is to be agreed with the Register having regard to the method of manufacture employed.

#### 3.12.6.5 As an alternative to 3.12.6.2, where a number of small castings of about the same size, each of which is under 1000 kg in mass, are made from one cast and heat treated in the same furnace charge, a batch testing procedure may be adopted using separately cast test samples of suitable dimensions. At least one test sample is to be provided for each batch of castings.

#### 3.12.6.6 The test samples are not to be detached from the casting until the specified heat treatment has been completed and they have been properly identified.

#### 3.12.6.7 One tensile test specimen is to be taken from each test sample.

#### 3.12.6.8 The preparation of test specimens and the procedures used for mechanical testing are to comply with the relevant requirements of Chapter 2. Unless otherwise agreed, all tests are to be carried out in the presence of the Surveyors.

### 3.12.7 Mechanical properties

#### 3.12.7.1 Table 3.12.7.1.2 gives the minimum requirements for yield stress, elongation and reduction of area corresponding to different strength levels. Where it is proposed to use a steel with a specified minimum tensile strength intermediate to those given, corresponding minimum values for the other properties may be obtained by interpolation.

#### 3.12.7.2 Castings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Table 3.12.7.1.2 but subject to any additional requirements of the relevant construction Rules.
3.12.7.3 The mechanical properties are to comply with the requirements of Table 3.12.7.1.2 appropriate to the specified minimum tensile strength or, where applicable, the requirements of the approved specification.

3.12.7.4 Re-test requirements for tensile tests to be in accordance with Chapter 2.

3.12.7.5 The additional tests detailed in 3.12.7.4 are to be taken, preferably from the same, but alternatively from another, test sample representative of the casting or batch of castings.

3.12.7.6 At the option of the manufacturer, when a casting or batch of castings has failed to meet the test requirements, it may be reheat treated and re-submitted for acceptance tests.

### Table 3.12.7.1.2

Mechanical properties for hull and machinery steel castings

<table>
<thead>
<tr>
<th>Specified minimum tensile strength(^{(1)}) (N/mm(^2))</th>
<th>Yield stress (N/mm(^2)) min.</th>
<th>Elongation on (5.65\sqrt{S_o}) (%) min.</th>
<th>Reduction of area (%) min.</th>
</tr>
</thead>
<tbody>
<tr>
<td>400</td>
<td>200</td>
<td>25</td>
<td>40</td>
</tr>
<tr>
<td>440</td>
<td>220</td>
<td>22</td>
<td>30</td>
</tr>
<tr>
<td>480</td>
<td>240</td>
<td>20</td>
<td>27</td>
</tr>
<tr>
<td>520</td>
<td>260</td>
<td>18</td>
<td>25</td>
</tr>
<tr>
<td>560</td>
<td>300</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>600</td>
<td>320</td>
<td>13</td>
<td>20</td>
</tr>
</tbody>
</table>

Note:
(1) A tensile strength range of 150 N/mm\(^2\) may additionally be specified.

### 3.12.8 Inspection

3.12.8.1 All castings are to be cleaned and adequately prepared for examination; suitable methods include pickling, caustic cleaning, wire brushing, local grinding, shot or sand blasting. The surfaces are not to be hammered, penned or treated in any way which may obscure defects.

3.12.8.2 Before acceptance all castings are to be presented to the Surveyors for visual examination. Where applicable, this is to include the examination of internal surfaces. Unless otherwise agreed, the verification of dimensions is the responsibility of the manufacturer.

3.12.8.3 When required by the relevant construction Rules, or by the approved procedure for welded composite components (see 3.12.2.5), appropriate non-destructive testing is also to be carried out before acceptance and the results are to be reported by the manufacturer. The extent of testing and acceptance criteria are to be agreed with the Register. IACS Recommendation No. 69 is regarded as an example of an acceptable standard.

3.12.8.4 When required by the relevant construction Rules castings are to be pressure tested before final acceptance. These tests are to be carried out in the presence of the Surveyor and are to be to their satisfaction.

3.12.8.5 In the event of any casting proving to be defective during subsequent machining or testing, it is to be rejected notwithstanding any previous certification.

### 3.12.9 Rectification of defective castings

3.12.9.1 General

a) The approval of the Register is to be obtained where steel castings, from which defects were removed, are to be used with or without weld repair.

b) Procedure of removal of defect and weld repair is to be in accordance with IACS Recommendation No. 69.

c) Where the defective area is to be repaired by welding, excavations are to be suitably shaped, to allow good access for welding. The resulting grooves are to be subsequently ground smooth and complete elimination of the defective material is to be verified by MT or PT.

d) Shallow grooves or depressions resulting from the removal of defects may be accepted provided that they will cause no appreciable reduction in the strength of the casting. The resulting grooves or depressions are to be subsequently ground smooth and complete elimination of the defective material is to be verified by MT or PT. Small surface irregularities sealed by welding are to be treated as weld repairs.

e) The manufacturer is to maintain full records detailing the extent and location of repairs made to each casting and details of weld procedures and heat treatments applied for repairs. These records are to
be available to the Surveyor and copies provided on request.

3.12.9.2 Weld repairs

When it has been agreed that a casting can be repaired by welding, the following requirements apply:

a) Before welding is started, full details of the extent and location of the repair, the proposed welding procedure, heat treatment and subsequent inspection procedures are to be submitted for approval.

b) All castings in alloy steels and all castings for crankshafts are to be suitably pre-heated prior to welding. Castings in carbon or carbon-manganese steel may also require to be pre-heated depending on their chemical composition and the dimensions and position of the weld repairs.

c) Welding is to be done under cover in positions free from draughts and adverse weather conditions by qualified welders with adequate supervision. As far as possible, all welding is to be carried out in the downhand (flat) position.

d) The welding consumables used are to be of an appropriate composition, giving a weld deposit with mechanical properties similar and in no way inferior to those of the parent castings. Welding procedure tests are to be carried out by the manufacturer to demonstrate that satisfactory mechanical properties can be obtained after heat treatment as detailed in 3.12.5.1.

e) After welding has been completed the castings are to be given either a suitable heat treatment in accordance with the requirements of 3.12.5.1 or a stress relieving heat treatment at a temperature of not less than 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.

f) Subject to the prior agreement of Register, special consideration may be given to the omission of postweld heat treatment or to the acceptance of local stress relieving heat treatment where the repaired area is small and machining of the casting has reached an advanced stage.

g) On completion of heat treatment the weld repairs and adjacent material are to be ground smooth and examined by magnetic particle or liquid penetrant testing. Supplementary examination by ultrasonics or radiography may also be required depending on the dimensions and nature of the original defect. Satisfactory results are to be obtained from all forms of non-destructive testing used.

3.12.10 Identification of castings

3.12.10.1 The manufacturer is to adopt a system of identification which will enable all finished castings to be traced to the original cast and the Surveyors are to be given full facilities for so tracing the castings, when required.

3.12.10.2 Before acceptance, all castings which have been tested and inspected with satisfactory results are to be clearly marked by the manufacturer. At the discretion of Register any of the following particulars may be required:

- Steel quality.
- Identification number, cast number or other marking which will enable the full history of the casting to be traced.
- Manufacturer's name or trade mark.
- The Register's name, initials or symbol.
- Abbreviated name of the Register's local office.
- Personal stamp of Surveyors responsible for inspection.
- Where applicable, test pressure.

3.12.10.3 Where small castings are manufactured in large numbers, modified arrangements for identification may be specially agreed with the Register.

3.12.11 Certification

3.12.11.1 The manufacturer is to provide the required type of inspection certificate, giving the following particulars for each casting or batch of castings which has been accepted:

- Purchaser's name and order number.
- Description of castings and steel quality.
- Identification number.
- Steel making process, cast number and chemical analysis of ladle samples.
- Results of mechanical tests.
- Results of non-destructive tests, where applicable.
- Details of heat treatment, including temperatures and holding times.
- Where applicable, test pressure.

3.13 IRON CASTINGS

3.13.1 Scope

These requirements applies to the manufacture and testing of grey and spheroidal or nodular graphite iron castings.

3.13.1.1 All important grey, spheroidal or nodular graphite iron castings, as defined in the relevant construction Rules, are to be manufactured and tested in accordance with the requirements of the following paragraphs.

3.13.1.2 Alternatively, castings which comply with national or proprietary specifications may be accepted provided such specifications give reasonable equivalence to these requirements or otherwise are specially approved or required by the Register.
3.13.1.3 Where small castings are produced in large quantities the manufacturer may adopt alternative procedures for testing and inspection subject to the approval of the Register.

3.13.2 Manufacture

3.13.2.1 All important castings are to be made at foundries where the manufacturer has demonstrated to the satisfaction of the Register that the necessary manufacturing and testing facilities are available and are supervised by qualified personnel. A programme of approval tests may be required in accordance with the procedures of the Register.

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

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

3.13.2.4 Quality of castings

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

3.13.3 Grey iron castings

3.13.3.1 Chemical composition

3.13.3.1.1 The chemical composition of the iron used is to be the discretion of the manufacturer, who is to ensure that it is suitable to obtain the mechanical properties specified for the castings.

3.13.3.2 Heat treatment

3.13.3.2.1 Except as required by 3.13.3.2.2 castings may be supplied in either as cast or heat treated condition.

3.13.3.2.2 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.

3.13.3.3 Mechanical tests

3.13.3.3.1 Test material sufficient for the required tests and for possible re-tests is to be provided for each casting or batch of castings.

3.13.3.3.2 Separately cast test samples are to be used unless otherwise agreed between the manufacturer and purchaser and generally are to be in the form of bars 30 mm in diameter and of suitable length. They are to be cast from the same ladle as the castings in moulds of the same type of material as the moulds for the castings and are not to 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 are to be at least 50 mm apart as given in Figure 3.13.3.3.2.

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

3.13.3.3.4 With the exception of 3.13.3.3.7, at least one test sample is to be cast with each batch.

3.13.3.3.5 With the exception of 3.13.3.3.6, a batch consists of the castings poured from a single ladle of metal, provided that they are similar type and dimensions. A batch should not normally exceed two tonnes of fettled castings and a single casting will constitute a batch if its mass is 2 tonnes or more.

3.13.3.3.6 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.

3.13.3.3.7 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.

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

3.13.3.3.9 Where castings are supplied in the heat treated condition, the test samples are to be heat treated together with the castings which they represent. For cast-on-test samples the sample shall not be cut off from the casting until after heat treatment.

3.13.3.3.10 One tensile test specimen is to be prepared from each test sample and for 30 mm diameter samples is to be machined to the dimensions given in Chapter 2, Section 2.4. Where test samples of other dimensions are specially required the tensile test specimens are to be machined to agreed dimensions.

3.13.3.3.11 All tensile tests are to be carried out using test procedures in accordance with Chapter 2. Unless otherwise agreed all tests are to be carried out in the presence of the Surveyors.

3.13.3.4 Mechanical properties

3.13.3.4.1 Only the tensile strength is to be determined and the results obtained from tests are to comply with the minimum value specified for the castings being supplied. The value selected for the specified minimum tensile strength is to be not less than 200 N/mm² but subjected to any additional requirements of the relevant construction Rules. The fractured surfaces of all tensile test specimens are to be granular and grey in appearance.

3.13.3.4.2 Re-test requirements for tensile tests are to be in accordance with Chapter 2.
3.13.3.5 Inspection

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

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

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

3.13.3.5.4 When required by the relevant construction Rules, castings are to be pressure tested before final acceptance.

3.13.3.5.5 In the event of any casting providing defective subsequent machining or testing it is to be rejected notwithstanding any previous certification.

3.13.3.6 Rectification of defective castings

3.13.3.6.1 At the discretion of the Surveyor, small surface blemishes may be removed by local grinding.

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

3.13.3.6.3 Repairs by welding are generally not permitted.

3.13.3.7 Identification of castings

3.13.3.7.1 The manufacturer is to adopt a system of identification, which will enable all finished castings to be traced to the original ladle of metal. The Surveyor is to be given full facilities for so tracing the castings when required.

3.13.3.7.2 Before acceptance, all castings which have been tested and inspected with satisfactory results are to be clearly marked by the manufacturer. At the discretion of Register any of following particulars may be required:
   i) Quality of cast iron.
   ii) Identification number or other marking which will enable the full history of the casting to be traced.
   iii) Manufacturer’s name or trade mark.
   iv) The Register’s name, initials or symbol.
   v) Abbreviated name of the Register’s local office.
   vi) Personal stamp of Surveyor responsible for inspection.
   vii) Where applicable, test pressure.
   viii) Date of final inspection.

3.13.3.7.3 Where small castings are manufactured in large numbers, modified arrangements for identification may be specially agreed with the Register.

3.13.3.8 Certification

3.13.3.8.1 The manufacturer is to provide the Surveyor with a test certificate or shipping statement giving the following particulars for each casting or batch of castings which has been accepted:
   i) Purchaser’s name and order number.
   ii) Description of castings and quality of cast iron.
   iii) Identification number.
   iv) Results of mechanical tests.
   vi) Where specially required, the chemical analysis of ladle samples.
   vii) Where applicable, test pressure.

3.13.4 Spheroidal or nodular graphite iron castings

3.13.4.1 Scope

3.13.4.1.1 These requirements are applicable only to castings where the design and acceptance tests are related to mechanical properties at ambient temperature. For other applications additional requirements may be necessary, especially when the castings are intended for service at low or elevated temperatures.

3.13.4.2 Chemical composition

3.13.4.2.1 Unless otherwise specially required, the chemical composition of the iron used is left to the discretion of the manufacturer, who is to ensure that it is suitable to obtain the mechanical properties specified for the castings. When re-
quired by the Register the chemical composition of ladle samples is to be reported.

3.13.4.3  Heat treatment

3.13.4.3.1  Except as required by 3.13.4.3.2 castings may be supplied in either as cast or heat treated condition.

3.13.4.3.2  For some applications, such as high temperature service or where dimensional stability is important, it may be required that castings be given a suitable tempering or stress relieving heat treatment. This is to be carried out after any refining heat treatment and before machining. The special qualities with 350 N/mm² and 400 N/mm² nominal tensile strength and impact test shall undergo a ferritizing heat treatment.

3.13.4.3.3  Where it is proposed to locally harden the surfaces of a casting full details of the proposed procedure and specification are to be submitted for approval by the Register.

3.13.4.4  Mechanical tests

3.13.4.4.1  Test material, sufficient for the required tests and for possible re-test purposes, is to be provided for each casting or batch of castings.

3.13.4.4.2  The test samples are generally to be one of the standard types detailed in Figures 3.13.4.4-1, 3.13.4.4-2 and 3.13.4.4-3 with a thickness of 25 mm. Test samples of other dimensions, as detailed in Figures 3.13.4.4-1, 3.13.4.4-2 and 3.13.4.4-3 may, however, be specially required for some components.

![Figure 3.13.4.4-1](image1)

![Figure 3.13.4.4-2](image2)

![Figure 3.13.4.4-3](image3)

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Standard sample</th>
<th>Alternative samples when specially required</th>
</tr>
</thead>
<tbody>
<tr>
<td>u (mm)</td>
<td>25</td>
<td>12 50 75</td>
</tr>
<tr>
<td>v (mm)</td>
<td>55</td>
<td>40 90 125</td>
</tr>
<tr>
<td>x (mm)</td>
<td>40</td>
<td>30 60 65</td>
</tr>
<tr>
<td>y (mm)</td>
<td>100</td>
<td>80 150 165</td>
</tr>
<tr>
<td>z</td>
<td>To suit testing machine</td>
<td></td>
</tr>
<tr>
<td>Rₚ</td>
<td>Approximately 5 mm</td>
<td></td>
</tr>
</tbody>
</table>

Figure 3.13.4.4-1
Type A test samples (U-type)

Figure 3.13.4.4-2
Type B test samples (double U-type)

Figure 3.13.4.4-3
Type C test samples (Y-type)

3.13.4.4.3  At least one test sample is to 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.
3.13.4.4.4 For large castings where more than one ladle of treated metal is used, additional test samples are to be provided so as to be representative of each ladle used.

3.13.4.4.5 As an alternative to 3.13.4.4.3, a batch testing procedure may be adopted for castings with a fettled mass of 1 tonne or less. All castings in a batch are to be of similar type and dimensions, cast from the same ladle of treated metal. One separately cast test sample is to be provided for each multiple of 2,0 tonnes of fettled castings in the batch.

3.13.4.4.6 Where separately cast test samples are used, they are to be cast in moulds made from the same type of material as used for the castings and are to be taken towards the end of pouring of the castings. The samples are not to be stripped from the moulds until the temperature is below 500°C.

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

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

3.13.4.4.9 One tensile test specimen is to be prepared from each test sample and is to be machined to the dimensions given in Chapter 2.

3.13.4.4.10 All tensile tests are to be carried out using test procedures in accordance with Chapter 2. Unless otherwise agreed all tests are to be carried out in the presence of the Surveyors.

3.13.4.4.11 Impact tests may additionally be required and in such cases a set of three test specimens of agreed type is to be prepared from each sample. Where Charpy V-notch test specimens are used, the dimensions and testing procedures are to be in accordance with Chapter 2.

3.13.4.5 Mechanical properties

3.13.4.5.1 Table 3.13.4.5 gives minimum requirements for 0.2% proof stress and elongation corresponding to different strength levels. Typical Brinell hardness values are also given in Table 3.13.4.5 and are intended for information purposes only.

3.13.4.5.2 Castings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Table 3.13.4.5 but subjected to any additional requirements of the relevant construction Rules.

3.13.4.5.3 Unless otherwise agreed only the tensile strength and elongation need to be determined. The results of all tensile tests are to comply with the appropriate requirements of Table 3.13.4.5.

3.13.4.5.4 Re-test requirements for tensile tests are to be in accordance with Chapter 2.

<table>
<thead>
<tr>
<th>Specified minimum tensile strength$^{(1)}$</th>
<th>0.2% proof stress</th>
<th>Elongation on $5.65 \sqrt{S_o}$</th>
<th>Typical hardness values (Brinell) $^{(2)}$</th>
<th>Impact energy</th>
<th>Typical structure of matrix $^{(3)}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>[N/mm²]</td>
<td>[N/mm²]</td>
<td>[%]</td>
<td>(see 3.13.4.5.1)</td>
<td>Test temp.</td>
<td>KV</td>
</tr>
<tr>
<td>Ordinary qualities</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>370</td>
<td>230</td>
<td>17</td>
<td>120-180</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>400</td>
<td>250</td>
<td>12</td>
<td>140-200</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>500</td>
<td>320</td>
<td>7</td>
<td>170-240</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>600</td>
<td>370</td>
<td>3</td>
<td>190-270</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>700</td>
<td>420</td>
<td>2</td>
<td>230-300</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>800</td>
<td>480</td>
<td>2</td>
<td>250-350</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Special qualities</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>350</td>
<td>220</td>
<td>2$^{(3)}$</td>
<td>110-170</td>
<td>+ 20</td>
<td>17 (14)</td>
</tr>
<tr>
<td>400</td>
<td>250</td>
<td>18$^{(3)}$</td>
<td>140-200</td>
<td>+ 20</td>
<td>14 (11)</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.
2) 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.
3) In the case of integrally cast samples, the elongation may be 2% less.

3.13.4.6 Inspection

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

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

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

3.13.4.6.4 When required by the relevant construction Rules, castings are to be pressure tested before final acceptance.

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

3.13.4.6.6 Cast crankshafts are to be subjected to a magnetic particle inspection. Crack like indications are not allowed.

3.13.4.7 Metallographic examination

3.13.4.7.1 For crankshafts the metallographic examination will be mandatory.

3.13.4.7.2 When required, a representative sample from each ladle of treated metal is to be prepared for metallographic examination. These samples may conveniently be taken from the tensile test specimens but alternative arrangements for the provision of the samples may be adopted provided that they are taken from the ladle towards the end of the casting period.

3.13.4.7.3 Examination of the samples is to show that at least 90% of the graphite is in dispersed spheroidal or nodular form. Details of typical matrix structures are given in Table 3.13.4.5 and are intended for information purposes only.

3.13.4.8 Rectification of defective castings

3.13.4.8.1 At the discretion of the Surveyor, small surface blemishes may be removed by local grinding.

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

3.13.4.8.3 Repairs by welding are generally not permitted.

3.13.4.9 Identification of castings

3.13.4.9.1 The manufacturer is to adopt a system of identification, which will enable all finished castings to be traced to the original ladle of metal. The Surveyor is to be given full facilities for so tracing the castings when required.

3.13.4.9.2 Before acceptance, all castings which have been tested and inspected with satisfactory results are to be clearly marked by the manufacturer. At the discretion of Register any of following particulars may be required:

i) Quality of cast iron.
ii) Identification number or other marking which will enable the full history of the casting to be traced.
iii) Manufacturer’s name or trade mark.
iv) The Register’s name, initials or symbol.
v) Abbreviated name of the Register’s local office.
v) Personal stamp of Surveyor responsible for inspection.

3.13.4.9.3 Where small castings are manufactured in large numbers, modified arrangements for identification may be specially agreed with the Register.

3.13.4.10 Certification

3.13.4.10.1 The manufacturer is to provide the Surveyor with a test certificate or shipping statement giving the following particulars for each casting or batch of castings which has been accepted:

i) Purchaser’s name and order number.
ii) Description of castings and quality of cast iron.
iii) Identification number.
iv) Results of mechanical tests.
vi) Where specifically required, the chemical analysis of ladle samples.

3.13.4.10.2 The scope of the procedure tests involved in the approval is to be agreed.

3.14 CAST STEEL PROPELLERS

3.14.1 General

3.14.1.1 These requirements applies to the manufacture of cast steel propellers, blades and bosses.

3.14.1.2 Where the use of alternative alloys is proposed, particulars of chemical composition, mechanical properties and heat treatment are to be submitted for approval.

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

3.14.2 Foundry approval

3.14.2.1 All propellers, blades and bosses are to be manufactured by foundries approved by the Register. The scope of the procedure tests involved in the approval is to be agreed.

3.14.3 General characteristics of castings

3.14.3.1 All castings are to have a workmanlike finish and are to be free from imperfections that could be considered to impair in-service performance.

3.14.4 Chemical composition

3.14.4.1 Typical cast steel propeller alloys are grouped into four types depending on their chemical composition as given in Table 3.14.4.1.
Table 3.14.4.1
Typical chemical composition for steel propeller castings

<table>
<thead>
<tr>
<th>Alloy type</th>
<th>C max. [%]</th>
<th>Mn max. [%]</th>
<th>Cr [%]</th>
<th>Mo max. [%]</th>
<th>Ni [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Martensitic (12 Cr 1 Ni)</td>
<td>0,15</td>
<td>2,0</td>
<td>11,5 – 17,0</td>
<td>0,5</td>
<td>max. 2,0</td>
</tr>
<tr>
<td>Martensitic (13 Cr 4 Ni)</td>
<td>0,06</td>
<td>2,0</td>
<td>11,5 – 17,0</td>
<td>1,0</td>
<td>3,5 – 5,0</td>
</tr>
<tr>
<td>Martensitic (16 Cr 5 Ni)</td>
<td>0,06</td>
<td>2,0</td>
<td>15,0 – 17,5</td>
<td>1,5</td>
<td>3,5 -6,0</td>
</tr>
<tr>
<td>Austenitic (19 Cr 1 1 Ni)</td>
<td>0,12</td>
<td>1,6</td>
<td>16,0 – 21,0</td>
<td>4,0</td>
<td>8,0 -13,0</td>
</tr>
</tbody>
</table>

1) Minimum values are to be in accordance with recognised national or international standards.

3.14.5 Heat treatment

3.14.5.1 Martensitic castings are to be austenitized and tempered. Austenitic castings should be solution treated.

3.14.6 Mechanical properties

3.14.6.1 The mechanical properties are to meet the requirements in Table 3.14.6.2. These values refer to the test specimens machined from integrally cast test bars attached to the hub or on the blade.

3.14.6.2 Where possible, the test bars attached on blades are to be located in an area between 0,5 to 0,6R, where R is the radius of the propeller.

3.14.6.3 The test bars are not to be detached from the casting until the final heat treatment has been carried out. Removal is to be by non-thermal procedures.

Table 3.14.6.2
Mechanical properties for steel propeller castings

<table>
<thead>
<tr>
<th>Alloy type</th>
<th>Proof stress $R_{p0.2}$ min. [N/mm²]</th>
<th>Tensile strength $R_m$ min. [N/mm²]</th>
<th>Elongation $A_5$ min. [%]</th>
<th>Reduction of area $Z$ min. [%]</th>
<th>Charpy V-notch $^{1)}$ Energy min. [J]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Martensitic (12 Cr 1 Ni)</td>
<td>440</td>
<td>590</td>
<td>15</td>
<td>30</td>
<td>20</td>
</tr>
<tr>
<td>Martensitic (13 Cr 4 Ni)</td>
<td>550</td>
<td>750</td>
<td>15</td>
<td>35</td>
<td>30</td>
</tr>
<tr>
<td>Martensitic (16 Cr 5 Ni)</td>
<td>540</td>
<td>760</td>
<td>15</td>
<td>35</td>
<td>30</td>
</tr>
<tr>
<td>Austenitic (19 Cr 1 1 Ni)</td>
<td>180$^{1)}$</td>
<td>440</td>
<td>30</td>
<td>40</td>
<td>-</td>
</tr>
</tbody>
</table>

1) Not required for general service and the lowest Ice class notations. For other Ice class notations, tests are to be made on -10°C.

3.14.6.4 Separately cast test bars may be used subject to prior approval of the Register. The test bars are to be cast from the same heat as the castings represented and heat treated with the castings represented.

3.14.6.5 At least one set of mechanical tests is to be made on material representing each casting in accordance with Chapter 2.

3.14.6.6 As an alternative to 3.14.6.5, where a number of small propellers of about the same size, and less than 1m in diameter, are made from one cast and heat treated in the same furnace charge, a batch testing procedure may be adopted using separately cast test samples of suitable dimensions. At least one set of mechanical tests is to be provided for each multiple of five castings in the batch.

3.14.7 Visual inspections

3.14.7.1 All finished castings are to be 100% visually inspected by the Surveyor. The Surveyor may require areas to be etched for the purpose of investigating weld repairs.

3.14.7.2 Castings are to be free from cracks, hot tears or other imperfections which, due to their nature, degree or extent, will interfere with the use of the castings.

3.14.8 Dimensions, dimensional and geometrical tolerances

3.14.8.1 The dimensions are the responsibility of the manufacturer and the report of the dimensional inspection is to be handed over to the Surveyor, who may require checks to be made in his presence.
3.14.8.2 Static balancing is to be carried out on all propellers in accordance with the approved drawing. Dynamic balancing may be necessary for propellers running above 500 rpm.

3.14.9 Non-destructive testing

3.14.9.1 All finished castings are subject to non-destructive testing in accordance with the requirements given in 3.14.9.2 to 3.14.9.9.

3.14.9.2 In order to relate the degree of non-destructive testing to the criticality of imperfections, propeller blades are divided into three severity Zones designated A, B and C. Further, a distinction is made between low skew and high skew propellers.

3.14.9.3 For all propellers, separately cast blades and hubs, the surfaces covered by severity Zones A, B and C are to be liquid penetrant tested. Testing of Zone A is to be undertaken in the presence of the Surveyor, whilst testing of Zone B and C may be witnessed by the Surveyor upon his request.

3.14.9.4 If repairs have been made either by grinding or by welding, the repaired areas are additionally to be subjected to the liquid penetrant testing independent of their location and/or severity Zone. Weld repairs are, independent of their location, always to be assessed according to Zone A.

3.14.9.5 The following definitions relevant to liquid penetrant indications apply:

a) **Indication**

The presence of detectable bleed-out of the penetrant liquid from the material discontinuities appearing at least 10 minutes after the developer has been applied.

b) **Linear indication**

An indication in which the length is at least three times the width.

c) **Nonlinear indication**

An indication of circular or elliptical shape with a length less than three times the width.

d) **Aligned indication**

Three or more indications in a line, separated by 2 mm or less edge-to-edge.

e) **Open indication**

An indication that can be detected by the use of contrast dye penetrant.

f) **Non-open indication**

An indication that cannot be detected by the use of contrast dye penetrant.

g) **Relevant indication**

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

3.14.9.6 For the purpose of evaluating indications, the surface is to be divided into reference areas of 100 cm², which may be square or rectangular with the major dimension not exceeding 250 mm. The area shall be taken in the most unfavourable location relative to the indication being evaluated.

3.14.9.7 The indications detected may, with respect to their size and number, not exceed the values given in Table 3.14.9.7.

3.14.9.8 Where serious doubt exists that the castings are not free from internal defects, further non-destructive inspections are to be carried out upon request of the Surveyor, e.g. radiographic and/or ultrasonic tests. The acceptance criteria are then to be agreed between the manufacturer and the Register.

3.14.9.9 The foundry is to maintain records of inspections traceable to each casting. These records are to be reviewed by the Surveyor. The foundry is also to provide the Surveyor with a statement confirming that non-destructive tests have been carried out with satisfactory results.

### Table 3.14.9.7

<table>
<thead>
<tr>
<th>Severity zone</th>
<th>Max. total number of indications</th>
<th>Indication type</th>
<th>Max. number for each type</th>
<th>Max. dimension 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</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>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</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>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</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>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.
3.14.10 Repair

3.14.10.1 Defective castings are to be repaired in accordance with the requirements given in 3.14.10.2 to 3.14.10.7 and, where applicable, the requirements of Section 3.14.11.

3.14.10.2 In general the repairs are to be carried out by mechanical means, e.g. by grinding or milling. The resulting grooves are to be blended into the surrounding surface so as to avoid any sharp contours. Complete elimination of the defective material is to be verified by liquid penetrant testing.

3.14.10.3 Weld repairs are to be undertaken only when they are considered to be necessary and have prior approval of the Surveyor. All weld repairs are to be documented by means of sketches or photographs showing the location and major dimensions of the grooves prepared for welding. The documentation is to be presented to the Surveyor prior to repair welding.

3.14.10.4 The excavations are to be suitably shaped to allow good access for welding. The resulting grooves are to be subsequently ground smooth and complete elimination of the defective material is to be verified by liquid penetrant testing. Welds having an area less than 5cm² are to be avoided.

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

3.14.10.6 Defects in severity Zone B that are not deeper than t/40 mm ("t" is the minimum local thickness according to the Rules) or 2 mm, whichever is greatest, are to be removed by grinding. Those defects that are deeper may be repaired by welding subject to prior approval from the Register.

3.14.10.7 Repair welding is generally permitted in severity Zone C.

3.14.11 Weld repair procedure


Before welding is started, a detailed welding procedure specification is to be submitted covering the weld preparation, welding positions, welding parameters, welding consumables, preheating, post weld heat treatment and inspection procedures.

3.14.11.2 All weld repairs are to be made by qualified welders using qualified procedures.

3.14.11.3 Welding is to be done under controlled conditions free from draughts and adverse weather.

3.14.11.4 Metal arc welding with electrodes or filler wire used in the procedure tests is to be used. The welding consumables are to be stored and handled in accordance with the manufacturer’s recommendations.

3.14.11.5 Slag, undercuts and other imperfections are to be removed before depositing the next run.

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

3.14.11.7 On completion of heat treatment the weld repairs and adjacent material are to be ground smooth. All weld repairs are to be liquid penetrant tested.

3.14.11.8 The foundry is to maintain records of welding, subsequent heat treatment and inspections traceable to each casting repaired. These records are to be reviewed by the Surveyor.

3.14.12 Identification

3.14.12.1 Prior to final inspection by the Surveyor, each casting is to be suitably identified by the manufacturer with the following symbols:

a) Heat number or other marking which will enable the full history of the casting to be traced,

b) The Register’s certificate number,

c) Ice class symbol, where applicable,

d) Skew angle for high skew propellers,

e) Date of final inspection.

3.14.12.2 The Register’s stamp is to be put on when the casting has been accepted.

3.14.13 Certification

3.14.13.1 The manufacturer is to provide the Surveyor with an inspection certificate giving the following particulars for each casting which has been accepted:

a) Purchaser’s name and order number,

b) Vessel identification, where known,

c) Description of the casting with drawing number,

d) Diameter, number of blades, pitch, direction of turning,

e) Skew angle for high skew propellers,

f) Final mass,

g) Alloy type, heat number and chemical composition,

h) Casting identification number,

i) Details of time and temperature of heat treatment,

j) Results of the mechanical tests.

3.14.13.2 The manufacturer is to provide a statement regarding non-destructive tests as required by 3.14.9.9 and, where applicable, records of weld repairs as required by 3.14.11.8.

3.14.14 Welding procedure qualification test


A test assembly of minimum 30 mm thickness is to be welded. The types of specimens to be prepared are shown in Figure 3.14.14.1.
3.14.14.2 Non-destructive testing

Prior to sectioning, the test assembly is to be visually inspected and liquid penetrant tested. Imperfections shall be assessed in accordance with 3.14.9.

3.14.14.3 Macro-examination

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

3.14.14.4 Tensile testing

Two flat transverse tensile test specimens shall be prepared. Testing procedures shall be in accordance with Chapter 2, Section 2.4.2.8 b).

The tensile strength shall meet the specified minimum value of the base material. The location of fracture is to be reported, i.e. weld metal, HAZ or base material.

3.14.14.5 Bend testing

Two transverse side bend specimens shall be prepared in accordance with Chapter 2. The former diameter shall be 4 x thickness except for austenitic steels, in which case the former diameter shall be 3 x thickness.

The test specimen, when visually inspected after bending, shall show no surface imperfections greater than 2 mm in length.

3.14.14.6 Charpy V-notch testing

Impact test is not required, except where the base material is impact tested. Charpy V-notch test specimens shall be in accordance with Chapter 2. Two sets shall be taken, one set with notch positioned in the center of the weld and one set with the notch positioned in the fusion line, respectively.

The test temperature and impact energy shall comply with the requirement specified for the base material.

3.14.14.7 Hardness testing

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

---

**Figure 3.14.1.1**

Weld test assembly

---

![Diagram of weld test assembly](image-url)
### 3.15 FITTINGS

#### 3.15.1 General

#### 3.15.1.1 These requirements applies to saddles, T-shaped fittings, tapered transition pieces and pipe elbows for welding into pipelines which are fabricated from pipe or plate sections made of ferritic or austenitic steels.

#### 3.15.2 Starting material

#### 3.15.2.1 Suitable plates or pipes are to be selected as starting materials in accordance with Chapter 3. Unless otherwise specified by the Register, the starting material shall be ordered with inspection certificates conforming to 3.1 of standard EN 10204 from manufacturers approved by the Register.

#### 3.15.3 Manufacture

##### 3.15.3.1 Pipe fittings may be hot or cold formed from sections of pipe. They may also be made from sections of plate hot or cold formed into one or more shells and then welded together.

##### 3.15.3.2 Proof shall be furnished to the Register, as a preliminary measure, of the suitability of the process and, for fittings welded together from individual components, the characteristics of the welded joints. For this purpose, the manufacturer shall send a process description containing all the details required for evaluating the process to the Register for consideration. The nature and scope of the procedure approval inspection shall be determined by the Register from case to case.

#### 3.15.4 Heat treatment

##### 3.15.4.1 All fittings shall be in heat-treated or "hot-worked" conditions specified for the material in accordance with the Rules or other relevant standards and material specifications.

##### 3.15.4.2 In the case of ferritic steels for which normalizing is prescribed and which undergo the hot forming, subsequent heat treatment may be dispensed with if a corresponding structure may be achieved by hot forming operation.

In the same circumstances, tempering may be sufficient for steels for which quenching and tempering is prescribed.

##### 3.15.4.3 Cold formed parts are generally required to undergo renewed heat treatment following the forming operation. If such treatment is not applied, the manufacturer shall prove that the finished part retains the required characteristics.

##### 3.15.4.4 Where fittings are welded together from hot or cold formed components, the nature of heat treatment shall be determined at the time of the procedure approval test.

##### 3.15.4.5 If the starting material is in the prescribed heat-treated condition, in the case of pipe elbows manufactured from ferritic or austenitic steels, the following procedure may be applied:

If these elbows are produced by cold bending with bending radius of \( r_0 \geq 1.3 \times d_a \), subsequent heat treatment is not required if the outside diameter \( d_o \leq 133 \) mm. The same applies to all elbows manufactured with bending radius of \( r_0 \geq 2.5 \times d_a \).

The exceptions are steel pipes tough at sub-zero temperatures with wall thicknesses \( > 2.5 \) mm and cold-bent pipes which have to be heat treated due to corrosive attack or because stressed parts have to be welded on outside of neutral zone.

#### 3.15.5 Required properties

In the finished condition, fittings shall possess all the required properties specified for the starting material used (pipes or plates).

#### 3.15.6 Testing

##### 3.15.6.1 All fittings shall be inspected and their dimensions checked in the condition of supply. For this purpose, the surface of the fittings shall be in a condition appropriate for inspection which enables major defects to be detected.

##### 3.15.6.2 For performing mechanical tests, the fittings shall be divided into test batches in accordance with Table 3.15.6.2.

A test batch in accordance with Table 3.15.6.2 consist of fittings made of the same materials and having same dimensions, and, in the case of alloy steel fittings with a diameter \( d_o > 100 \) mm, originating from the same heat. If final heat treatment is necessary, testing shall be also performed by simultaneous heat treatment batches.

Unalloyed steel fittings from the same heats which have been heat-treated separately but in the same way may be tested together if the uniformity of the fittings has been proved to the Surveyor by means of a hardness test on 10%, but at least 3 of the fittings.

#### 3.15.6.3 The scope of mechanical tests is shown in Table 3.15.6.3. For preparing the test specimens, either additional fittings shall be provided or fittings of excess length shall be manufactured. Tensile and notched bar impact tests may be performed on either tangential or longitudinal test specimens, depending on the geometry (shape) of fittings: the specimens shall be prepared from the hardest and softest fit-
tings determined in the hardness test. The required values shall be the definitive values for the starting material.

3.15.6.4 In the case of fittings made from steels tough at sub-zero temperatures, the notched bar impact test shall be performed at the appropriate test temperature.

3.15.6.5 In the case of austenitic or austenitic-ferritic stainless steel fittings for use on chemical tankers, each heat and heat treatment batch shall be tested by the manufacturer for resistance to intercrystalline corrosion in accordance with ISO 3651-2, or an equivalent standard and a test certificate shall be issued.

3.15.6.6 Alloy steel fittings shall be subjected to appropriate testing by the manufacturer to verify the use of correct material.

3.15.6.7 Welded alloy steel fittings with nominal bores >75 mm shall be subjected by the manufacturer to random radiographic inspection of the welds. Unless otherwise specified in the specification or order, the number of fittings to be tested shall be agreed with the Surveyor.

The specimens shall be selected in such a way that every size of fitting are included.

3.15.7 Marking

The fittings shall be marked as follows:
- manufacturer’s mark (symbol)
- material designation
- where applicable, quality level in the case of boiler tubes
- heat number or code, if the starting material had a corresponding mark.

### Table 3.15.6.3

<table>
<thead>
<tr>
<th>Test groups</th>
<th>Size $d_n$ [mm]</th>
<th>Material</th>
<th>Hardness test1)</th>
<th>Tensile test</th>
<th>Notched bar impact test2) (set of specimens = 3 specimens)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>&lt; 100</td>
<td>unalloyed</td>
<td>10% min. on 3 fittings</td>
<td>14)</td>
<td>2 sets of specimens, 1 set only if less than 10 fittings</td>
</tr>
<tr>
<td>II</td>
<td>&lt; 100</td>
<td>alloyed</td>
<td>14)</td>
<td>14)</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>≥ 100</td>
<td>unalloyed</td>
<td>R$_m$ ≥ 500 N/mm$^2$</td>
<td>2 specimens, 1 specimen only if less than 10 fittings</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>≥ 100 (DN ≤ 200)</td>
<td>unalloyed</td>
<td>10% min. on 3 fittings</td>
<td>10%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt; 225 (DN &gt; 200)</td>
<td>or alloyed</td>
<td>100%$^5$</td>
<td>10%</td>
<td></td>
</tr>
</tbody>
</table>

1) With austenitic steels, the hardness test may be dispensed with if geometry allows tensile tests to be performed.
2) The notched bar impact test is only performed in the case of materials for which minimum values for the absorbed energy are stated for the starting material. Furthermore, specimens are only be taken where wall thickness is ≥ 6 mm and geometry allows this to be done.
3) Starting with the second batch of a complete final inspection, the scope of hardness testing may be reduced by half if the hardness values measured for the first batch lie within the specified strength range.
4) The tensile test is to be carried out on the starting pipe.
5) For elbows made of 16 Mo 3, 13 Cr Mo 4-5 and 10 CrMo 9-10 confirming to En 10028-2, the scope of hardness test specified for test group IV is applicable.

### 3.16 PRESSED PARTS

#### 3.16.1 General

3.16.1.1 These requirements applies to the testing of pressed parts for pressure vessels, e.g. pressed heads and shell components fabricated from ferritic or austenitic steel plates by hot forming or by cold forming followed by heat treatment. The requirements apply also to the method of heat treatment which may be required after forming has been carried out.

3.16.1.2 These requirements are also applicable to pressed parts made from individual parts by welding and subsequent forming. Testing of these welded joints before and after forming is to be carried out according to Part 26 - Welding.

#### 3.16.2 Requirement applicable to the starting material

3.16.2.1 The grades of steel from which the starting plates are made shall be specified in the order. In selecting them, care shall be taken to ensure that they fulfill the requirements to be met by the basic material concerned after forming and, where applicable, heat treatment.

3.16.2.2 The plates 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 (if required) shall be performed using test
specimens which have undergone the heat treatment intended for the finished part.

The condition of supply of plates and method of heat treatment of the test specimens shall be indicated in the test certificate.

### 3.16.3 Dimensions, dimensional tolerances and geometrical tolerances

Dimensions as well as dimensional and geometrical tolerances are governed by the relevant standards and/or the information in the order documents. The manufacturer shall keep relevant documents ready for the testing.

### 3.16.4 Principles governing hot forming and heat treatment

#### 3.16.4.1 The manufacturer of finished part shall have available suitable equipment for the proper execution of the necessary heat treatments. Preliminary proof of this shall be submitted to the Surveyor.

#### 3.16.4.2 The heat treatment equipment shall be fitted with a sufficient number of calibrated temperature measuring devices, and fixed items of plant shall be additionally equipped with automatic temperature recording instruments. All these instruments shall be re-calibrated at regular intervals.

#### 3.16.4.3 As far as possible, all parts shall be completely heat treated or annealed. With the consent of the Surveyor, this Part of the Rules may be waived where only local forming is performed. In these cases, heat treatment shall, however, embrace the whole area of deformation.

#### 3.16.4.4 The temperatures, holding time 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 component concerned. The manufacturer is required to guarantee compliance with the conditions.

#### 3.16.4.5 Where testing of finished parts are allowed to be carried out on separate test sections, provisions shall be made to ensure that these receive the same heat treatment as the finished part. For this purpose, the test sections shall be laid on top of the corresponding finished parts for the annealing operation.

### 3.16.5 Heat treatment after hot forming

#### 3.16.5.1 Ferritic steels

a) Hot forming shall normally be followed by renewed heat treatment as prescribed for the base material concerned. This requirement may be waived where the forming operation has started and ended within temperature range specified for this purpose in the standard or manufacturer’s material specification.

b) For the steels tough at sub-zero temperatures, preliminary tests must be proved that the intended heat treatment imparts to the finished part the necessary impact energy at the specified test temperature. In these cases, subsequent heat treatment may be dispensed with for air quenched and tempered steels.

c) For water-quenched and tempered steels, the nature of heat treatment to be applied after hot forming shall be specially determined.

d) The exceptional provisions specified in 3.16.5.1 a) and 3.16.5.1 b) may also be applied where local hot forming is performed, provided that, prior to forming, the plates were in a heat-treated condition appropriate to the material.

### 3.16.5.2 Austenitic steels

After hot forming, parts made of austenitic steels shall be subjected to renewed heat treatment which shall normally comprise solution annealing and quenching. This requirement may be waived where the forming operation has started in the temperature range from 1150 to 1000°C, and has ended above 750°C for stabilized steels and steels with a carbon content of C ≤ 0.03% or above 875°C for non-stabilized steels with a carbon content of ≤ 0.08%, followed by a rapid cooling to ambient temperature.  

1) For further details on heat treatment of austenitic steels, see AD-Data Sheet HP/7.3.

### 3.16.5.3 Clad plates

Where parts are made of clad plates, the nature of heat treatment is governed by the basic material (see 3.16.5.1). Where the cladding material requires a heat treatment different from that of the base material, the details of this shall be specified by the manufacturer of the material and made known to the Register.

### 3.16.6 Heat treatment after cold forming

#### 3.16.6.1 Ferritic steels

All plates shall be in the prescribed condition of supply before cold forming is carried out (see individual Rules in Chapter 3 - Steel and Iron materials).
Due to the changes in material properties which may result from cold forming and ageing, the following procedure applies:

### 3.16.6.1 Pressed parts for pressure vessels operating at ambient temperatures or feedstock temperatures down to -10°C shall, if the degree of deformation exceeds 5% (wall thickness \( s > 0.05 \times D_m \) for cylindrical shell rings and sphere segments) shall be subjected to heat treatment (normalizing or quenching and tempering) in accordance with the relevant standards or material specifications.

#### 3.16.6.1.2 Pressed parts for pressure vessels operating at charging media temperatures below -10°C shall,

**a)** if the degree of deformation exceeds 2% in the case of steel grades conforming to EN 10028-2, EN 10028-3, EN 10028-4 and EN 10028-6, with the exception of 12Ni14, 12Ni19, X7Ni9 and X8Ni9;

**b)** if the degree of deformation exceeds 5% in the case of steel grades 12Ni14, 12Ni19, X7Ni9 and X8Ni9 conforming to EN 10028-4,

be subjected to heat treatment (normalizing or quenching and tempering) in accordance with the relevant standards or material specifications.

#### 3.16.6.1.3 Pressed parts for gas tanks with design temperatures below 0°C shall be treated in accordance with 3.16.6.1.2.

#### 3.16.6.1.4 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.

#### 3.16.6.1.5 The requirements stipulated in 3.16.6.1.1, 3.16.6.1.2 and 3.16.6.1.4 may be relaxed if proof is furnished that the properties of the materials properties make them able to withstand the stresses prevailing when the pressure vessel is in service.

#### 3.16.6.1.6 Cold-formed dished heads made of steel grade S235 JR, S235 J0, S235 J2 and S235 J2+N according to EN 10025-2, P235 GH and P265 GH to EN 10028-2, P275 N according to EN 10028-3, as well as of other steel grades of comparable strength, do not require heat treatment if the temperature of the charging media is -10°C or above, the design temperature shall not exceed 120°C in accordance with the Rules and the nominal wall thickness is ≤ 8 mm.

#### 3.16.6.1.7 If the acceptable degrees of deformation are exceeded in cold forming, heat treatment shall as a rule be performed before welding.

#### 3.16.6.1.8 In the case of clad pressure vessel or pressure vessel components, heat treatment shall be performed in accordance with the base material, unless special conditions have been agreed with regard to the cladding.

### 3.16.6.2 Austenitic Steels

#### 3.16.6.2.1 Acceptable heat treatments are solution annealing with quenching or, for stabilized steels (exception: Molybdenum stabilized steels with more than 0.03% C) and steels with carbon contents of C ≤ 0.03%, stabilization annealing.

#### 3.16.6.2.2 Heat treatment of solution annealed and quenched or stabilization annealed material after cold forming may be dispensed with if:

- In the case of austenitic steels with required minimum elongation values, \( A \geq 30\% \) in respect of the initial material, the degree of deformation does not exceed 15% or proof is furnished that the residual elongation capacity \( A \) after cold forming is at least 15%. For size ranges in which the required minimum elongation values \( A \) are less than 30%, proof that the residual elongation capacity \( A \) is 15% is deemed to have been furnished if an elongation \( A \) of ≥ 30% is shown in the acceptance test certificate;

- In the case of degrees of deformation higher than 15%, proof is furnished that the residual elongation capacity \( A \) after cold forming is at least 15%.

- In the case of dished, ellipsoidal and hemispherical heads, the following elongations \( A \) are shown in the acceptance test certificates for the starting materials:

  - **a)** \( \geq 40\% \) for nominal wall thickness ≤ 15 mm at design temperatures down to -196°C;
  - **b)** \( \geq 45\% \) for nominal wall thickness > 15 mm at design temperatures down to -196°C;
  - **c)** \( \geq 50\% \) at design temperatures below -196°C;

- In the case of pressure vessel components, (except heads) which are operating at design temperatures below -196°C, the degree of deformation does not exceed 10%.

### 3.16.6.3 Clad plates

Cold-formed finished parts made of clad plates are subject to the conditions stated in 3.16.6.1 for the base material concerned.

### 3.16.7 Testing

#### 3.16.7.1 Test of mechanical and technological properties

- **3.16.7.1.1** The testing of pressed parts shall comprise tensile and notched bar impact tests performed on specimens taken from the finished parts after the final heat treatment transverse to the original rolling direction of the plate. The tolerance of up to 20° from the required specimen orientation can be tolerated. The necessary test sections, the quantity of which is specified in Table 3.16.7.1.1, shall be taken from surplus material at the edges of pressed parts or from cutouts.

- **3.16.7.1.2** Where stress relief heat treatment is sufficient after forming, the test sections may be removed from the test piece beforehand and subjected to the same annealing treatment.
3.16.7.1.3 Where Table 3.16.7.1.1 specifies testing by test batches, a test batch may only comprise items made from plates originating from the same heat, which have been pressed 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.

3.16.7.1.4 Where individual testing of the pressed parts is prescribed, testing of the starting material by the Register may be dispensed with.

3.16.7.1.5 Instead of individual testing of pressed parts, the Register may accept the testing by rolled plate (1 set of specimens per starting plate) provided that the manufacturer of pressed parts demonstrates to the Register by a preliminary test of the manufacturing method used that the requirements can be met and products with constant characteristics can be manufactured. In this case, the starting plates shall be tested.

3.16.7.2 Test of surface finish and dimensions

The surface finish and dimensions of each finished part shall be checked by the manufacturer. The parts shall then be submitted to the Surveyor for final testing and verification of dimensions.

3.16.8 Marking

Each part shall be marked by the manufacturer with the manufacturer’s mark, material designation, heat number and specimen number.

3.16.9 Certificates

3.16.9.1 In the case of pressed parts which are heat treated after forming, the manufacturer shall certify the proper execution of heat treatment, stating the temperatures, the holding times and type of cooling applied.

3.16.9.2 In the case of pressed parts which may be supplied in "hot-pressed condition", the manufacturer shall certify that the forming operation started and ended within the specified temperature limits and shall indicate the standard or material specification applicable. In addition, the method of cooling and condition of supply of the starting material shall also be stated.

### Table 3.16.7.1.1

Scope of testing on pressed parts made from plate

<table>
<thead>
<tr>
<th>Grades of steel</th>
<th>Base material according to Chapter 3</th>
<th>Test performed on</th>
<th>Extent of test on pressed parts</th>
</tr>
</thead>
<tbody>
<tr>
<td>All unalloyed steels with a minimum tensile strength ≤ 410 N/mm²</td>
<td>3.3, 3.5</td>
<td>Starting plate</td>
<td>not required</td>
</tr>
<tr>
<td>Unalloyed and fine-grained structural steels with minimum tensile strength 410 &lt; Rₜₚ ≤ 510 N/mm², and Rₑₜ ≤ 355 N/mm², also 0.3% Mo alloy steels</td>
<td>3.3, 3.5</td>
<td>Starting plate Pressed part</td>
<td>Testing by batches</td>
</tr>
<tr>
<td>Fine-grained structural steels Rₑₜ &gt; 355 N/mm²</td>
<td>3.5</td>
<td>Pressed part</td>
<td>1 set of specimens from each pressed part¹</td>
</tr>
<tr>
<td>High-temperature Cr Mo alloy steels</td>
<td>3.5</td>
<td>Pressed part</td>
<td>1 set of specimens from each pressed part¹</td>
</tr>
<tr>
<td>Steels tough at sub-zero temperatures</td>
<td>3.6</td>
<td>Pressed part</td>
<td>1 set of specimens from each pressed part¹</td>
</tr>
<tr>
<td>Austenitic stainless steel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thickness [mm]</td>
<td>≤ 20</td>
<td>3.7</td>
<td>Starting plate</td>
</tr>
<tr>
<td></td>
<td>&gt; 20</td>
<td></td>
<td>Starting plate Pressed part</td>
</tr>
<tr>
<td>Clad plates</td>
<td>3.8</td>
<td></td>
<td>The extent of test depends on the base material</td>
</tr>
</tbody>
</table>

1) Testing by rolled plate may be agreed if conditions specified in 3.16.7.1.5 are satisfied.
3.17 FASTENERS

3.17.1 General

3.17.1.1 These requirements are applicable to the manufacture, the mechanical properties and the testing of bolts and nuts for:
- boilers, process equipment, pressure vessels and pipelines;
- other components of the machinery plant for which proof of quality is required as specified in the Rules.

3.17.1.2 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 Rules and shall be stated in purchase order.

3.17.2 Materials

3.17.2.1 Bolts and nuts are to be selected in accordance with recognized standards or the manufacturer’s material specifications which have been approved by the Register. The steels used in manufacture of bolts shall have a guaranteed impact energy. Under these conditions, the following materials may be considered:

3.17.2.2 Bolts and nuts conforming to 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.

3.17.2.3 Steels conforming to EN 10269 in conjunction with DIN 267-13.

3.17.2.4 Steels conforming to DIN 267-13.

3.17.2.5 Stainless steels according to ISO 3506-1 and -2.

3.17.2.6 Bolts and nuts conforming to other standards or the manufacturer’s material specifications may be used, provided that the Register has confirmed their suitability for intended application. Unless otherwise specified, the materials shall satisfy the requirements in 3.17.4.3 and 3.17.4.4.

3.17.2.7 Free cutting steels with a high sulphur, phosphorus or lead content may not be used.

3.17.3 Manufacture

3.17.3.1 Bolts and nuts may be manufactured by hot or cold forming or by machining. Cold formed bolts shall be subjected to subsequent heat treatment. The same applies to hot formed bolts and nuts with exception of bolts and nuts made of quenched and tempered steels, provided that the latter are to be used at normal ambient temperatures and if hot forming process results in an uniform structure.

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

3.17.4 Requirements

3.17.4.1 Bolts and nuts conforming to the standards to 3.17.2.2 to 3.17.2.5 shall meet the chemical composition and mechanical properties set out in these standards.

3.17.4.2 Steels tough at sub-zero temperatures for bolts and nuts shall achieve the impact energy of at least 41 Joules at the prescribed test temperature, using longitudinal Charpy V-notch specimens.

3.17.4.3 Steels for bolts and nuts with threads exceeding M39 as well as according to 3.17.2.6 shall have the characteristic values of the material properties and shall meet the following conditions in testing at room temperature with longitudinal specimens:

a) elongation $A \geq 14\%$;

b) impact energy using Charpy V-notch specimens $\geq 52$ Joules for quenched and tempered steels and $\geq 40$ Joules for unalloyed steels.

3.17.4.4 The impact energy value shall be average value obtained with three test specimens. Only one specimen may have a value which is below the required average value but not less than 70% of the average value.

3.17.4.5 Bolts and nuts shall be in heat treated condition, specified in the material order, with purpose to achieve the minimum values of mechanical properties. The material shall not undergo unacceptable embrittlement up to the maximum temperatures 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 reasonably above the maximum in-service temperature.

3.17.5 Testing of bolts

3.17.5.1 The manufacturer shall demonstrate the chemical composition of each heat according to 3.17.7.

3.17.5.2 Tensile testing shall be performed on bolts and, for thread diameters $\geq 16$ mm, the notched bar impact test shall be performed. For preparing the specimens, bolts of the same type and strength category or made from the same material shall be grouped into test batches in accordance with Table 3.17.5.2.

If proof is furnished that the bolts 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.

3.17.5.3 For the tensile test, the specimens may be machined from the sample material, or turned specimens of the type shown in Fig. 3.17.5.3, may be used.
3.17.5 Testing of nuts

3.17.5.1 Nuts with nominal thread diameters of up to and including 39 mm are to be subjected to the expansion test using a mandrel with a 1:100 taper, see Fig.3.17.6.1. Before testing, the nuts are to be drilled out to the thread outside diameter. The expansion shall be at least 6% for nuts with a depth of \( \geq 0.8 \times \) nominal thread diameter \( d \) (at least 4% for nuts with a depth of \( \geq 0.5d \) to \( <0.8d \)). The numbers of test specimens shown in Table 3.17.5.2 are applicable, but for quantities of \( \leq 200 \) at least 2 nuts shall be tested.

3.17.5.2 Nuts with nominal thread diameters \( > 39 \) mm are to be subjected to testing of the starting material as specified in 3.17.5.2 rather than the expansion test.

3.17.5.3 The uniformity of delivery is to be demonstrated by the manufacturer by means of hardness tests. For this purpose, at least 20 nuts from each test batch are to be tested, and at least 10 nuts in the case of quantities \( \leq 200 \). The results of test are to be submitted to the Surveyor.

3.17.5.4 The surface finish, dimensions and compliance with tolerances shall be verified by the Surveyor in the same way as described in 3.17.5.6.

3.17.5.5 The surface finish, dimensions and compliance with tolerances shall be verified by the Surveyor in the same way as described in 3.17.5.6.

3.17.5.6 The surface finish, dimensions and compliance with tolerances shall be verified by the Surveyor in the same way as described in 3.17.5.6.

3.17.5.7 The uniformity of delivery is to be demonstrated by the manufacturer by means of hardness tests. For this purpose, at least 20 bolts from each test batch are to be tested, and at least 10 bolts in the case of quantities \( \leq 200 \). The results of test are to be submitted to the Surveyor.

3.17.5.8 For bolts calculated for elevated temperature application on the basis of their high-temperature mechanical characteristics, the 0.2% or 1% proof stress shall be proved by a high-temperature tensile test performed on one specimen from each batch. The test shall be performed at the temperature which approximates most closely to the level of the operating temperature, rounded off to the nearest 50°C. The test may be dispensed with in the case of bolts to recognized standards, the high-temperature mechanical properties of which are regarded as proven.

---

Table 3.17.5.2
Batch sizes for the testing of mechanical properties

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Number of sets of specimens for mechanical testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \leq 200 )</td>
<td>1</td>
</tr>
<tr>
<td>( &gt; 200 ) to ( \leq 400 )</td>
<td>2</td>
</tr>
<tr>
<td>( &gt; 400 ) to ( \leq 800 )</td>
<td>3</td>
</tr>
<tr>
<td>( &gt; 800 ) to ( \leq 1200 )</td>
<td>4</td>
</tr>
<tr>
<td>( &gt; 1200 ) to ( \leq 1600 )</td>
<td>5</td>
</tr>
<tr>
<td>( &gt; 1600 ) to ( \leq 3500 )</td>
<td>6</td>
</tr>
<tr>
<td>( &gt; 3500 )</td>
<td>7</td>
</tr>
</tbody>
</table>

---

Figure 3.17.5.3
Turned specimen
3.17.10 Marking

3.17.10.1 Bolts and nuts are to be marked with the manufacturer's symbol and with the strength category or grade of steel, as well as with heat number in the case of bolts of M52 size and above. Bolts of M 52 in size and above are to be individually marked with the Register's stamp, which is in all other cases to be applied at the packing label.

3.17.10.2 Steel bars over 25 mm in diameter for the machining of bolts and nuts are to be marked at one end with the manufacturer's symbol, the steel grade and the Register's stamp, and the alloy steel bars are to be additionally marked with the heat number. Where the diameter of steel bars is 25 mm or less, it is sufficient to apply the corresponding markings to the label attached to the bundle of bars.

3.17.9.2 Where one of the test specimens required for carrying out hardness testing, non-destructive testing to check for surface defects, or for carrying out a dimensional check fails to meet the requirements, a further random sample of 20 specimens (or 10 specimens in the case of batch sizes ≤ 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 once he has carried out 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.

Figure 3.17.6.1
Expansion testing of nuts – test arrangement
4 COPPER ALLOYS

4.1 PIPES OF COPPER AND WROUGHT COPPER ALLOYS

4.1.1 General

4.1.1.1 These requirements apply to pipes and fittings made of copper and wrought copper alloys intended for use in pressure lines and for condensers and heat exchangers.

4.1.2 Method of manufacture

4.1.2.1 The pipes shall generally be manufactured by seamless methods, e.g. by hot pressing followed by rolling and cold drawing.

4.1.2.2 Where welded pipes or fittings are to be used, the characteristics of these and the method of manufacture employed shall be introduced to the Register. The Register reserve the right to demand a approval of welding procedure in these cases.

4.1.2.3 Cold-formed pipes and fittings shall be subject-ed to recrystallization annealing. Notwithstanding this, copper pipes, which are to be supplied in "half hard" to "hard" condition, (e.g. conditions R250 and R290 under EN 12449) may be cold formed after annealing. CuNi2Si pipes are cold formed in the solution annealed condition or hot formed with simultaneous solution annealing and subsequent quenching. After cold forming hardening occurs.

4.1.3 Suitable material grades of pipes

All pipes shall be suitable for the intended application and satisfy the requirements specified in 4.1.7. Subject to these conditions, the following grades of pipes may be used:

4.1.3.1 Copper and wrought copper alloy pipes according to EN 12449, in the grades specified in Table 4.1.3.1.

4.1.3.2 Copper and wrought copper alloy pipes for condensers and heat exchangers according to EN 12451, preferably in the grades shown in Table 4.1.3.1.

4.1.3.3 Pipes conforming to other standards or specifications, provided that they are comparable to the grades specified in 4.1.3.1 and 4.1.3.2, and their suitability has been confirmed by the Register.

Table 4.1.3.1
Suitable grades for pipes

<table>
<thead>
<tr>
<th>Material designation</th>
<th>Number</th>
<th>Composition: Weight fraction [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cu-DHP CW024A</td>
<td>min.</td>
<td>Cu: 99,901) max.</td>
</tr>
<tr>
<td>CuNi2Si CW111C</td>
<td>min.</td>
<td>remainder</td>
</tr>
<tr>
<td>CuNi010Fe1Mn CW352H</td>
<td>min.</td>
<td>remainder</td>
</tr>
<tr>
<td>CuNi30Mn1Fe CW354H</td>
<td>min.</td>
<td>remainder</td>
</tr>
<tr>
<td>CuZn20Al2As CW702R</td>
<td>min.</td>
<td>CuNi: 99,901) max.</td>
</tr>
</tbody>
</table>

1) Including Ag up to max. 0,015%.
2) Co max. 0,1 is counted as Ni.
3) For applications exposed to seawater: 1,5 ≤ Fe ≤ 1,8.

4.1.4 Surface finish

4.1.4.1 Pipes shall have a smooth surface compatible with the manufacturing method. The surface shall be free from impurities, e.g. pickling residues or burnt drawing lubricants, and may not be cracked or suffered mechanical damage.

Die marks and laminations which may impair further manufacturing operations or the use of materials are not allowed.

4.1.4.2 Surface defects may be repaired by grinding, provided that a gradual transition is made to the surface of pipe and that the dimensional tolerances are not exceeded.

Repairs by welding or soldering are not permitted.
4.1.5 Dimensions, dimensional and geometrical tolerances

4.1.5.1 Tolerances on wall thickness and diameter shall be prescribed in recognized standards (EN 12449). Pipe ends shall be cut of f at right angles to the pipe axis and shall be free from burrs.

4.1.6 Resistance to leakage

Pipes shall not leak when submitted to the hydraulic pressure test at the prescribed test pressures.

4.1.7 Requirements applicable to the material

4.1.7.1 Chemical composition

The chemical composition shall conform to the Table 4.1.3.1.

4.1.7.2 Mechanical properties

The mechanical properties shall conform to the relevant standards.

Table 4.1.7.2 gives an extract from EN 12449 for pipe grades specified in 4.1.3.1.

4.1.7.3 Formability

With exception of pipes made of copper Cu-DHP in condition R290 and CuNi2Si in condition R460, all pipes shall be capable of being cold formed with the degrees of deformation customary in the workshop practice, e.g. by bending and expansion.

4.1.7.4 Absence of stresses

Pipes made of copper-zinc alloys shall be free from stresses liable to cause stress cracks.

4.1.7.5 Resistance to hydrogen embrittlement

Copper pipes may not become brittle due to the effect of hydrogenous gases and elevated temperatures, such as occur in gas welding, soldering and hot forming.

4.1.7.6 Grain size

The average grain diameter of the materials specified in the Table 4.1.7.2 in the conditions mentioned in the Table shall be between 0.01 and 0.05 mm. The exception is material Cu-DHP in condition R290.

Table 4.1.7.2

<table>
<thead>
<tr>
<th>Material designation</th>
<th>Condition</th>
<th>Wall thickness [mm]</th>
<th>Yield strength ( R_{\text{p0.2}} ) [N/mm²]</th>
<th>Tensile strength ( R_m ) [N/mm²]</th>
<th>Elongation ( A ) [%] min.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cu-DHP</td>
<td>soft</td>
<td>R200</td>
<td>≤ 20</td>
<td>≤ 110</td>
<td>≥ 200</td>
</tr>
<tr>
<td></td>
<td>half-hard</td>
<td>R250</td>
<td>≤ 10</td>
<td>≥ 150</td>
<td>≥ 250</td>
</tr>
<tr>
<td></td>
<td>hard</td>
<td>R290</td>
<td>≤ 5</td>
<td>≥ 250</td>
<td>≥ 290</td>
</tr>
<tr>
<td>CuZn20Al2As</td>
<td>annealed</td>
<td>R340</td>
<td>≤ 10</td>
<td>≥ 120</td>
<td>≥ 340</td>
</tr>
<tr>
<td>CuNi10Fe1Mn</td>
<td>annealed</td>
<td>R290</td>
<td>≤ 20</td>
<td>≥ 90</td>
<td>≥ 290</td>
</tr>
<tr>
<td>CuNi30Mn1Fe</td>
<td>annealed</td>
<td>R370</td>
<td>≤ 10</td>
<td>≥ 120</td>
<td>≥ 370</td>
</tr>
<tr>
<td>CuNi2Si</td>
<td>solution annealed</td>
<td>R260</td>
<td>≤ 10</td>
<td>≥ 60</td>
<td>≥ 260</td>
</tr>
<tr>
<td></td>
<td>solution annealed and precipitation hardened</td>
<td>R460</td>
<td></td>
<td>≥ 300</td>
<td>≥ 460</td>
</tr>
<tr>
<td></td>
<td>solution annealed and cold formed</td>
<td>R380</td>
<td></td>
<td>≥ 260</td>
<td>≥ 380</td>
</tr>
<tr>
<td></td>
<td>solution annealed, cold formed and precipitation hardened</td>
<td>R600</td>
<td></td>
<td>≥ 480</td>
<td>≥ 600</td>
</tr>
</tbody>
</table>

1) Without former annealing, cold forming is not possible.

4.1.8 Testing and scope of tests

4.1.8.1 For the purpose of testing, the pipes shall be grouped into batches in accordance with Table 4.1.8.1. A test batch shall comprise pipes which have been manufactured by the same method, are made of the same material and are in the same condition and of the same thickness. It is not necessary for a test batch to originate from a single heat or heat treatment.

Where 2 or more test specimens are required, they shall be taken from different pipes in the test batch. If pipes are supplied in rings, a test specimen shall be taken from every fifth ring, if there are less than five rings, however, at least one specimen shall be taken.
4.1.8.2 Chemical composition

The manufacturer shall determine chemical composition of each manufactured batch and present the information to the Surveyor.

4.1.8.3 Determination of grain size

In the case of condenser and heat exchanger tubes, the manufacturer shall determine the average grain diameter on at least one specimen from each test batch according to ISO 2624.

4.1.8.4 Tensile test

Pipes shall be subjected to tensile test to determine the tensile strength, 0.2% proof stress and elongation.

4.1.8.5 Ring flattening test

Pipes shall be subjected to the ring flattening test. Test specimens shall be flattened until inner surfaces touch. This shall not cause cracks visible to the eye.

Cu-DHP copper pipes in condition R290 are to be annealed before testing. CuNi2Si pipes are to be solution annealed beforehand.

4.1.8.6 Expanding test

Pipes with outside diameter up to 76 mm shall be subjected to the expanding test, using a drift with a 45°C taper.

The expansion shall be equal to at least 30% of the original inside diameter and no cracks may appear. Cu-DHP copper pipes in condition R290 are to be annealed before testing. CuNi2Si pipes have to be in solution annealed condition.

4.1.8.7 Testing for absence of internal stresses (CuZn pipes)

The manufacturer shall prove that CuZn alloy pipes are free from internal stresses by carrying out the ammonia tests according to ISO 6957 or DIN 50916 and then test specimens shall be presented to the Surveyor.

At the express request of the purchaser, this test may be replaced by mercurous nitrate test according to ISO 196.

Should a specimen reveal cracks when tested, the manufacturing batch shall be rejected. The manufacturer shall be free to submit the batch to renewed heat treatment before presenting it for re-testing.

4.1.8.8 Test of resistance to hydrogen embrittlement (Cu pipes)

For this purpose, the pipe specimens of 10 to 20 mm in length shall be annealed for 30 minutes at 800 to 850°C in a reducing atmosphere (hydrogen or fuel gas), cooled and flattened between two parallel plates until the inner surfaces touch.

In the case of thick-walled and large diameter pipes, flattening test specimens may comprise approximately 10 mm wide strips taken from the sample pipe. The points of folding shall neither reveal cracks nor fracture.

4.1.8.9 Test of surface finish and dimensions

The manufacturer shall inspect the finish of the outer and inner surfaces of every pipe and shall also check the diameter and wall thickness.

The pipes shall then be submitted to the Surveyor for final inspection.

4.1.8.10 Tightness test

The manufacturer shall subject all pipes to the tightness test.

Preferably, this shall be done by applying an eddy-current test carried out in accordance with a recognized standard (e.g. EN 1971) or test specification.

Instead of eddy-current test, another equivalent non-destructive test method may be agreed, or a hydraulic pressure test shall be performed. Each pipe is to be subject for at least 5 s to an inner water pressure, which shall be calculated according to the following formula:

\[
P = \frac{2 \cdot S \cdot t}{D}
\]

Where:

- \( P \) = inner water pressure,
- \( t \) = wall thickness (nominal) of the pipe,
- \( D \) = outer diameter (nominal) of the pipe,
- \( S \) = half of the minimum value for the 0.2% proof stress

The pipes need not to be tested with a water pressure above 6.9 MPa, if not otherwise agreed.

4.1.8.11 Retest in the event of failure

If the required values are not met in the mechanical and technological tests, then, before manufacturing batch is rejected, the procedures for retests prescribed in accordance with Chapter 2, Section 2.9 may be applied.

4.1.9 Marking

4.1.9.1 The following marks shall be applied by the manufacturer to each pipe with an outside diameter ≥ 25 mm using an indelible and weatherproof dye:

a) Manufacturer’s mark,

b) Designation of material or material number,

c) Test batch number or another mark enabling the pipe to be clearly identified.

In the case of pipes with an outside diameter <25 mm, the marking shall be in a form which enables the pipe to be matched up with the test certificate.

4.1.9.2 Where pipes are supplied in bundles or packed in crates, the marks specified in 4.1.9.1 may be affixed by means of securely fastened tags or labels; however, pipes with an outside diameter ≥25 mm shall be marked individually.

4.1.10 Certificates issued by the manufacturer

4.1.10.1 For each consignment the manufacturer shall supply to the Surveyor a certificate giving the following details:

a) Purchaser and order number,

b) Number, size and weight of pipes,

c) Material designation,

d) Test batch number or identification mark,
e) Results of the analysis, of the mechanical and technological tests, the tightness test and, if specified for the type of pipe concerned or specially stipulated, of the tests to determine absence of internal stresses, resistance to hydrogen embrittlement and average grain size.

4.1.11 Copper and wrought copper alloy fittings

4.1.11.1 General

The present requirements apply to saddles, T-shaped fittings, tapered transition pieces and pipe elbows. Fittings conforming to recognized standards shall be used.

4.1.11.2 Approval of manufacture

The fittings manufacturer should be approved by the Register. The scope of testing for approval is to be determined by a relevant standard, such as DIN 86086 to DIN 86090, for fittings manufactured from pipes by cold or hot forming.

The scope of testing for welded fittings shall be determined by the Register.

4.1.11.3 Properties

Chemical composition and mechanical properties of the fittings shall correspond to those of the grades of pipe used for their manufacture.

4.1.11.4 Testing

4.1.11.4.1 The manufacturer shall furnish the proof of the chemical composition of the starting materials by means of certificates issued by the manufacturer of the starting material.

4.1.11.4.2 For the testing, the fittings shall be grouped into test batches. A test batch shall comprise units of the same shape and size, made of the same grade of material in the same condition and produced in a single manufacturing cycle.

Two specimens shall be taken from each test batch for the following tests:

a) tensile test, where nominal bore is 100 mm or over;

b) ring flattening test;

c) test for absence of internal stresses if fittings are made of CuZn alloys.

Where the number of units is 10 or less, one test specimen is sufficient.

The manufacturer shall inspect the fittings for their dimensional accuracy and surface finish.

4.1.11.5 Marking and certification

4.1.11.5.1 The marking and the certification of the characteristics of the material are subject, in analogous manner, to the provisions of 4.1.9 and 4.1.10.

4.2 CAST COPPER ALLOYS

4.2.1 General

The present requirements apply to cast copper alloys, for the manufacture of valve and pump housings, shaft liners, bushes and similar parts.

4.2.2 Manufacture

The method of manufacture shall be chosen to suit the shape of casting. Sand casting, chill casting, centrifugal casting and continuous casting may be used.

Castings may be supplied in the as cast or as heat-treated condition, at the manufacturer's option unless this is specified in the order.

4.2.3 Suitable grades of cast alloy

The grades of cast alloy shall be suitable for the intended application. Subject to these conditions, the following grades of alloys may be used:

4.2.3.1 Grades stated in Table 4.2.3.1 for applications exposed to sea water.

4.2.3.2 Grades conforming to other standards or specifications, provided that their suitability has been confirmed by the Register.

4.2.4 Characteristics of castings

4.2.4.1 All castings shall be supplied in a clean fettled condition. They shall be free from shrinkage cavities, pores, blow holes, cracks, inclusions and other defects, which impair their use and further course of manufacture.

Small surface defects may be removed by grinding provided that the dimensional tolerances are not exceeded.

4.2.4.2 Where defects are to be repaired by welding, the details of process shall be submitted to the Surveyor for approval before the repair work has begun and he shall be notified of the location, nature and extent of defect. Bearing bushes and liners of cast CuPbSn alloys may not be welded. Welds aimed solely at improving the appearance of the casting, shall not be acceptable.

4.2.5 Dimensional and geometrical tolerances

Dimensional and geometrical tolerances shall be within limits specified in the relevant standards. The standards shall be stated in the order and made known to the Surveyor.
4.2.6 Resistance to leakage

Castings subjected to internal pressure by the operating medium shall be tight at the prescribed test pressure.

4.2.7 Requirements applicable to material

The chemical composition and mechanical properties shall conform to Table 4.2.3.1 and Table 4.2.7, the relevant standards or the approved specifications.

4.2.8 Tests and scope of testing

The following tests are to be performed:

4.2.8.1 Test of chemical composition

The manufacturer shall determine the chemical composition of each heat and issue a relevant certificate.

Where castings are made of remelting ingots of the same grade without further additions to the heat, the certificate of the manufacturer for starting material can be accepted as a proof of chemical composition.

Minor additions to compensate for melting losses, may be disregarded. In case of doubt the chemical composition shall be determined by the casting analysis.

4.2.8.2 Tensile Test

For this purpose, one test specimen shall be taken from each heat and subjected to testing. If the weight of the heat exceeds 1000 kg, a second test specimen is required. The specimens shall be taken as follows:

a) In the case of sand and chill casting, the specimens shall be taken from integrally cast sample bars or from separately cast sample pieces. Separately cast sample pieces shall have dimensions shown in Fig.4.3.7.1, and shall originate from the same heat and shall be cast using the same mould material.

b) In the case of centrifugal and continuous castings, the specimens shall be taken from the cast part.

c) Where casting is supplied in the heat treated condition, the specimen shall be subjected to the same heat treatment.

4.2.8.3 Test of surface finish and dimensions

The manufacturer shall inspect each casting with regard to its surface finish and compliance with dimensional and geometrical tolerances, after which the castings shall be presented to the Surveyor for final inspection.

4.2.8.4 Tightness test

Where this is required in the other parts of the Rules, the castings shall be subjected to hydraulic pressure test, in the presence of the Surveyor. Shaft liners shall be tested at a pressure of at least 2 bars. For all other components, the test pressure is normally 1,5 times the operating pressure.

4.2.9 Marking

4.2.9.1 The manufacturer shall employ monitoring system which enables every casting to be traced back to its heat. On request, the Surveyor shall be given proof of this.

4.2.9.2 Prior to final inspection by the Surveyor, each casting shall be marked by the manufacturer as follows:

a) Manufacturer’s mark,  
b) Short designation of the alloy.

---

### Table 4.2.3.1

<table>
<thead>
<tr>
<th>Material designation</th>
<th>Composition [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Al</td>
</tr>
<tr>
<td>CuAl10Ni</td>
<td></td>
</tr>
<tr>
<td>CuSn7ZnPb</td>
<td></td>
</tr>
<tr>
<td>CuSn5ZnPb</td>
<td></td>
</tr>
<tr>
<td>CuSn12Ni</td>
<td></td>
</tr>
<tr>
<td>CuSn12</td>
<td></td>
</tr>
<tr>
<td>CuNi30</td>
<td></td>
</tr>
<tr>
<td>CuNi10</td>
<td></td>
</tr>
<tr>
<td>CuAl10Ni30Fe1Mn1</td>
<td></td>
</tr>
<tr>
<td>CuSn7ZnPb30Ni5Sb2</td>
<td></td>
</tr>
</tbody>
</table>

---

---
c) Charge number or a code marking enabling the manufacturing process to be traced back,
d) Specimen number,
e) Date of test,
f) Test pressure, where applicable.

At the request of the Surveyor, the test certificate number shall also be stamped on. In the case of small castings produced in series, e.g. valve housings, the marking shall be in a form which enables the casing to be matched up with the test certificate.

4.2.10 Test certificates

4.2.10.1 For each consignment the manufacturer shall supply to the Surveyor a test certificate or delivery specification containing the following details:

a) Purchaser and order number,
b) Number and weight of the castings,
c) Material designation and condition in which supplied,
d) Composition of the heat (or of the starting material, where applicable),
e) Method of manufacture,
f) Results of mechanical tests if performed by the manufacturer,
g) Test pressure, where applicable.

### Table 4.2.7

**Mechanical properties of cast copper alloys**

<table>
<thead>
<tr>
<th>Material code</th>
<th>Condition of supply</th>
<th>Yield strength $R_{p,0.2}$ [N/mm$^2$] min.</th>
<th>Tensile strength $R_m$ [N/mm$^2$] min.</th>
<th>Elongation $A$ [%] min.</th>
<th>Hardness HB 10 min.</th>
</tr>
</thead>
<tbody>
<tr>
<td>CuSn10</td>
<td>sand cast</td>
<td>130</td>
<td>270</td>
<td>18</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>permanent mould cast</td>
<td>160</td>
<td>270</td>
<td>10</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>centrifugally cast</td>
<td>160</td>
<td>270</td>
<td>10</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>continuously cast</td>
<td>170</td>
<td>280</td>
<td>10</td>
<td>80</td>
</tr>
<tr>
<td>CuSn7ZnPb</td>
<td>sand cast</td>
<td>120</td>
<td>240</td>
<td>15</td>
<td>65</td>
</tr>
<tr>
<td></td>
<td>permanent mould cast</td>
<td>120</td>
<td>230</td>
<td>12</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>centrifugally cast</td>
<td>130</td>
<td>270</td>
<td>13</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td>continuously cast</td>
<td>130</td>
<td>270</td>
<td>16</td>
<td>70</td>
</tr>
<tr>
<td>CuSn5ZnPb</td>
<td>sand cast</td>
<td>90</td>
<td>240</td>
<td>18</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>permanent mould cast</td>
<td>110</td>
<td>220</td>
<td>8</td>
<td>65</td>
</tr>
<tr>
<td></td>
<td>centrifugally cast</td>
<td>110</td>
<td>250</td>
<td>13</td>
<td>65</td>
</tr>
<tr>
<td></td>
<td>continuously cast</td>
<td>110</td>
<td>250</td>
<td>13</td>
<td>65</td>
</tr>
<tr>
<td>CuSn12</td>
<td>sand cast</td>
<td>140</td>
<td>260</td>
<td>12</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>permanent mould cast</td>
<td>150</td>
<td>270</td>
<td>5</td>
<td>65</td>
</tr>
<tr>
<td></td>
<td>centrifugally cast</td>
<td>150</td>
<td>280</td>
<td>8</td>
<td>65</td>
</tr>
<tr>
<td></td>
<td>continuously cast</td>
<td>150</td>
<td>300</td>
<td>6</td>
<td>65</td>
</tr>
<tr>
<td>CuSn12Ni</td>
<td>sand cast</td>
<td>160</td>
<td>280</td>
<td>14</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td>centrifugally cast</td>
<td>180</td>
<td>300</td>
<td>8</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>continuously cast</td>
<td>180</td>
<td>300</td>
<td>10</td>
<td>95</td>
</tr>
<tr>
<td>CuAl10Ni</td>
<td>sand cast</td>
<td>270</td>
<td>600</td>
<td>13</td>
<td>140</td>
</tr>
<tr>
<td></td>
<td>permanent mould cast</td>
<td>300</td>
<td>650</td>
<td>10</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td>centrifugally cast</td>
<td>300</td>
<td>700</td>
<td>13</td>
<td>160</td>
</tr>
<tr>
<td></td>
<td>continuously cast</td>
<td>300</td>
<td>700</td>
<td>13</td>
<td>160</td>
</tr>
<tr>
<td>CuAl11Ni</td>
<td>sand cast</td>
<td>320</td>
<td>680</td>
<td>5</td>
<td>170</td>
</tr>
<tr>
<td></td>
<td>permanent mould cast</td>
<td>400</td>
<td>750</td>
<td>5</td>
<td>200</td>
</tr>
<tr>
<td></td>
<td>centrifugally cast</td>
<td>400</td>
<td>750</td>
<td>5</td>
<td>185</td>
</tr>
<tr>
<td>CuNi10</td>
<td>sand cast</td>
<td>150</td>
<td>310</td>
<td>20</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>centrifugally cast</td>
<td>100</td>
<td>280</td>
<td>25</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>continuously cast</td>
<td>100</td>
<td>280</td>
<td>25</td>
<td>70</td>
</tr>
<tr>
<td>CuNi30</td>
<td>sand cast</td>
<td>230</td>
<td>400</td>
<td>18</td>
<td>115</td>
</tr>
</tbody>
</table>
4.3 CAST COPPER ALLOY PROPELLERS

4.3.1 Scope

These requirements are applicable to the moulding, casting, inspection and repair procedures of new cast copper alloy propellers, blades and bosses. Upon special consideration of the Register these requirements may also be applied for the repair and inspection of propellers becoming damaged during service.

4.3.2 Approval of the manufacturer

The manufacturer shall be approved by the Register. The approval procedure shall carried out in accordance with the Rules, Part I - General Requirements, Chapter 4 - Approval of Manufacturers and Service Suppliers. Scope of the testing for the approval shall be determined by the Register for each particular case.

4.3.3 Moulding and casting

4.3.3.1 Pouring

The pouring must be carried out into dried moulds using degassed liquid metal. The pouring is to be controlled as to avoid turbulence of flow. Special devices and/or procedures must prevent slag flowing into the mould.

4.3.3.2 Stress relieving

Subsequent stress relieving heat treatment may be performed to reduce the residual stresses. For this purpose, the manufacturer shall submit a specification containing the details of the heat treatment to the Register for approval. For stress relieving temperatures and holding times see tables 4.3.14.2 and 4.3.15.3.6.

4.3.4 General characteristics of castings

4.3.4.1 Freedom form defects

All castings must have a workman like finish and must be free from defects liable to impair their use. 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, cf. para. 4.3.14.

4.3.4.2 Removal of defects

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. They may be removed by one of the methods described in para. 4.3.14 and repaired within the limits and restrictions for the severity zones. Full description and documentation must be available for the Surveyor.

4.3.5 Dimensions, dimensional and geometrical tolerances

4.3.5.1 The dimensions and the dimensional and geometrical 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.

The accuracy and verification of the dimensions are the responsibility of the manufacturer, unless otherwise agreed.

4.3.5.2 Static balancing is to be carried out on all propellers in accordance with the approved drawing. Dynamic balancing is necessary for propellers running above 500 rpm.

4.3.6 Chemical composition and structure characteristics

4.3.6.1 Chemical composition

Typical copper propeller alloys are grouped into the four types CU1, CU2, CU3 and CU4 depending on their chemical composition as given in table 4.3.6.1. Copper alloys whose chemical composition deviate from the typical values of table 4.3.6.1 must be specially approved by the Register.

4.3.6.2 Metallurgical characteristics

Note:

The main constituents of the microstructure in the copper-based alloys categories CU1 and CU2 are alpha and beta phase.

Important properties such as ductility and resistance to corrosion fatigue are strongly influenced by the relative proportion of beta phase (too high a percentage of beta phase having a negative effect on these properties). To ensure adequate cold ductility and corrosion fatigue resistance, the proportion of beta phase is to be kept low. The concept of the zinc equivalent should be used as control since it summarises the effect of the tendency of various chemical elements to produce beta phase in the structure”.

The structure of CU1 and CU2 type alloys must contain an alpha phase component of at least 25% as measured on a test by the manufacturer. To ensure adequate ductility and corrosion fatigue resistance, the proportion of beta phase is to be kept low. For this purpose, the zinc equivalent defined by the following formula shall not exceed a value of 45%:

\[
\text{Zinc equivalent} = \frac{100 - \frac{100 \cdot C_u}{100 + A}}
\]

In which A is algebraic sum for the following values:

- 1 % Sn
- 5 % Al
- 0,5 % Mn
- 0,1 % Fe
- -0,3 % 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.
### Table 4.3.6.1

Typical chemical compositions of cast copper alloys for propellers

<table>
<thead>
<tr>
<th>Alloy type</th>
<th>Cu</th>
<th>Al</th>
<th>Mn</th>
<th>Zn</th>
<th>Fe</th>
<th>Ni</th>
<th>Sn</th>
<th>Pb</th>
</tr>
</thead>
<tbody>
<tr>
<td>CU1</td>
<td>52-62</td>
<td>0,5-3,0</td>
<td>0,5-4,0</td>
<td>35-40</td>
<td>0,5-2,5</td>
<td>max.1,0</td>
<td>max.1,5</td>
<td>max.0,5</td>
</tr>
<tr>
<td>CU2</td>
<td>50-57</td>
<td>0,5-2,0</td>
<td>1,0-4,0</td>
<td>33-38</td>
<td>0,5-2,5</td>
<td>3,0-8,0</td>
<td>max.1,5</td>
<td>max.0,5</td>
</tr>
<tr>
<td>CU3</td>
<td>77-82</td>
<td>7,0-11,0</td>
<td>0,5-4,0</td>
<td>max.1,0</td>
<td>2,0-6,0</td>
<td>3,0-6,0</td>
<td>max.0,1</td>
<td>max.0,03</td>
</tr>
<tr>
<td>CU4</td>
<td>70-80</td>
<td>6,5-9,0</td>
<td>8,0-20,0</td>
<td>max.6,0</td>
<td>2,0-5,0</td>
<td>1,5-3,0</td>
<td>max.1,0</td>
<td>max.0,05</td>
</tr>
</tbody>
</table>

### 4.3.7 Mechanical characteristics

#### 4.3.7.1 Standardised alloys

The mechanical characteristics must conform to the values shown in table 4.3.7.1. These values are applicable to test specimens taken for separately cast samples in accordance with Fig. 4.3.7.1, or with any other recognised national standard.

Note:

These properties are a measure of the mechanical quality of the metal in each heat; and they are generally not representative of the mechanical properties of the propeller casting itself, which may be up to 30% lower than that of a separately cast test coupon.

For integrally cast test specimens the requirements are specially to be agreed with the Register.

### Table 4.3.7.1

Mechanical characteristics of cast copper alloys for propellers (separately cast test coupons)

<table>
<thead>
<tr>
<th>Alloy type</th>
<th>Proof stress $R_{p0.2}$ [N/mm$^2$] min</th>
<th>Tensile strength $R_m$ [N/mm$^2$] min</th>
<th>Elongation $A_5$ [%] min</th>
</tr>
</thead>
<tbody>
<tr>
<td>CU1</td>
<td>175</td>
<td>440</td>
<td>20</td>
</tr>
<tr>
<td>CU2</td>
<td>175</td>
<td>440</td>
<td>20</td>
</tr>
<tr>
<td>CU3</td>
<td>245</td>
<td>590</td>
<td>16</td>
</tr>
<tr>
<td>CU4</td>
<td>275</td>
<td>630</td>
<td>18</td>
</tr>
</tbody>
</table>

Figure 4.3.7.1

Test sample casting

$H = 100$ mm
$B = 50$ mm
$L > 150$ mm
$T = 15$ mm
$D = 25$ mm
4.3.7.2 Other alloys

The mechanical characteristics of alloys not meeting the limiting values of Table 4.3.7.1 must be in accordance with a specification approved by the Register.

4.3.8 Inspection and tests

The following tests and inspections are to be performed. For test specimen’s dimensions and testing procedures reference is made to Chapter 2 - Methods of testing.

4.3.8.1 Chemical composition

The manufacturer shall furnish proof of the composition of each ladle.

4.3.8.2 Tensile test

4.3.8.2.1 The tensile strength 0,2% proof stress and elongation shall be determined by tensile test. For this purpose, at least one tensile test specimen shall be taken from each ladle.

4.3.8.2.2 Generally, the specimens shall be taken from separately cast sample pieces, see 4.3.7.1. The test samples shall be cast in moulds made of the same material as the mould for the propeller and they must be cooled down under the same conditions as the propeller.

4.3.8.2.3 If propellers are subjected to a heat treatment the test samples are to be heat treated together with them.

4.3.8.2.4 Where test specimens are to be taken from integrally cast test samples, this shall be the subject of special agreement with the Register. Wherever possible, the test samples shall be located on the blades in an area lying between 0,5 to 0,6 R, where R is the radius of the propeller. The test sample material must be removed from the casting by non thermal procedures.

4.3.8.3 Micrographic examination

The micro structure of alloy types CU1 and CU2 shall be verified by determining the proportion of alpha phase. For this purpose, at least one specimen shall be taken from each heat. The proportion of alpha phase shall be determined as the average value of 5 counts. The requirements of para. 4.3.6.2 are to be fulfilled.

4.3.8.4 Surface quality and dimensions

4.3.8.4.1 Propeller casting should be visually inspected at all stages of manufacture and the whole surface is to be subjected to a comprehensive visual inspection in the finished condition by the Surveyor. This has to include the bore.

4.3.8.4.2 The dimensions are to be checked by the manufacturer and the report on the dimensional inspection is to be handed over to the Surveyor, who may require checks to be made in his presence.

4.3.8.4.3 The Surveyor may require areas to be etched (e.g. by iron chloride) for the purpose of investigating weld repairs.

4.3.8.4.4

4.3.8.4.5

4.3.8.4.6

4.3.9 Non-destructive inspections

4.3.9.1 Dye penetrant inspection

4.3.9.1.1 The severity zones “A” (see para. 4.3.12) are to be subjected to a dye penetrant inspection in the presence of the Surveyor. For the inspection and acceptance standard see para. 4.3.13. In zones “B” and “C” the dye penetrant inspection is to be performed by the manufacturer and may be witnessed by the Surveyor upon his request.

4.3.9.1.2 If repairs have been made either by grinding or by welding the repaired areas are additionally to be subjected to the dye penetrant inspection independent of their location and/or severity zone.

4.3.9.2 Radiographic and ultrasonic inspection

Where serious doubts exist that the castings are not free from internal defects further non-destructive inspections are to be carried out upon request of the Surveyor, e.g. radiographic and/or ultrasonic tests. For this purpose, the following is to be observed:

The acceptance criteria are to be agreed between the manufacturer and the Register in accordance with a recognised standard.

Footnote for Guidance

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 Co 60 gamma-rays up to 160 mm thickness. Due to the limited thickness’ that can be radiographed as well as for other practical reasons radiography is generally not a realistic method for checking of the thickest parts of large propellers.

As a general rule, ultrasonic testing of CU1 and CU2 is not feasible due to the high damping capacity of these materials. For CU3 and CU4, ultrasonic inspection of subsurface defects is possible.

4.3.9.3 Documentation of defects and inspections

All defects requiring welding repair on the castings are to be documented preferably on drawings or special sketches showing their dimensions and locations. Furthermore, the inspection procedure is to be reported. The documentation is to be presented to the Surveyor prior to any repair weldings will be carried out.

4.3.10 Identification and marking

4.3.10.1 Identification

Identification the manufacturer must employ a monitoring system which enables all castings to be traced back to their heats. on request, the Surveyor shall be given proof of this.

4.3.10.2 Marking

Prior to final inspection by the Surveyor each casting shall be marked by the manufacturer at least with the following symbols:

a) Grade of cast material or corresponding abbreviated designation
b) Manufacturer’s mark
c) Heat number, casting number or another mark enabling the manufacturing process to be traced back.
d) Specimen number
e) Date of final inspection
f) Number of the Register’s test certificate
g) Ice class symbol, where applicable
h) Skew angle for high skew propellers.

**4.3.11 Manufacturer’s certificates**

For each propeller the manufacturer must supply to the Surveyor a certificate containing the following details:

a) Purchaser and order number
b) Shipbuilding project number, if known
c) Description of the casting with drawing number
d) Diameter, number of blades, pitch, direction of turning
e) Grade of alloy and chemical composition of each heat
f) Heat or casting number
g) Final weight
h) Results of non-destructive tests and details of test procedure where applicable
i) Portion of alpha-structure for CU1 and CU2 alloys
j) Results of the mechanical tests
k) Casting identification No.
l) Skew angle for high skew propellers, see 4.3.12.1

**4.3.12 Definition of skew and severity zones**

**4.3.12.1 Definition of skew**

The skew of a propeller is defined as follows:

The maximum skew angle of a propeller blade if defined as the angle, in projected view of the blade, between a line drawn through the blade tip and the shaft centre-line and a second line through the shaft centreline which acts as a tangent to the locus of the mid-points of the helical blade section, see Fig. 4.3.12.1.

High skew propellers have a skew angle greater than 25°, low skew propellers a skew angle of up to 25°.

**4.3.12.2 Severity zones**

In order to relate the degree of inspection to the criticality of defects in propeller blades and to help reduce the risk of failure by fatigue cracking after repair, propeller blades are divided into the three zones designated A, B and C.

Zone A is the region carrying the highest operating stresses and which, therefore, requires the highest degree of inspection. Generally, the blade thickness are greatest in this area giving the greatest degree of restraint in repair welds and this in turn leads to the highest residual stresses in and around any repair welds. High residual tensile stresses frequently lead to fatigue cracking during subsequent service so that relief of these stresses by heat treatment is essential for any welds made in this zone. Welding is generally not permitted in Zone A and will only be allowed after special consideration by the Register. Every effort should be made to rectify a propeller which is either defective or damaged in this area without recourse to welding even to the extent of reducing the scantlings, if this is acceptable. If a repair using welding is agreed, postweld stress relief heat treatment is mandatory.

Zone B is a region where the operation stresses may be high. Welding should preferably be avoided but generally is allowed subject to prior approval from the Register. Complete details of the defect/damage and the intended repair procedure are to be submitted for each instance in order to obtain such approval.

Zone C is a region in which the operation stresses are low and where the blade thickness are relatively small so that repair welding is safer and, if made in accordance with an approved procedure is freely permitted.

**4.3.12.2.1 Low-skew propellers**

Zone A is in the area on the pressure side of the blade, from and including the fillet to 0.4R 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 Fig. 4.3.12.2.1).

Where the hub radius (Rb) exceeds 0.27R, the other boundary of zone A is to be increased to 1.5 Rb.

Zone A also includes the parts of the separate cast propeller hub which lie in the area of the windows as described in Fig. 4.3.12.2.3 and the flange and fillet area of controllable pitch and built-up propeller blades as described in Fig. 4.3.12.2.4.

Zone B is on the pressure side the remaining area up to 0.7R and on the suction side the area from the fillet to 0.7R (see Fig. 4.3.12.2.1).

Zone C is the area outside 0.7R on both sides of the blade. It also includes the surface of the hub of a monobloc propeller and all the surfaces of the hub of a controllable pitch propeller other than those designated Zone A above.
Figure 4.3.12.2.1
Severity zones for integrally cast low skew propellers

Figure 4.3.12.2.2
Severity zones in blades with skew angles greater than 25°
Figure 4.3.12.2.3
Severity zones for controllable pitch propeller boss

Figure 4.3.12.2.4
Severity zones for controllable pitch and built-up propeller

Note:
The remaining surface of the propeller blades are to be divided into the severity zones as given for solid cast propellers (cf. Fig.4.3.12.2.1 and Fig.4.3.12.2.2).
4.3.12.2  High-skew propellers

Zone A 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 for the root to 0.9 R and with its inner boundary at 0.15 of the chord lengths from the trailing edge.

Zone B constitutes the whole of the remaining blade surfaces.

Zone A and B are illustrated in Fig.4.3.12.2.2

4.3.13  Acceptance criteria for dye penetrant inspection

4.3.13.1  Inspection procedure

The dye penetrant inspection is to be carried out in accordance with a standard or specification approved by the Register.

4.3.13.2  Definitions

Indication:

In the dye penetrant inspection and indication is the presence of detectable bleed-out of the penetrant liquid from the material discontinuities appearing at least 10 minutes after the developer has been applied.

Shape of indications:

A distinction is made between circular, linear and aligned indications, see Fig. 4.3.13.1

Reference area: The reference area is defined as an area of 100 cm² which may be square or rectangular with the major dimension not exceeding 250 mm.

4.3.13.3  Acceptance standard

4.3.13.3.1 For the judgement, the surface to be inspected is to be divided into reference areas of 200 cm² as given in the definitions, see para. 4.3.13.2. The indications detected may, with respect to their size and number, not exceed the values given in the Table 4.3.13.2.

The area shall be taken in the most unfavourable location relative to the indication being evaluated.

4.3.13.3.2 Areas which are prepared for welding are independent of their location always to be assessed according to zone A. The same applies to the welded areas after being finished machined and/or ground.

![Shape of indications](image)

**Figure 4.3.13.1**

Shape of indications

<table>
<thead>
<tr>
<th>Severity zones</th>
<th>Max. total number of indications</th>
<th>Type of indication</th>
<th>Max. number of each type of indications</th>
<th>Max. acceptable value for “a” or “l” of indications [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>7</td>
<td>Circular</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Linear</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Aligned</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>B</td>
<td>14</td>
<td>Circular</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Linear</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Aligned</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>C</td>
<td>20</td>
<td>Circular</td>
<td>14</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Linear</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Aligned</td>
<td>6</td>
<td>6</td>
</tr>
</tbody>
</table>

**Notes:**

1) Singular circular indications less than 2 mm for zone A and less than 3 mm for the other zones may be disregarded.

2) The total number of circular indications may be increased to the max. total number, or part thereof, represented by the absence of linear/aligned indications.
4.3.14 Repair of defects

4.3.14.1 Definition

Indications exceeding the acceptance standard of Table 4.3.13.2, cracks, shrinkage cavities, sand, slag and other non-metallic inclusions, blow holes and other discontinuities which may impair the safe service of the propeller are defined as defects and must be repaired.

4.3.14.2 Repair procedures

4.3.14.2.1 In general the repairs shall be carried out by mechanical means, e.g. by grinding, chipping or milling. Welding may be applied subject to the agreement of the Register’s Surveyor if the requirements of the paragraphs 4.3.14.3, 4.3.14.4 and/or 4.3.14.5 will be complied with.

4.3.14.2.2 After milling or chipping grinding is to be applied for such defects which are not to be welded. Grinding is to be carried out in such a manner that the contour of the ground depression is as smooth as possible in order to avoid stress concentrations or to minimise cavitation corrosion.

4.3.14.2.3 Welding of areas less than 5 cm² is to be avoided.

4.3.14.3 Repair of defects in zone A

4.3.14.3.1 In zone A repair welding will generally not be allowed unless specially approved by the Register.

4.3.14.3.2 Grinding may be carried out to an extent which maintains the blade thickness of the approved drawing.

4.3.14.3.3 The possible repair of defects which are deeper than those referred to above is to be considered by the Register.

4.3.14.4 Repair of defects in zone B

4.3.14.4.1 Defects that are not deeper than \( dB = (t/40) \) mm \((t = \text{min. local thickness in mm according to the Rules})\) or 2 mm (whichever is greatest) below min. local thickness according to the Rules should be removed by grinding.

4.3.14.4.2 Those defects that are deeper than allowable for removal by grinding may be repaired by welding.

4.3.14.5 Repair of defects in zone C

In zone C, repair welds are generally permitted.

4.3.15 Repair Welding

4.3.15.1 General requirements

4.3.15.1.1 Companies wishing to carry out welding work on propellers must have at their disposal the necessary workshops, lifting gear, welding equipment, preheating and, where necessary, annealing facilities, testing devices as well as certified welders and expert welding supervisors to enable them to perform the work properly. Proof shall be furnished to the Surveyor that these conditions are satisfied before welding work begins.

4.3.15.1.2 The company concerned shall prepare and submit to the Register a detailed welding specification covering the weld preparation, welding procedure, filler metals, preheating and post weld heat treatment and inspection procedures.

4.3.15.1.3 Before welding is started, Welding Procedure Qualification Test are to be carried out and witnessed by the Surveyors. Each welder/operator is to demonstrate his ability to carry out the proposed welding using the same process, consumable and position which are to be used in actual repair (the scope of tests is given in 4.3.17).

4.3.15.2 Welding preparation

Defects to be repaired by welding are to be ground to sound material according to the requirements as given under para 4.3.14.2. To ensure complete removal of the defects the ground areas are to be examined by dye penetrant methods in the presence of the Surveyor. The welding grooves are to be prepared in such a manner which will allow a good fusion of the groove bottom.

4.3.15.3 Welding repair procedure

4.3.15.3.1 Metal arc welding is recommended for all types of repair on bronze propellers.

For material thickness less than 30 mm, gas welding may give a satisfactory weldment for CU1 and CU2 materials.

Arc welding with coated electrodes and gas-shielded metal arc process (GMAW) are generally to 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 4.3.15.3.1.

4.3.15.3.2 Adequate pre-heating is to be carried out with care to avoid local overheating, c.f. Table 4.3.15.3.1.

4.3.15.3.3 All propeller alloys are generally to be welded in down-hand (flat) position. Where this cannot be done, gas-shielded metal arc welding should be carried out.

The section to be welded is to be clean and dry. Flux-coated electrodes are to be dried before welding according to the maker’s instructions.

To minimise distortion and the risk of cracking, interpass temperatures are to be kept low. This is especially the case with CU3 alloys.

Slag, undercut and other defects are to be removed before depositing the next run.

4.3.15.3.4 All welding work is to be carried out preferably in the shop free from draughts and influence of the weather.

4.3.15.3.5 With the exception of alloy CU3 (Ni-Al-bronze) all weld repairs are to be stress relief heat treated, in order to avoid stress corrosion cracking. However, stress relief heat treatment of alloy CU3 propeller castings may be required after major repairs in zone B (and specially approved welding in Zone A) or if a welding consumable susceptible to stress corrosion cracking is used. In such cases the propeller is to be either stress relief heat treated in the tem-
temperature 450 to 500°C or annealed in the temperature range 650-800°C, depending on the extent of repair, c.f. Table 4.3.15.3.1.

**4.3.15.3.6** The soaking times for stress relief heat treatment of copper alloy propellers should be in accordance with Table 4.3.15.3.6. The heating and cooling is to be carried out slowly under controlled conditions. The cooling rate after any stress relieving heat treatment shall not exceed 50°C/h until the temperature of 200°C is reached.

<table>
<thead>
<tr>
<th>Table 4.3.15.3.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recommended filler metals and heat treatments</td>
</tr>
<tr>
<td><strong>Alloy type</strong></td>
</tr>
<tr>
<td>CU1</td>
</tr>
<tr>
<td>CU2</td>
</tr>
<tr>
<td>CU3</td>
</tr>
<tr>
<td>CU4</td>
</tr>
</tbody>
</table>

Notes:
1) Ni-Al-bronze and Mn-Al bronze are acceptable
2) Stress relieving not required, if filler metal Ni-Al bronze is used.

<table>
<thead>
<tr>
<th>Table 4.3.15.3.6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soaking times for stress relief heat treatment of copper alloy propellers</td>
</tr>
<tr>
<td><strong>Stress relief temperature °C</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>350</td>
</tr>
<tr>
<td>400</td>
</tr>
<tr>
<td>450</td>
</tr>
<tr>
<td>500</td>
</tr>
<tr>
<td>550</td>
</tr>
<tr>
<td>600</td>
</tr>
</tbody>
</table>

Note:
1) 550°C and 600°C only applicable for CU4 alloys.

**4.3.16 Straightening**

**4.3.16.1 Application of load**

For hot and cold straightening purposes, static loading only is to be used.

**4.3.16.2 Hot straightening**

Hot straightening of a bent propeller blade or a pitch modification should be carried out after heating the bent region and approximately 500 mm wide zones on either side of it to the suggested temperature range given in Table 4.3.15.3.1. The heating should be slow and uniform and the concentrated flames such as oxy-acetylene and oxy-propane should not be used. Sufficient time should be allowed for the temperature to become fairly uniform through the full thickness for the blade section. The temperature must be maintained within the suggested range throughout the straightening operation. A thermocouple instrument or temperature indicating crayons should be used for measuring the temperature.

**4.3.16.3 Cold straightening**

Cold straightening should be used for minor repairs of tips and edges only. Cold straightening on CU1, CU2...
and CU4 bronze should always be followed by a stress relieving heat treatment, see Table 4.3.15.3.1.

4.3.17  Welding procedure and welder’s qualification test

4.3.17.1  General

The qualification test is to be carried out with the same welding process filler metal, preheating and stress-relieving treatment as those intended applied by the actual repair work.

4.3.17.2  Test sample

A test sample of minimum 30 mm thickness is to be welded in down-hand (flat) position. The test specimens to be prepared and their dimensions are shown in Fig. 4.3.17.1-1.

4.3.17.3  Qualification testing

4.3.17.3.1  Non-destructive testing

After completion, the weldment is to be 100% tested by a dye-penetrant method. No cracks are permitted.

4.3.17.3.2  Macro-etching

Three macro-etch samples should be prepared (see Fig. 4.3.17.1-1). A suitable etching for this purpose is:

- 5 g iron (III) chloride
- 30 ml hydrochloric acid (cone)
- 100 ml water

Pores greater than 3 mm and cracks are not permitted.

4.3.17.3.3  Mechanical testing:

Two tensile tests should be prepared as shown in Ch. 2.4.2.8 b). The table requirements to the tensile strength, a given in Table 4.3.17.3.3, should be met. Alternatively tensile test specimens according to recognised standards may be used.

<table>
<thead>
<tr>
<th>ALLOY TYPE</th>
<th>TENSILE STRENGTH N/mm², min</th>
</tr>
</thead>
<tbody>
<tr>
<td>CU1</td>
<td>370</td>
</tr>
<tr>
<td>CU2</td>
<td>410</td>
</tr>
<tr>
<td>CU3</td>
<td>500</td>
</tr>
<tr>
<td>CU4</td>
<td>550</td>
</tr>
</tbody>
</table>

Figure 4.3.17.1-1
Test specimen
5 ALUMINIUM ALLOYS

5.1 ALUMINIUM WROUGHT ALLOYS

5.1.1 General

5.1.1.1 These requirements apply to wrought aluminium alloys used in the construction of hulls, superstructures and other marine structures. They are not applicable to the use of aluminium alloys at low temperature for cryogenic applications.

5.1.1.2 These Requirements are applicable to wrought aluminium alloy products within a thickness range of 3 mm and 50 mm inclusive. The application of aluminium alloys products outside this thickness range requires prior agreement of the Register.

5.1.1.3 The numerical designation (grade) of aluminium alloys and the temper designation are based on those of the Aluminium Association.

5.1.1.4 Temper conditions (delivery heat treatment) are defined in the European Standard EN 515, or ANSI H35.1.

5.1.1.5 Consideration may be given to aluminium alloys not specified in these Requirements, and to alternative temper conditions, subject to prior agreement with the Register further to a detailed study of their properties, including corrosion resistance, and of their conditions of use (in particular-welding procedures).

5.1.2 Approval

5.1.2.1 All materials, including semi finished products, are to be manufactured at works which are approved by the Register for the grades of aluminium alloy supplied.

5.1.3 Aluminium alloys and their temper conditions

5.1.3.1 Rolled products (sheets, strips and plates)

The following aluminium alloys are covered by these Requirements:

- 5083, 5086, 5383, 5059, 5754, 5456
  with the hereunder temper conditions:
  - O, H111, H112, H116, H321

5.1.3.2 Extruded products (sections, shapes bars and closed profiles)

The following aluminium alloys are covered by these Requirements:

- 5083, 5086, 5383, 5059
  with the hereunder temper conditions:
  - O, H111, H112,
  - 6005A, 6061, 6082

with the hereunder temper conditions:

- T5 or T6

Note:

The alloy grades 6005A, 6061 of the 6000 series should not be used in direct contact with sea water unless protected by anodes and/or paint system.

5.1.4 Chemical composition

5.1.4.1 The manufacturer is to determine the chemical composition of each cast.

5.1.4.2 The chemical composition of aluminium alloys is to comply with the requirement’s given in Table 5.1.4.

5.1.4.3 The Manufacturer’s declared analysis will be accepted subject to occasional checks if required by the Surveyor, in particular, product analysis may be required where the final product chemistry is not well represented by the analysis from the cast.

5.1.4.4 When the aluminium alloys are not cast in the same works in which they are manufactured into semi finished products, the Register’s Surveyor shall be given a certificate issued by the works in question which indicates the reference numbers and chemical composition of the heats.

5.1.5 Mechanical properties

5.1.5.1 The mechanical properties are to comply with the requirements given in tables 5.1.5.2 and 5.1.5.3.

Note:

It should be recognised that the mechanical properties of the welded joint are lower for strain hardened or heat treated alloys, when compared with those of the base material, in general. For reference, see the requirements for Aluminium Consumables.(Rules Part 26-Welding).

5.1.6 Freedom of defects

5.1.6.1 The finished material is to have a workmanlike finish and is to be free from internal and surface defects prejudicial to the use of the concerned material for the intended application.

5.1.6.2 Slight surface imperfections may be removed by smooth grinding or machining as long as the thickness of the material remains within the tolerances given in Section 5.1.7.

5.1.7 Tolerances

5.1.7.1 The underthickness tolerances for rolled products given in Table 5.1.5 are minimum requirements.

5.1.7.2 The underthickness tolerances for extruded products are to be in accordance with the requirements of recognized international or national standards.

5.1.7.3 Dimensional tolerances other than underthickness tolerances given in Table 5.1.5 are to comply with a recognised national or international standard.
5.1.8 Testing and inspection

5.1.8.1 Tensile test

The test specimens and procedures are to be in accordance with Chapter 2.

5.1.8.2 Non-destructive examination.

In general, the non-destructive examination of material is not required for acceptance purposes.

Note:

Manufacturers are expected, however, to employ suitable methods of non-destructive examination for the general maintenance of quality standards.

5.1.8.3 Dimensions

It is the manufacturer’s responsibility to check the materials for compliance with the tolerances given in Section 5.1.7.

5.1.8.4 Verification of proper fusion of press welds for closed profiles

5.1.8.4.1 The manufacturer has to demonstrate by macrosection tests or drift expansion tests of closed profiles performed on each batch of closed profiles that there is no lack of fusion at the press welds.

5.1.8.4.2 Drift expansion tests

.1 Every fifth profile shall be sampled after final heat treatment.

.2 Each profile sampled will have two samples cut from the front and end of the production profile.

.3 The test specimens are to be cut with the ends perpendicular to the axis of the profile.

.4 The length of the specimen is to be in accordance with Chapter 2.

.5 Testing is to be carried out at ambient temperature and is to consist of expanding the end of the profile by means of a hardened conical steel mandrel having and included angle of at least 60°.

.6 The sample is considered to be unacceptable if the sample fails with a clean split along the weld line which confirms lack of fusion.

5.1.8.5 Corrosion testing

5.1.8.5.1 Rolled 5xxx-alloys of type 5083, 5383, 5059, 5086 and 5456 in the H116 and H321 tempers intended for use in marine hull construction or in marine applications where frequent direct contact with seawater is expected are to be corrosion tested with respect to exfoliation and intergranular corrosion resistance.

5.1.8.5.2 The manufacturers shall establish the relationship between microstructure and resistance to corrosion when the above alloys are approved. A reference photomicrograph taken at 500x, under the conditions specified in ASTM B928, Section 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 exhibited no evidence of exfoliation corrosion and a pitting rating of PB or better, when subjected to the test described in ASTM G66 (ASSET). The samples shall also have exhibited resistance to intergranular corrosion at a mass loss no greater than 15 mg/cm², when subjected to the test described in ASTM G67 (NAMLT). Upon satisfactory establishment of the relationship between microstructure and resistance to corrosion, the master photomicrographs and the results of the corrosion tests are to be approved by the Register. Production practices shall not be changed after approval of the reference micrographs.

Other test methods may also be accepted at the discretion of the Register.

5.1.8.5.3 For batch acceptance of 5xxx-alloys in the H116 and H321 tempers, metallographic examination of one sample selected from mid width at one end of a coil or random sheet or plate is to be carried out. The microstructure of the sample is to be compared to the reference photomicrograph of acceptable material in the presence of the Surveyor. A longitudinal section perpendicular to the rolled surface shall be prepared for metallographic examination, under the conditions specified in ASTM B928, Section 9.6.1. If the microstructure shows evidence of continuous grain boundary network of aluminium-magnesium precipitate in excess of the reference photomicrographs of acceptable material, the batch is either to be rejected or tested for exfoliation-corrosion resistance and intergranular corrosion resistance subject to the agreement of the Surveyor. The corrosion tests are to be in accordance with ASTM G66 and G67 or equivalent standards. Acceptance criteria are that the sample shall exhibit no evidence of exfoliation corrosion and a pitting rating of PB or better when test subjected to ASTM G66 ASSET test, and the sample shall exhibit resistance to intergranular corrosion at a mass loss no greater than 15 mg/cm² when subjected to ASTM G67 NAMLT test. If the results from testing satisfy the acceptance criteria stated in paragraph 5.1.8.5.2 the batch is accepted, else it is to be rejected.

As an alternative to metallographic examination, each batch may be tested for exfoliation-corrosion resistance and intergranular corrosion resistance, in accordance with ASTM G66 and G67 under the conditions specified in ASTM B928, or equivalent standards. If this alternative is used, then the results of the test must satisfy the acceptance criteria stated in paragraph 5.1.8.5.3.

5.1.9 Test materials

5.1.9.1 Definition of batches

Each batch is made up of products:

- of the same alloy grade and from the same cast
of the same product form and similar dimensions (for plates, the same thickness)
- manufactured by the same process
- having been submitted simultaneously to the same temper condition.

5.1.9.2 The test samples are to be taken
- at one third of the width from a longitudinal edge of rolled products.
- In the range 1/3 to 1/2 of the distance from the edge to the centre of the thickest part of extruded products.

5.1.9.3 Test samples are to be taken so that the orientation of test specimens is as follows:
   a) Rolled products
      Normally, tests in the transverse direction are required. If the width is insufficient to obtain transverse test specimen, or in the case of strain hardening alloys, test in the longitudinal direction will be permitted.
   b) Extruded products
      The extruded products are tested in longitudinal direction.

5.1.9.4 After removal of test samples, each test specimen is to be marked in order that its original identity, location and orientation is maintained.

5.1.10 Mechanical test specimens

5.1.10.1 Type and location of tensile test specimens are to be in accordance with Chapter 2.

5.1.11 Number of test specimens

5.1.11.1 Tensile test
   a) Rolled products
      One tensile test specimen is to be taken from each batch of the product. If the weight of one batch exceeds 2000 kg, one extra tensile test specimen is to be taken from every 2000 kg of the product or fraction thereof, in each batch.
      For single plates or for coils weighting more than 2000 kg each, only one tensile test specimen per plate or coil shall be taken.
   b) Extruded products
      For the products with a nominal weight of less than 1 kg/m, one tensile test specimen is to be taken from each 1000 kg, or fraction thereof, in each batch. For nominal weights between 1 and 5 kg/m, one tensile test specimen is to be taken from each 2000 kg or fraction thereof, in each batch. If the nominal weight exceeds 5 kg/m, one tensile test specimen is to be taken for each 3000 kg of the product or fraction thereof, in each batch.

5.1.11.2 Verification of proper fusion of press welds
   For closed profiles, verification of proper fusion of press welds is to be performed on each batch as indicated in 5.1.8.4.

5.1.11.3 Corrosion tests
   For rolled plates of grade 5083, 5383, 5059, 5086 and 5456 delivered in the tempers H116 or H321, one sample is to be tested per batch.

5.1.12 Re-testing procedures

5.1.12.1 When the tensile test from the first piece selected in accordance with Section 5.1.11 fails to meet the requirements, two further, tensile tests may be made from the same piece. If both of these additional tests are satisfactory, this piece and the remaining pieces from the same batch may be accepted.

5.1.12.2 If one or both the additional test referred to above are unsatisfactory, the piece is to be rejected, but the remaining material from the same batch may be accepted provided that two of the remaining pieces in the batch selected in the same way, are tested with satisfactory results. If unsatisfactory results are obtained from either of these two pieces then the batch of material is to be rejected.

5.1.12.3 In the event or any material bearing the Register’s brand failing to comply with the test requirements, the brand is to be unmistakably defaced by the manufacturer.

5.1.13 Marking

5.1.13.1 The manufacturer shall mark each product at least one place with the following details:
   a) Manufacturer’s mark
   b) Abbreviated designation of aluminium alloy according to Section 5.1.3
   c) Abbreviated designation of temper condition according to Section 5.1.3.
   d) Tempers that are corrosion tested in accordance with section 5.1.8.5 are to be marked “M” after the temper condition, e.g. 5083 H321 M.
   e) Number of the manufacturing batch enabling the manufacturing process to be traced back.

5.1.13.2 The product is also to bear the Register’s brand.

5.1.13.3 When extruded products are bundled together or packed in crates for delivery, the marking specified in para 5.1.13.1 should be affixed by a securely fastened tag or label.

5.1.14 Documentation

5.1.14.1 For each tested batch, the manufacturer must supply to the Register’s Surveyor a test certificate, or a shipping statement containing the following details:
   a) Purchaser and order number
   b) Construction project number, when known
   c) Number, dimensions and weight of the product
d) Designation of the aluminium alloy (grade) and of its temper condition (delivery heat treatment).

e) Chemical composition

f) Manufacturing batch number or identifying mark

g) Mechanical test results

h) Corrosion test results (if any).

Table 5.1.4
Chemical composition

<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>Each</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>5083</td>
<td>0.40</td>
<td>0.40</td>
<td>0.10</td>
<td>0.40-1.0</td>
<td>4.0-4.9</td>
<td>0.05-0.25</td>
<td>0.25</td>
<td>0.15</td>
<td>0.05</td>
<td>0.15</td>
</tr>
<tr>
<td>5383</td>
<td>0.25</td>
<td>0.25</td>
<td>0.20</td>
<td>0.7-1.0</td>
<td>4.0-5.2</td>
<td>0.25</td>
<td>0.40</td>
<td>0.15</td>
<td>0.05</td>
<td>0.15</td>
</tr>
<tr>
<td>5059</td>
<td>0.45</td>
<td>0.50</td>
<td>0.25</td>
<td>0.6-1.2</td>
<td>5.0-6.0</td>
<td>0.25</td>
<td>0.40-0.90</td>
<td>0.20</td>
<td>0.05</td>
<td>0.15</td>
</tr>
<tr>
<td>5086</td>
<td>0.40</td>
<td>0.50</td>
<td>0.10</td>
<td>0.20-0.70</td>
<td>3.5-4.5</td>
<td>0.05-0.25</td>
<td>0.25</td>
<td>0.15</td>
<td>0.05</td>
<td>0.15</td>
</tr>
<tr>
<td>5754</td>
<td>0.40</td>
<td>0.40</td>
<td>0.10</td>
<td>0.50(^7)</td>
<td>2.6-3.6</td>
<td>0.30(^7)</td>
<td>0.20</td>
<td>0.15</td>
<td>0.05</td>
<td>0.15</td>
</tr>
<tr>
<td>5456</td>
<td>0.25</td>
<td>0.40</td>
<td>0.10</td>
<td>0.50-1.0</td>
<td>4.7-5.5</td>
<td>0.05-0.20</td>
<td>0.25</td>
<td>0.20</td>
<td>0.05</td>
<td>0.15</td>
</tr>
<tr>
<td>6005A</td>
<td>0.50-0.90</td>
<td>0.35</td>
<td>0.30</td>
<td>0.50(^7)</td>
<td>0.40-0.70</td>
<td>0.30(^7)</td>
<td>0.20</td>
<td>0.10</td>
<td>0.05</td>
<td>0.15</td>
</tr>
<tr>
<td>6061</td>
<td>0.40-0.80</td>
<td>0.70</td>
<td>0.15-0.40</td>
<td>0.15</td>
<td>0.8-1.2</td>
<td>0.40-0.35</td>
<td>0.25</td>
<td>0.15</td>
<td>0.05</td>
<td>0.15</td>
</tr>
<tr>
<td>6082</td>
<td>0.7-1.3</td>
<td>0.50</td>
<td>0.10</td>
<td>0.40-1.0</td>
<td>0.6-1.2</td>
<td>0.25</td>
<td>0.20</td>
<td>0.10</td>
<td>0.05</td>
<td>0.15</td>
</tr>
</tbody>
</table>

Notes:

1) Composition in percentage mass by mass maximum unless shown as a range or as a minimum.
2) Includes Ni, Ga, V and listed elements for which no specific limit is shown. Regular analysis need not be made.
3) Mn + Cr: 0.10-0.60
4) Mn + Cr: 0.12-0.50
5) Zr: maximum 0.20. The total for other elements does not include Zirconium.
6) Zr: 0.05-0.25. The total for other elements does not include Zirconium.
Table 5.1.5.2
Mechanical properties for rolled products, $3 \text{ mm} \leq t \leq 50 \text{ mm}$

<table>
<thead>
<tr>
<th>Grade</th>
<th>Temper condition3)</th>
<th>Thickness, t</th>
<th>Yield strength Rp0.2 min. or range N/mm²</th>
<th>Tensile strength Rm min. or range N/mm²</th>
<th>Elongation, % min.1)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>$A_{50\text{mm}}$</td>
<td>$A_{5d}$</td>
<td></td>
</tr>
<tr>
<td>5083</td>
<td>O</td>
<td>$3 \leq t \leq 50 \text{ mm}$</td>
<td>125</td>
<td>275-350</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>H111</td>
<td>$3 \leq t \leq 50 \text{ mm}$</td>
<td>125</td>
<td>275-350</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>H112</td>
<td>$3 \leq t \leq 50 \text{ mm}$</td>
<td>125</td>
<td>275</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>H116</td>
<td>$3 \leq t \leq 50 \text{ mm}$</td>
<td>215</td>
<td>305</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>H321</td>
<td>$3 \leq t \leq 50 \text{ mm}$</td>
<td>215-295</td>
<td>305-385</td>
<td>12</td>
</tr>
<tr>
<td>5383</td>
<td>O</td>
<td>$3 \leq t \leq 50 \text{ mm}$</td>
<td>125</td>
<td>275-350</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>H111</td>
<td>$3 \leq t \leq 50 \text{ mm}$</td>
<td>125</td>
<td>275-350</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>H112</td>
<td>$3 \leq t \leq 50 \text{ mm}$</td>
<td>125</td>
<td>275</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>H116</td>
<td>$3 \leq t \leq 50 \text{ mm}$</td>
<td>220</td>
<td>305</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>H321</td>
<td>$3 \leq t \leq 50 \text{ mm}$</td>
<td>220</td>
<td>305</td>
<td>10</td>
</tr>
<tr>
<td>5059</td>
<td>O</td>
<td>$3 \leq t \leq 50 \text{ mm}$</td>
<td>160</td>
<td>330</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>H111</td>
<td>$3 \leq t \leq 50 \text{ mm}$</td>
<td>160</td>
<td>330</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>H116</td>
<td>$3 \leq t \leq 20 \text{ mm}$</td>
<td>270</td>
<td>370</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>$20 &lt; t \leq 50 \text{ mm}$</td>
<td>260</td>
<td>360</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>H321</td>
<td>$3 \leq t \leq 20 \text{ mm}$</td>
<td>270</td>
<td>370</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>$20 &lt; t \leq 50 \text{ mm}$</td>
<td>260</td>
<td>360</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>5086</td>
<td>O</td>
<td>$3 \leq t \leq 50 \text{ mm}$</td>
<td>95</td>
<td>240-305</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>H111</td>
<td>$3 \leq t \leq 50 \text{ mm}$</td>
<td>95</td>
<td>240-305</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>H112</td>
<td>$3 \leq t \leq 12,5 \text{ mm}$</td>
<td>125</td>
<td>250</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>$12,5 &lt; t \leq 50 \text{ mm}$</td>
<td>105</td>
<td>250</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>H116</td>
<td>$3 \leq t \leq 50 \text{ mm}$</td>
<td>195</td>
<td>275</td>
<td>9</td>
</tr>
<tr>
<td>5754</td>
<td>O</td>
<td>$3 \leq t \leq 50 \text{ mm}$</td>
<td>80</td>
<td>190-240</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>H111</td>
<td>$3 \leq t \leq 50 \text{ mm}$</td>
<td>80</td>
<td>190-240</td>
<td>18</td>
</tr>
<tr>
<td>5456</td>
<td>O</td>
<td>$3 \leq t \leq 6,3 \text{ mm}$</td>
<td>130-205</td>
<td>290-365</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>$6,3 &lt; t \leq 50 \text{ mm}$</td>
<td>125-205</td>
<td>285-360</td>
<td>16</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>H116</td>
<td>$3 \leq t \leq 30 \text{ mm}$</td>
<td>230</td>
<td>315</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>$30 &lt; t \leq 40 \text{ mm}$</td>
<td>215</td>
<td>305</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>$40 &lt; t \leq 50 \text{ mm}$</td>
<td>200</td>
<td>285</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>H321</td>
<td>$3 \leq t \leq 12,5 \text{ mm}$</td>
<td>230-315</td>
<td>315-405</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>$12,5 &lt; t \leq 50 \text{ mm}$</td>
<td>215-305</td>
<td>305-385</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>$40 &lt; t \leq 50 \text{ mm}$</td>
<td>200-295</td>
<td>285-370</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>

Notes:
1) Elongation in 50 mm apply for thicknesses up to and including 12.5 mm and in 5d for thicknesses over 12.5 mm.
2) 8% for thicknesses up to and including 6.3 mm.
3) The mechanical properties for the O and H111 tempers are the same. However, they are separated to discourage dual certification as these tempers represent different processing.
### Table 5.1.5.3
Mechanical properties for extruded products 3 ≤ t ≤ 50 mm

<table>
<thead>
<tr>
<th>Grade</th>
<th>Temper</th>
<th>Thickness, t</th>
<th>Yield strength $R_{0.2}$ min N/mm²</th>
<th>Tensile strength $R_m$ min. or range N/mm²</th>
<th>Elongation, % min.</th>
<th>$A_{50\text{mm}}$</th>
<th>$A_{5d}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>5083</td>
<td>O</td>
<td>3 ≤ t ≤ 50 mm</td>
<td>110</td>
<td>270-350</td>
<td>14</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td></td>
<td>H111</td>
<td>3 ≤ t ≤ 50 mm</td>
<td>165</td>
<td>275</td>
<td>12</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td></td>
<td>H112</td>
<td>3 ≤ t ≤ 50 mm</td>
<td>110</td>
<td>270</td>
<td>12</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>5383</td>
<td>O</td>
<td>3 ≤ t ≤ 50 mm</td>
<td>145</td>
<td>290</td>
<td>17</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td></td>
<td>H111</td>
<td>3 ≤ t ≤ 50 mm</td>
<td>145</td>
<td>290</td>
<td>17</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td></td>
<td>H112</td>
<td>3 ≤ t ≤ 50 mm</td>
<td>190</td>
<td>310</td>
<td>13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5059</td>
<td>H112</td>
<td>3 ≤ t ≤ 50 mm</td>
<td>200</td>
<td>330</td>
<td></td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>5086</td>
<td>O</td>
<td>3 ≤ t ≤ 50 mm</td>
<td>95</td>
<td>240-315</td>
<td>14</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td></td>
<td>H111</td>
<td>3 ≤ t ≤ 50 mm</td>
<td>145</td>
<td>250</td>
<td>12</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td></td>
<td>H112</td>
<td>3 ≤ t ≤ 50 mm</td>
<td>95</td>
<td>240</td>
<td>12</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>6005A</td>
<td>T5</td>
<td>3 ≤ t ≤ 50 mm</td>
<td>215</td>
<td>260</td>
<td>9</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>T6</td>
<td>3 ≤ t ≤ 10 mm</td>
<td>215</td>
<td>260</td>
<td>8</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>10 &lt; t ≤ 50 mm</td>
<td>200</td>
<td>250</td>
<td>8</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>6061</td>
<td>T6</td>
<td>3 ≤ t ≤ 50 mm</td>
<td>240</td>
<td>260</td>
<td>10</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>6082</td>
<td>T5</td>
<td>3 ≤ t ≤ 50 mm</td>
<td>230</td>
<td>270</td>
<td>8</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>T6</td>
<td>3 ≤ t ≤ 5 mm</td>
<td>250</td>
<td>290</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 &lt; t ≤ 50 mm</td>
<td>260</td>
<td>310</td>
<td>10</td>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>

Notes:
1) The values are applicable for longitudinal and transverse tensile test specimens as well.
2) Elongation in 50 mm applies for thicknesses up to and including 12.5 mm and in 5d for thicknesses over 12.5 mm.

### Table 5.1.5
Underthickness tolerances for rolled products

<table>
<thead>
<tr>
<th>Nominal thickness (t), mm</th>
<th>Thickness tolerances for nominal width (w), mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>w ≤ 1500</td>
</tr>
<tr>
<td>3.0 ≤ t &lt; 4.0</td>
<td>0,10</td>
</tr>
<tr>
<td>4.0 ≤ t &lt; 8.0</td>
<td>0,20</td>
</tr>
<tr>
<td>8.0 ≤ t &lt; 12.0</td>
<td>0,25</td>
</tr>
<tr>
<td>12.0 ≤ t &lt; 20.0</td>
<td>0,35</td>
</tr>
<tr>
<td>20.0 ≤ t &lt; 50.0</td>
<td>0,45</td>
</tr>
</tbody>
</table>

### 5.2 ALUMINIUM ALLOY CASTINGS

#### 5.2.1 General

5.2.1.1 These requirements are applicable to aluminium casting alloys which are intended for the fabrication of ships’ hulls and also machine construction parts and other shipbuilding components.

5.2.1.2 Foundries producing aluminium casting alloys shall be approved by the Register.

5.2.1.3 If castings are required to be weldable, this is to be stated in the order and proof of suitability furnished to the Register.

#### 5.2.2 Permitted grades of castings

5.2.2.1 Suitable grades of castings to international standards, e.g. to EN 1706 shall generally be used. Where castings conforming to the manufacturer’s specifications are to be used, these are to be submitted to the Register for examination and approval.

5.2.2.2 Castings such as fittings, housings and fan rotors which are exposed without protection to the action of seawater and salty atmosphere should be made of alloys suitable for this kind of use. AlSi-, AlSiMg- and AlMg- alloys with a maximum copper content of 0.1% should normally be used. AlSi- and AlSiMg- alloys shall not come into direct...
contact with seawater. Where necessary, they are to be protected by anodes or coatings.

5.2.2.3 For the applications mentioned in 5.2.1.1, use may be made of the casting alloys conforming to EN 1706 listed in Table 5.2.2.3.

Use may be made of other alloys provided these are suitable for the intended application and their use has been approved by the Register.

5.2.3 Requirements

5.2.3.1 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 casting for each charge.

5.2.3.2 With regard to mechanical properties, the requirements stated in the standards or the manufacturer’s specifications are applicable. Specimens taken from integrally cast test pieces shall meet the requirements for separately cast sample bars.

5.2.3.3 All castings shall be free from internal and external defects which could have more than just a slight adverse effect on the application and any appropriate further manufacturing processes carried out on the castings. Where defects are to be repaired by welding, a welding specification shall be produced by the manufacturer for this purpose and the approval of the Surveyor sought.

<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 (AlSi2MgTi)</td>
<td>S, K</td>
<td>F, T6</td>
<td>good</td>
</tr>
<tr>
<td>EN AC-42100 (AlSi7Mg0,3)</td>
<td>S, K, L</td>
<td>T6, T64</td>
<td>good</td>
</tr>
<tr>
<td>EN AC-42200 (AlSi7Mg0,6)</td>
<td>S, K, L</td>
<td>T6, T64</td>
<td>good</td>
</tr>
<tr>
<td>EN AC-43100 (AlSi10Mg(b))</td>
<td>S, K, L</td>
<td>F, T6, T64</td>
<td>good / moderate</td>
</tr>
<tr>
<td>EN AC-44100 (AlSi12(b))</td>
<td>S, K, L, D</td>
<td>F</td>
<td>good / moderate</td>
</tr>
<tr>
<td>EN AC-51000 (AlMg3(b))</td>
<td>S, K, L</td>
<td>F</td>
<td>very good</td>
</tr>
<tr>
<td>EN AC-51300 (AlMg5)</td>
<td>S, K, L</td>
<td>F</td>
<td>very good</td>
</tr>
<tr>
<td>EN AC-51400 (AlMg5(Si))</td>
<td>S, K, L</td>
<td>F</td>
<td>very good</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)

5.2.4 Testing and scope of tests

5.2.4.1 Castings which shall form part of the ship’s hull or are designed as structural components of the propulsion system are to be presented to the Surveyor for testing. A tensile test shall be performed on the castings in his presence to establish their mechanical properties.

5.2.4.2 For the tensile test, one test specimen is to be provided from each charge or each heat treatment batch. For unfinished castings weighing 300 kg and over, a tensile test specimen is required for each casting.

5.2.4.3 Specimens for tensile testing shall normally be taken from integrally cast sample bars which may only be separated from the casting when the final heat treatment has been performed.

The use of separately cast sample pieces shall be subject to special agreement with the Register with regard to their casting and the requirements applicable to the mechanical properties of the tensile test specimens taken from them.

5.2.4.4 Where stipulated following examination of the drawings or in the order, and also where there is some doubt
as to whether the castings are free from the defects, the manufacturer of the castings shall perform non-destructive tests at the places specified for the purpose, and the results are to be certified by him. Critical areas of casting and repaired defects are also to be incorporated in the test.

5.2.5 Marking

5.2.5.1 As a minimum requirement, the manufacturer shall apply the following marks on the castings:
   a) Manufacturer’s mark,
   b) Short designation of the casting alloys,
   c) Short designation of the condition of the material,
   d) Charge number or some other mark to permit identification of the casting.

5.2.6 Certificates

5.2.6.1 For each delivery, the manufacturer shall present to the Register’s Surveyor a test certificate, or a delivery specification containing the following minimum details:
   a) Purchaser and order number,
   b) Type of casting and grade of casting,
   c) Item numbers and quantities,
   d) Method of manufacture,
   e) Heat numbers and chemical composition,
   f) Details of heat treatment,
   g) Test pressures, where applicable,
   h) Weight of the delivery.

5.3 ALUMINIUM/STEEL TRANSITION JOINTS

5.3.1 General

5.3.1.1 These requirements apply to explosion bonded steel/aluminium transition joints for the connecting of steel structures with aluminium structures.

5.3.1.2 Each individual application is to be separately agreed and approved by the Register.

5.3.2 Manufacture

5.3.2.1 The manufacturer shall demonstrate by means of an initial test of product suitability that the clad products satisfy the requirements stated in 5.3.6 and the required properties of the base material are preserved after cladding.

5.3.2.2 As base materials steels according to Sections 3.2, 3.3 and 3.5 are to be used. As cladding materials the aluminium alloys according to Section 5.1, come into question.

5.3.2.3 Cladding is performed by explosive cladding without additional heat transfer or change of thickness.

5.3.2.4 In general, clad materials are to be delivered in untreated, smoothed condition.

5.3.3 Dimensions and tolerances

5.3.3.1 Where no other tolerances are specified in the order, the specifications in Table 5.3.3.1 apply.

5.3.3.2 The tolerances for the base materials shall be governed by the requirements for the respective steel grades and product shapes.

5.3.4 Surface finish

5.3.4.1 The surface finish shall meet the respective requirements for the base material.

5.3.5 Requirements applicable to the material

5.3.5.1 Shear strength

The bond between the base and cladding materials shall be adequate to ensure that the cladding material cannot break away from the base material when proper manufacturing processes and service condition are applied. The shear strength shall be at least 60 N/mm² irrespective of the direction of testing, unless higher values have been agreed in the order.

5.3.5.2 Bonding

The proportion of bonded surface shall be at least 99% and the area of isolated points where bonding has not occurred shall not exceed 650 mm². Rods and circular blanks of 300 mm or less width and diameter respectively shall not show indications to be registered. If rods or circular blanks are cut from the original plate, the distance to indications to be registered shall be at least 20 mm.

5.3.5.3 Tensile test

The tensile strength of a clad plate subjected to a tensile test shall be at least 60 N/mm², unless higher values have been agreed in the order.

5.3.5.4 Technological properties

When subjected to the side bend test, the clad plate shall be capable of being bent through 90° over a mandrel with a diameter of 6 times the thickness of the specimen, without separation of the cladding material or formation of incipient cracks.

5.3.6 Testing

5.3.6.1 Tensile test

From each end of the original plate 2 specimens with their longitudinal axis perpendicular to the product surface shall be taken and tested. Specimen shape is to be chosen according to Section 3.9. One specimen of each end is to be heated to 300° before testing.

5.3.6.2 Shear test

From each test batch a specimen shall be taken with its axis transverse to the rolling direction and this shall be subjected to the shear test.
The test shall be performed in accordance with a recognised standard, e.g. DIN 50162. The dimensions of the test specimen and the test arrangement are shown in Figure 3.8.9.4 - Shear test.

5.3.6.3 Side bend test

If specially agreed in the order, one specimen of each original plate is to be taken and tested. Dimensions of the test specimen and test arrangement are shown in Figure 3.8.9.5 – Side bend test. Where the product thickness exceeds 80 mm, the specimens may be reduced to 80 mm by machining the base material side.

5.3.6.4 Test of surface finish and dimensions

The surface finish and dimensions of all plates shall be checked by the manufacturer and the thickness of the cladding shall be measured at the edges and in the middle of the plate. All plates shall be submitted to the Surveyor for final testing and verification of the dimensions.

5.3.6.5 Non-destructive testing

To ascertain the quality of the bond between the base and cladding materials, the manufacturer shall carry out 100% ultrasonic testing of the surfaces and edges of all plates.

5.3.7 Marking

5.3.7.1 All plates are to be marked on the base material side as follows:
- manufacturer's mark,
- short name of steel grade designation or material number of base and cladding material,
- heat numbers of base and cladding material,
- thickness of base and cladding material,
- specimen no.

<table>
<thead>
<tr>
<th>Table 5.3.3.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permissible tolerance</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Thickness</td>
</tr>
<tr>
<td>Length</td>
</tr>
<tr>
<td>Width rods</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Diameter circular blanks</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Rectangularity plates (difference between the diagonals)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Evenness (aluminium side)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Straightness of longitudinal edges rods</td>
</tr>
</tbody>
</table>

1) Rods are contrary to plates flat products of a width ≤ 300 mm.
6 ANCHORS

6.1 GENERAL REQUIREMENTS

6.1.1 Scope

These requirements applies to the materials, design, manufacture, testing and certification of anchors, shanks and anchor shackles produced from cast or forged steel, or fabricated by welded rolled steel plate and bars. Frequent reference is made to Rules for the classification of ships Part 3 Hull equipment, Chapter 3, Anchor arrangement.

With regard to holding power tests at sea for high holding power (HHP) and super high holding power (SHHP) anchors, refer to Rules for the classification of ships Part 3 Hull equipment, Chapter 3, Anchor arrangement.

6.1.2 Types of anchor

The types of anchor covered include:

a) Ordinary anchors
   i) Stockless anchors
   ii) Stocked anchors

b) HHP anchors

c) SHHP anchors, not exceeding 1500 kg in mass.

Any changes to the design made during manufacture are to have prior written agreement from the Register.

6.2 MATERIALS

6.2.1 Materials for anchors

All anchors are to be manufactured from materials meeting the requirements as indicated below:

a) Cast steel anchor flukes, shanks, swivels and shackles are to be manufactured and tested in accordance with the requirements of Chapter 3.12 Hull and machinery steel castings and comply with the requirements for castings for welded construction. The steel is to be fine grain treated with Aluminium. If test programme B is selected in Section 6.4.2 then Charpy V notch (CVN) impact testing of cast material is required. Special considerations is to be given to the use of other grades of steels for the manufacture of swivels.

b) Forged steel anchor pins, shanks, swivels and shackles are to be manufactured and tested in accordance with the requirements of Chapter 3.11 Hull and machinery steel forgings and comply with the requirements for carbon and carbon-manganese steels for welded construction. Special consideration is to be given to the use of other grades of steels for the manufacture of swivels.

c) Rolled billets, plate and bar for fabricated steel anchors are to be manufactured and tested in accordance with the requirements of Chapter 3.2 Normal and higher strength hull structural steels.

d) Rolled bar intended for pins, swivels and shackles are to be manufactured and tested in accordance with the requirements of Chapter 3.11 Hull and machinery steel forgings and Chapter 3.2 Normal and higher strength hull structural steels.

6.2.2 Materials for SHHP anchors

In addition to the requirements of 6.2.1, SHHP anchors are to be produced in accordance with the material toughness requirements of Rules for the classification of ships Part 3 Hull equipment, Chapter 3, Anchor arrangement.

6.3 MANUFACTURE OF ANCHORS

6.3.1 Tolerance

If not otherwise specified in standards or on drawings demonstrated to be appropriate, the following assembly and fitting tolerance are to be applied.

The clearance either side of the shank within the shackle jaws is to be no more than 3 mm for small anchors up to 3 tonnes weight, 4 mm for anchors up to 5 tonnes weight, 6 mm for anchors up to 7 tonnes weight and is not to exceed 12 mm for larger anchors.

The shackle pin is to be a push fit in the eyes of the shackle, which are to be chamfered on the outside to ensure a good tightness when the pin is clenched over on fitting. The shackle pin to hole tolerance is to be no more than 0,5 mm for pins up to 57 mm and 1,0 mm for pins of larger diameter.

The trunnion pin is to be a snug fit within the chamber and be long enough to prevent horizontal movement. The gap is to be no more than 1% of the chamber length.

The lateral movement of the shank is not to exceed 3°, see Figure 6.3.1.

6.3.2 Welding of anchors

Welded construction of fabricated anchors is to be done in accordance with procedures approved by the Register. Welding is to be carried out by qualified welders, following the approved welding procedures qualified in accordance with Rules for the classification of ships Part 26 Welding Chapter 1.4 Welding procedure qualification test, using consumables manufactured in accordance with the requirements of Rules for the classification of ships Part 26 Welding Chapter 1.5 Welding consumables. NDE is to be carried out in accordance with the requirements of 6.4.2 Product tests.
6.3.3 Heat treatment

Components for cast or forged anchors are to be properly heat treated; fully annealed; normalised or normalised and tempered in accordance with Chapter 3.11 and Chapter 3.12.

Fabricated anchors may require stress relief after welding depending upon weld thickness. Stress relief is to be carried out as indicated in the approved welding procedure. Stress relief temperatures are not to exceed the tempering temperature of the base material.

6.3.4 Freedom from defects

All parts are to have a clean surface consistent with the method of manufacture and be free from cracks, notches, inclusions and other defects that would impair the performance of the product.

6.3.5 Repairs

Any necessary repairs to forged and cast anchors are to be agreed by the Surveyor and carried out in accordance with the repair criteria indicated in Chapter 3.11 and Chapter 3.12. Repairs to fabricated anchors are to be agreed by the Surveyor and carried out in accordance with qualified weld procedures, by qualified welders, following the parameters of the welding procedures used in construction.

6.3.6 Anchor assembly

Assembly and fitting are to be done in accordance with the design details.

Securing of the anchor pin, shackle pin or swivel nut by welding is to be done in accordance with an approved procedure.

6.4 TESTING AND CERTIFICATION

6.4.1 Proof load test

Proof load tests are to be carried out by an approved testing facility.

Proof load testing for Ordinary, HHP and SHHP anchors is to be carried out in accordance with the pertinent requirements of Rules for the classification of ships Part 3 Hull equipment Chapter 3 Anchor arrangement.

6.4.2 Product tests

6.4.2.1 Product test programmes

The Register can request that either programme A or programme B be applied.

Table 6.4.2.1 a)

<table>
<thead>
<tr>
<th>Product test</th>
<th>Product form</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cast components</td>
</tr>
<tr>
<td>Programme A</td>
<td>Applicable</td>
</tr>
<tr>
<td>Programme B</td>
<td>Applicable</td>
</tr>
</tbody>
</table>

Notes:
1) CVN impact tests are to be carried out to demonstrate at least 27 Joules average at 0°C. Refer to 6.2.1 a).

6.4.2.2 Drop test

Each anchor fluke and shank is individually raised to a height of 4 m and dropped on to a steel slab without fracturing. The steel slab is to be suitable to resist the impact of the dropped component.

6.4.2.3 Hammering test

After the drop test, hammering tests are carried out on each anchor fluke and shank, which is slung clear of the ground, using a non-metallic sling, and hammered to
check the soundness of the component. A hammer of at least 3 kg mass is to be used.

6.4.2.4 Visual inspection

After proof loading visual inspection of all accessible surfaces is to be carried out.

6.4.2.5 General non-destructive examination

After proof loading general NDE is to be carried out as indicated in the following tables 6.4.2.5 a) and 6.4.2.5 b).

<table>
<thead>
<tr>
<th>Table 6.4.2.5 a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
</tr>
<tr>
<td>Feeders of castings</td>
</tr>
<tr>
<td>Risers of castings</td>
</tr>
<tr>
<td>Weld repairs</td>
</tr>
<tr>
<td>Forged components</td>
</tr>
<tr>
<td>Fabrication welds</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 6.4.2.5 b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
</tr>
<tr>
<td>Feeders of castings</td>
</tr>
<tr>
<td>Risers of castings</td>
</tr>
<tr>
<td>All surfaces of castings</td>
</tr>
<tr>
<td>Weld repairs</td>
</tr>
<tr>
<td>Forged components</td>
</tr>
<tr>
<td>Fabrication welds</td>
</tr>
</tbody>
</table>

6.4.2.6 Extended non-destructive examination

After proof loading extended NDE is to be carried out as indicated in the following Table 6.4.2.6.

<table>
<thead>
<tr>
<th>Table 6.4.2.6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
</tr>
<tr>
<td>Feeders of castings</td>
</tr>
<tr>
<td>Risers of castings</td>
</tr>
<tr>
<td>All random areas of castings</td>
</tr>
<tr>
<td>Weld repairs</td>
</tr>
<tr>
<td>Forged components</td>
</tr>
<tr>
<td>Fabrication welds</td>
</tr>
</tbody>
</table>

6.4.2.7 Repair criteria

If defects are detected by NDE, repairs are to be carried out in accordance with 6.3.5. For fracture and un-

soundness detected in a drop test or hammering test, repairs are not permitted and the component is to be rejected.

6.4.2.8 Mass and dimensional inspection

Unless otherwise agreed, the verification of mass and dimensions is the responsibility of the manufacturer. The Surveyor is only required to monitor this inspection. The mass of the anchor is to exclude the mass of the swivel, unless this is an integral component.

6.4.2.9 Retests

Mechanical retest are permitted in accordance with the requirements of Chapter 2.

6.4.2.10 Marking

Anchors which meet the requirements are to be stamped on the shank and the fluke. The markings on the shank are to be approximately level with the fluke tips. On the fluke, these markings are to be approximately at a distance of two thirds from the tip of the bill to the center line of the crown on the right hand fluke looking from the crown towards the shank. The markings are to include:

a) Mass of anchor
b) Identification, e.g. test No. or certificate No.
c) Register’s stamp
d) Manufacturer’s mark

Additionally the unique cast identification is to be cast on the shank and the fluke.

6.4.2.11 Certification

Anchors which meet the requirements are to be certified by the Register at least with the following items:

a) Manufacturer’s name
b) Type
c) Mass
d) Fluke and shank identification numbers
e) Grade of materials
f) Proof test loads
h) Heat treatment
i) Marking applied to anchor

6.4.2.12 Painting

All types of anchor are not to be painted until all tests and inspections have been completed.
7 ANCHOR CHAIN CABLES AND ACCESSORIES

7.1 GENERAL REQUIREMENTS

7.1.1 Scope

This Chapter apply to the materials, design, manufacture and testing of stud link anchor chain cables and accessories used for ships. Where, in exceptional cases, studless short link chain cables are used with the consent of the Register, they must comply with recognized national or international standards.

The requirements for chafing chain for Emergency Towing Arrangements (ETA) are given in the Appendix E.

7.1.2 Chain cable grades

Depending on the nominal tensile strength of the chain cable steel used for manufacture, stud link chain cables are to be subdivided into CRS-L1, CRS-L2 and CRS-L3.

7.1.3 Approval of chain manufacturers

7.1.3.1 Anchor chain cables and accessories are to be manufactured only by works approved by the Register. For this purpose approval tests are to be carried out, the scope of which is to be agreed with the Register.

7.1.3.2 Applications for approval are to be made to the Register, stating the method of manufacture used, the grades of materials, the nominal dimensions and - where applicable - the material specification. A procedure test carried out on a high-strength chain cable may cover approval of lesser grades, provided that the material type, method of manufacture and the nature of the heat treatment are the same.

7.2 MATERIALS

7.2.1 Scope

This Chapter apply to rolled steels, forgings and castings used for the manufacture of anchor chain cables and accessories.

7.2.2 Requirements for material manufacturers

7.2.2.1 All materials used for the manufacture of anchor chain cables and accessories are to be supplied by manufacturers approved by the Register. Register approval is not required for CRS-L1 steel bars.

7.2.2.2 Materials suppliers or chain cable manufacturers are to submit specifications for CRS-L3 steel bars. These specifications should contain all necessary details, such as manufacturing procedure, deoxidation practice, specified chemical composition, heat treatment and mechanical properties.

7.2.3 Rolled steel bars

7.2.3.1 Supply condition

Unless otherwise stipulated, the steel bars will be supplied in as rolled condition.

7.2.3.2 Chemical composition

The chemical composition of the steel bars is to be generally within the limits given in Table 7.2.3.2.

7.2.3.3 Mechanical tests

7.2.3.3.1 Mechanical tests representing the steel bars are normally to be carried out by the steel mill, and the results are to meet the requirements in Table 7.2.3.3.1. The test coupons are to be in a heat treatment condition equivalent to that of the finished chain cable and accessories.

7.2.3.3.2 For performance of the mechanical tests, the steel bars shall be sorted according to heats and diameters into test units not exceeding 50 tons each. From each test unit a test sample shall be taken for the tests mentioned in 7.2.3.3.4 and 7.2.3.3.5. Prior to sampling, the test samples must be subjected to the heat treatment provided for the finished chain cable; (see 7.3.3). Details of the heat treatment must be indicated by the chain cable manufacturer.

7.2.3.3.3 Tensile and Charpy V-notch impact test specimens shall be taken from the test sample in the longitudinal direction at a distance of 1/6 diameter from the surface or as close as possible to this position, as shown in Figure 7.2.3.3.3.

7.2.3.3.4 For the tensile test, one specimen shall be taken from each test unit and tested, all in accordance with Ch. 2, Section 2.4.

7.2.3.3.5 One set of longitudinal Charpy V-notch test specimens shall be taken from each test unit and tested at the temperature prescribed in Table 7.2.3.3.1, all in accordance with Ch. 2, Section 2.5. The specimen transverse axis is to be radial to the steel bar. The average value obtained from one set of three impact specimens is to comply with the requirements given in Table 7.2.3.3.1. One individual value only may be below the specified average value provided it is not less than 70% of that value.
Table 7.2.3.2
Chemical composition of rolled steel bars

<table>
<thead>
<tr>
<th>Grade</th>
<th>Chemical composition in maximum percent, unless specified</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C</td>
</tr>
<tr>
<td>CRS-L1</td>
<td>0.20</td>
</tr>
<tr>
<td>CRS-L2&lt;sup&gt;2&lt;/sup&gt;</td>
<td>0.24</td>
</tr>
<tr>
<td>CRS-L3&lt;sup&gt;3&lt;/sup&gt;</td>
<td>In accordance with an approved specification.</td>
</tr>
</tbody>
</table>

1) Aluminium may be replaced partly by other grain refining elements.
2) If the Register agrees, additional alloying elements may be added.
3) To be killed and fine grain.

NR = Not required

Table 7.2.3.3.1
Mechanical properties of rolled steel bars

<table>
<thead>
<tr>
<th>Grade</th>
<th>$R_{el}$ N/mm$^2$</th>
<th>$R_m$ N/mm$^2$</th>
<th>$A_5$ %</th>
<th>$Z$ %</th>
<th>Test temp. in °C</th>
<th>Absorbed energy in Joules, min.</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRS-L1</td>
<td>NR</td>
<td>370-490</td>
<td>25</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>CRS-L2</td>
<td>295</td>
<td>490-690</td>
<td>22</td>
<td>NR</td>
<td>0</td>
<td>27&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
<tr>
<td>CRS-L3</td>
<td>410</td>
<td>min. 690</td>
<td>17</td>
<td>40</td>
<td>0&lt;sup&gt;2&lt;/sup&gt;</td>
<td>60</td>
</tr>
</tbody>
</table>

1) The impact test of CRS-L2 materials may be waived, if the chain cable is to be supplied in a heat treated condition as per Table 7.4.3.2.
2) Testing is normally to be carried out at 0°C.

NR = Not required

Table 7.2.3.4
Dimensional tolerance of rolled steel bar

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

7.2.3.3.6 Re-test requirements for tensile tests are to be in accordance with Chapter 2 with specimens taken from the same sample. Failure to meet the specified requirements of either of both additional tests will result in rejection of the test unit represented unless it can be clearly attributable to improper simulated heat treatment; see 7.2.3.3.8.

7.2.3.3.7 Re-test requirements for Charpy impact tests are to be in accordance with Chapter 2. Specimens are to be selected from the same sample. Failure to meet the requirements will result in rejection of the test unit represented unless it can be clearly attributable to improper simulated heat treatment; see 7.2.3.3.8.

7.2.3.3.8 If failure to pass the tensile test or the Charpy V-notch impact test is definitely attributable to improper heat treatment of the test sample, a new test sample may be taken from the same piece and reheat treated. The complete test (both tensile and impact test) is to be repeated; and the original results obtained may be disregarded.
7.2.3.4 Dimensional tolerances
The diameter and roundness shall be within the tolerances specified in Table 7.2.3.4, unless otherwise agreed.

7.2.3.5 Freedom from defects
The materials have to be free from internal and surface defects that might impair proper workability and use. Surface defects may be repaired by grinding, provided the admissible tolerance is not exceeded.

7.2.3.6 Identification of material
Manufacturers are to effectively operate an identification system ensuring traceability of the material to the original cast.

7.2.3.7 Marking
The minimum markings required for the steel bars are the manufacturers' brandmark, the steel grade and an abbreviated symbol of the heat. Steel bars having diameters of up to and including 40 mm and combined into bundles, may be marked on permanently affixed labels.

7.2.3.8 Material certification
Bar material for Grade CRS-L2 or Grade CRS-L3 is to be certified by the Register. For each consignment manufacturers shall forward to the Surveyor a certificate containing at least the following data:
- manufacturer's name and/or purchaser's order No.
- number and dimensions of bars and weight of consignment
- steel specification and chain grade
- heat number
- manufacturing procedure
- chemical composition
- details of heat treatment of the test sample (where applicable)
- results of mechanical tests (where applicable)
- number of test specimens (where applicable)

7.2.4 Forged steels for chain cables and accessories

7.2.4.1 General requirements
Forged steels used for the manufacture of chain cables and accessories are to be in compliance with 3.11, Hull and machinery steel forgings, unless otherwise specified in the following paragraphs.

7.2.4.2 Chemical composition
The chemical composition is to comply with the specification approved by the Register. The steel manufacturer must determine and certify the chemical composition of every heat of material.

7.2.4.3 Heat treatment
The stock material may be supplied in the as rolled condition. Finished forgings are to be properly heat treated, i.e. normalized, normalized and tempered or quenched and tempered, whichever is specified for the relevant steel grade in Table 7.3.5.

7.2.5 Cast steels for chain cables and accessories

7.2.5.1 General requirements
Cast steels used for the manufacture of chain cables and accessories are to be in compliance with Chapter 3.12 Hull and machinery steel castings, unless otherwise specified in the following paragraphs.

7.2.5.2 Chemical composition
The chemical composition is to comply with the specification approved by the Register. The foundry is to determine and certify the chemical composition of every heat.

7.2.5.3 Heat treatment
All castings must be properly heat treated, i.e., normalized, normalized and tempered or quenched and tempered, whichever is specified for the relevant cast steel grade in Table 7.3.5.

7.2.6 Materials for studs
The studs are to be made of steel corresponding to that of the chain cable or from rolled, cast or forged mild steels. The use of other materials, e.g. grey or nodular cast iron is not permitted.

7.3 DESIGN AND MANUFACTURE OF CHAIN CABLES AND ACCESSORIES

7.3.1 Design
Chain cables must be designed according to a recognized standard, such as ISO 1704. A length of chain cable must comprise an odd number of links. Where designs do not comply with this and where accessories are of welded construction, drawings giving full details of the design, the manufacturing process and the heat treatment are to be submitted to the Register for approval.

7.3.2 Dimensions and dimensional tolerances

7.3.2.1 The shape and proportions of links and accessories must conform to a recognized standard, such as ISO 1704 or the designs specially approved.

7.3.2.2 The following tolerances are applicable to links:
a) Diameter measured at the crown (Two measurements are to be taken at the same location:
one in the plane of the link (see dp in Figure 7.3.2.2), and one perpendicular to the plane of the link): up to 40mm nominal diameter: –1 mm over 40 up to 64 mm nominal diameter: –2 mm
over 84 up to 122 mm nominal diameter:
- 3 mm
over 122 mm nominal diameter: – 4 mm
The plus tolerance may be up to 5% of the nominal diameter. The cross sectional area of the crown must have no negative tolerance.

b) Diameter measured at locations other than the crown:
The diameter is to have no negative tolerance. The plus tolerance may be up to 5% of the nominal diameter. The approved manufacturer’s specification is applicable to the plus tolerance of the diameter at the flush-butt weld.

c) The maximum allowable tolerance on assembly measured over a length of 5 links may equal +2.5%, but may not be negative (measured with the chain under tension after proof load test).

d) All other dimensions are subject to a manufacturing tolerance of ±2.5%, provided always that all of the final link parts of the chain cable fit together properly.

e) Studs must be located in the links centrally and at right angles to the sides of the link, although the studs at each end of any length may also be located off-centre to facilitate the insertion of the joining shackle. The following tolerances are regarded as being inherent in the method of manufacture and will not be objected to, provided that the stud fits snugly and its ends lie practically flush against the inside of the link.

Maximum off-centre distance "X":
10% of the nominal diameter d
Maximum deviation "α" from the 90° - position: 4°
The tolerances are to be measured in accordance with Figure 7.3.2.2.

\[ x = \frac{A-a}{2} \]

Figure 7.3.2.2
Manufacturing tolerances

7.3.2.3 The following tolerances are applicable to accessories:
nominal diameter: +5%, -0%
other dimensions: ±2.5%

7.3.3 Manufacturing process

7.3.3.1 Stud link chain cables should preferably be manufactured by flash butt welding using Grade CRS-L1, CRS-L2 or CRS-L3 bar material. Manufacture of the links by drop forging or castings is permitted.

On request, pressure butt welding may also be approved for studless, Grade CRS-L1 and CRS-L2 chain cables, provided that the nominal diameter of the chain cable does not exceed 26 mm.

7.3.3.2 Accessories such as shackles, swivels and swivel shackles are to be forged or cast in steel of at least Grade CRS-L2. The welded construction of these parts may also be approved.

7.3.4 Welding of studs

The welding of studs is to be in accordance with an approved procedure subject to the following conditions:

a) The studs must be of weldable steel; (see 7.2.6.

b) The studs are to be welded at one end only, i.e., opposite to the weldment of the link. The stud ends must fit the inside of the link without appreciable gap.

c) The welds, preferably in the horizontal position, shall be executed by qualified welders using suitable welding consumables.

d) All welds must be carried out before the final heat treatment of the chain cable.

e) The welds must be free from defects liable to impair the proper use of the chain. Under-cuts, end craters and similar defects shall, where necessary, be ground off.

The Register reserves the right to call for a procedure test for the welding of chain studs.

7.3.5 Heat treatment

According to the grade of steel, chain cables and accessories are to be supplied in one of the conditions specified in Table 7.3.5. The heat treatment shall in every case be performed before the proof load test, the breaking load test, and all mechanical testing.

The mechanical properties of finished chain cables and accessories are to be in accordance with Table 7.4.3.3.
Table 7.3.5
Condition of supply of chain cables and accessories

<table>
<thead>
<tr>
<th>Grade</th>
<th>Chain cables</th>
<th>Accessories</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRS-L1</td>
<td>As welded or Normalized</td>
<td>NA</td>
</tr>
<tr>
<td>CRS-L2</td>
<td>As welded or Normalized(^1)</td>
<td>Normalized</td>
</tr>
<tr>
<td>CRS-L3</td>
<td>Normalized, Normalized and tempered or Quenched and tempered</td>
<td>Normalized, Normalized and tempered or Quenched and tempered</td>
</tr>
</tbody>
</table>

\(^1\) Grade CRS-L2 chain cables made by forging or casting are to be supplied in the normalized condition.

7.3.6 Freedom from defects

7.3.6.1 All individual parts must have a clean surface consistent with the method of manufacture and be free from cracks, notches, inclusions and other defects impairing the performance of the product. The flashes produced by upsetting or drop forging must be properly removed.

7.3.6.2 Minor surface defects may be ground off so as to leave a gentle transition to the surrounding surface. Remote from the crown local grinding up to 5% of the nominal link diameter may be permitted.

7.4 TESTING AND CERTIFICATION OF FINISHED CHAIN CABLES

7.4.1 Proof and breaking load tests

7.4.1.1 Finished chain cables are to be subjected to the proof load test and the breaking load test in the presence of the Surveyor, and shall not fracture or exhibit cracking. Special attention is to be given to the visual inspection of the flash-butt weld, if present. For this purpose, the chain cables must be free from paint and anti-corrosion media.

7.4.1.2 Each chain cable length (27.5 m) is to be subjected to a loading test at the proof load appropriate to the particular chain cable as given by Table 7.4.1.2 and using an approved testing machine.

Table 7.4.1.2
Formulas for proof load and breaking load tests

<table>
<thead>
<tr>
<th>Test</th>
<th>Grade CRS-L1</th>
<th>Grade CRS-L2</th>
<th>Grade CRS-L3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proof load (kN)</td>
<td>0,00686d^2 (44-0,08d)</td>
<td>0,00981d^2 (44-0,08d)</td>
<td>0,01373d^2 (44-0,08d)</td>
</tr>
<tr>
<td>Breaking load (kN)</td>
<td>0,00981d^2 (44-0,08d)</td>
<td>0,01373d^2 (44-0,08d)</td>
<td>0,01961d^2 (44-0,08d)</td>
</tr>
</tbody>
</table>

Note: \(d\) = nominal diameter, in mm.

7.4.1.3 For the breaking load test, one sample comprising at least of three links is to be taken from every four lengths or fraction of chain cables and tested at the breaking loads given by Table 7.4.1.2. The breaking load is to be maintained for a minimum of 30 seconds. The links concerned shall be made in a single manufacturing cycle together with the chain cable and must be welded and heat treated together with it.

Only after this may they be separated from the chain cable in the presence of the Surveyor.

7.4.1.4 If the tensile loading capacity of the testing machine is insufficient to apply the breaking load for chain cables of large diameter, another equivalent testing method shall be agreed with the Register.

7.4.2 Re-testing

7.4.2.1 Should a breaking load test fail, a further test specimen may be taken from the same length of chain cable and tested. The test shall be considered successful if the requirements are then satisfied.

If re-testing fails, the length of chain cable concerned shall be rejected. If the manufacturer so wishes, the remaining three lengths belonging to the unit test quality may then be individually subjected to test at the breaking load. If one such test fails to meet the requirements, the entire unit test quantity is rejected.

7.4.2.2 Should a proof load test fail, the defective link(s) is (are) to be replaced, a local heat treatment to be carried out on the new link(s) and the proof load test is to be re-
peated. In addition, an investigation is to be made to identify the cause of the failure.

7.4.3 Mechanical tests on grades CRS-L2 and CRS-L3 chain cable

7.4.3.1 For Grade CRS-L2 and CRS-L3 chain cables, mechanical test specimens required in Table 7.4.3.2 are to be taken from every four lengths in accordance with 7.4.3.2. For forged or cast chain cables where the batch size is less than four lengths, the sampling frequency will be by heat and heat treatment charge. Mechanical tests are to be carried out in the presence of the Surveyor. For the location of the test specimens see 7.2.3.3.3 and Figure 7.2.3.3.3. Testing is to follow 7.2.3.3.4 and 7.2.3.3.5. Re-testing is to follow 7.2.3.3.6 and 7.2.3.3.7.

7.4.3.2 An additional link (or where the links are small, several links) for mechanical test specimen removal is (are) to be provided in a length of chain cable not containing the specimen for the breaking test. The specimen link must be manufactured and heat treated together with the length of chain cable.

7.4.3.3 The mechanical properties must be in accordance with the values indicated in Table 7.4.3.3.

Table 7.4.3.2

<table>
<thead>
<tr>
<th>Grade</th>
<th>Manufacturing method</th>
<th>Condition of supply</th>
<th>Number of mechanical test specimens</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Tensile test for base metal</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Base metal</td>
</tr>
<tr>
<td>CRS-L1 Flush-butt welded</td>
<td>AW</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>CRS-L2 Flush-butt welded</td>
<td>AW</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Forged or Cast</td>
<td>N</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>CRS-L3 Flush butt welded</td>
<td>N</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Forged or Cast</td>
<td>N</td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>

1) AW = As welded, N = Normalized, NT = Normalized and tempered, QT = Quenched and tempered
2) For chain cables, Charpy V-notch impact test is not required.
NR = Not required
NA = Not applicable

Table 7.4.3.3

<table>
<thead>
<tr>
<th>Grade</th>
<th>$R_{0.2}$ N/mm$^2$ min.</th>
<th>$R_m$ N/mm$^2$</th>
<th>$A_k$ % min.</th>
<th>$Z$ % min.</th>
<th>Notched bar impact test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Test temp. in °C</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Base metal</td>
</tr>
<tr>
<td>CRS-L1</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>CRS-L2</td>
<td>295</td>
<td>490-690</td>
<td>22</td>
<td>NR</td>
<td>0</td>
</tr>
<tr>
<td>CRS-L3</td>
<td>410</td>
<td>min. 690</td>
<td>17</td>
<td>40</td>
<td>0</td>
</tr>
</tbody>
</table>

1) Testing is normally to be carried out at 0°C.
NR = Not required
7.4.4 Marking

Chain cables which meet the requirements are to be stamped at both ends of each length at least with the following marks; cf. Figure 7.4.4.
- Chain cable grade
- Certificate number
- Register's stamp

Figure 7.4.4 Marking of chain cables

7.4.5 Certification

Chain cables which meet the requirements are to be certified by the Register with the following items:
- Manufacturer’s name
- Grade
- Chemical composition (including total aluminium content)
- Nominal diameter/weight
- Proof/break loads
- Heat treatment
- Marks applied to chain
- Length
- Mechanical properties, where applicable

7.5 TESTING AND CERTIFICATION OF ACCESSORIES

7.5.1 Proof load test

All accessories are to be subjected to the proof load test at the proof load specified for the corresponding chain given by Table 7.4.1.2, and in accordance with the provisions of 7.4.1, as appropriate.

7.5.2 Breaking load test

7.5.2.1 From each manufacturing batch (same accessory type, grade, size and heat treatment charge, but not necessarily representative of each heat of steel or individual purchase order) of 25 units or less of detachable links, shackles, swivels, swivel shackles, enlarged links, and end links, and from each manufacturing batch of 50 units or less of kenter shackles, one unit is to be subjected to the breaking load test at the break load specified for the corresponding chain given by Table 7.4.1.2 and in accordance with the provisions of 7.4.1, as appropriate. Parts tested in this way may not be put to further use. Enlarged links and end links need not be tested provided that they are manufactured and heat treated together with the chain cable.

7.5.2.2 The Register may waive the breaking load test if:
  a) the breaking load has been demonstrated on the occasion of the approval testing of parts of the same design, and
  b) the mechanical properties of each manufacturing batch are proved, and
  c) the parts are subjected to suitable non-destructive testing.

7.5.2.3 Notwithstanding the above, the accessories, which have been successfully tested at the prescribed breaking load appropriate to the chain, may be used in service at the discretion of the Register where the accessories are manufactured with the following:
  a) the material having higher strength characteristics than those specified for the part in question (e.g. Grade CRS-L3 material for accessories for Grade CRS-L2 chain),
  b) or alternatively, the same grade material as the chain but with increased dimensions subject to the successful procedure tests that such accessories are so designed that the breaking strength is not less than 1.4 times the prescribed breaking load of the chain for which they are intended.

7.5.3 Mechanical properties and tests

Unless otherwise specified, the forging or casting must at least comply with the mechanical properties given in Table 7.4.3.3, when properly heat treated. For test sampling, forgings or castings of similar dimensions originating from the same heat treatment charge and the same heat of steel are to be combined into one test unit. Mechanical tests are to be carried out in the presence of the Surveyor depending on the type and grade of material used. From each test unit, one tensile test specimen and three Charpy V-notch impact test specimens are to be taken in accordance with Table 7.4.3.2 and tested in accordance with Ch.2.7. For the location of the test specimens see 7.2.3.3.3 and Figure 7.2.3.3.3. Testing is to follow 7.2.3.3.4 and 7.2.3.3.5. Re-testing is to follow 7.2.3.3.6 and 7.2.3.3.7. Enlarged links and end links need not be tested provided that they are manufactured and heat treated together with the chain cable.

7.5.4 Marking

Accessories which meet the requirements are to be stamped as follows:
- Chain cable grade
- Certificate number
- Register's stamp.
7.5.5 Certification

Chain accessories which meet the requirements are to be certified by the Register at least with the following items:
- Manufacturer’s name
- Grade
- Heat Number
- Chemical composition (including total aluminium content)
- Nominal diameter/weight
- Proof/break loads
- Heat treatment
- Marks applied to accessory
- Mechanical properties, where applicable.
8 WIRE ROPES

8.1 GENERAL

8.1.1 These requirements apply to wire ropes for use as a hawsers (towlines, mooring lines) and as standing and running rigging for cargo handling gear and other lifting tackle.

8.1.2 The manufacturer shall be recognized in accordance with Rules, Part I - Chapter 4 – Approval of the Manufacturers and Service Suppliers, with respect to method of manufacture and quality control.

8.1.3 Applications for approval are to be submitted to the Register in writing with description containing at least following details:
- type, composition and strengths of the ropes concerned,
- manufacturing facilities,
- testing equipment: copies of the last calibration reports on the testing machines are to be attached.

By a works inspection, the manufacturer shall demonstrate the availability of the equipment necessary for the proper manufacture and testing of wire ropes. The Register reserve the right to call for a preliminary test of suitability to be carried out on samples of the rope.

8.1.4 The ropes shall conform to recognized standards (e.g. ISO 2408, DIN 3057 to DIN 3060 and DIN 3064 to DIN 3066) and should, wherever possible, comply with the Table 8.1.4. Ropes of a different construction and ropes with high nominal breaking strengths, e.g. 1960 N/mm², or containing austenitic stainless steel wires may be approved on application provided that they are suitable for the proposed application.

<table>
<thead>
<tr>
<th>Table 8.1.4</th>
<th>Usual types of wire ropes approved by the Register</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Use</strong></td>
<td><strong>Structure of rope</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Number of strands</strong></td>
</tr>
<tr>
<td>Standing rigging</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>6</td>
</tr>
<tr>
<td>Hawser (towlines, mooring lines)</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>6</td>
</tr>
<tr>
<td>Running rigging</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>6</td>
</tr>
</tbody>
</table>

³ This rope may also be used as a single reeved span rope not moved under load.

8.1.5 With the exception of wire ropes made of austenitic stainless steel wires, wire ropes shall normally be manufactured from individually galvanized wires. The use of ungalvanized wires requires the special consent of the Register.

8.2 REQUIREMENTS APPLIED TO WIRE ROPES

8.2.1 Nominal breaking strength

Wire ropes shall have the nominal breaking strengths of 1570 N/mm² and 1770 N/mm² specified in Table

<table>
<thead>
<tr>
<th>Table 8.2.1</th>
<th>Positive tolerances for nominal breaking strengths</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nominal wire diameter [mm]</strong></td>
<td><strong>Limiting deviations [N/mm²]</strong></td>
</tr>
<tr>
<td>0,20 up to &lt; 0,50 mm</td>
<td>+ 390</td>
</tr>
<tr>
<td>0,50 up to &lt; 1,00 mm</td>
<td>+ 350</td>
</tr>
<tr>
<td>1,00 up to &lt; 1,50 mm</td>
<td>+ 320</td>
</tr>
<tr>
<td>1,50 up to &lt; 2,00 mm</td>
<td>+ 290</td>
</tr>
<tr>
<td>2,00 up to ≤ 6,00 mm</td>
<td>+ 260</td>
</tr>
</tbody>
</table>

8.1.4 These values shall not be exceeded by more than the values shown in Table 8.2.1.
8.2.2  Ductility

Individual wires shall possess sufficient ductility, measured by their ability to withstand a fixed number of reverse bends and/or twists without starting to crack. These requirements are regarded as fulfilled if the values specified in EN 10264, or in an equivalent standard recognized by the Register are achieved.

8.2.3  Tolerances on diameter

The tolerance on the diameter of rope wires shall lie within the limits specified in recognized standards, e.g. in EN 10264.

8.2.4  Galvanizing method

Hawsers and standing rigging shall be manufactured from fully galvanized wires. Normally galvanized wires may be used for all other ropes. The zinc coating shall conform to the data shown in Table 8.2.4.

<table>
<thead>
<tr>
<th>Zinc coatings</th>
<th>Nominal wire diameter [mm]</th>
<th>Minimum mass per unit area of zinc coating [g/m²] for type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Normally galvanized</td>
</tr>
<tr>
<td>0,20 up to &lt; 0,25 mm</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>0,25 up to &lt; 0,40 mm</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>0,40 up to &lt; 0,50 mm</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>0,50 up to &lt; 0,60 mm</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>0,60 up to &lt; 0,70 mm</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>0,70 up to &lt; 0,80 mm</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>0,80 up to &lt; 1,00 mm</td>
<td>70</td>
<td>130</td>
</tr>
<tr>
<td>1,00 up to &lt; 1,20 mm</td>
<td>80</td>
<td>150</td>
</tr>
<tr>
<td>1,20 up to &lt; 1,50 mm</td>
<td>90</td>
<td>165</td>
</tr>
<tr>
<td>1,50 up to &lt; 1,90 mm</td>
<td>100</td>
<td>180</td>
</tr>
<tr>
<td>1,90 up to &lt; 2,50 mm</td>
<td>110</td>
<td>205</td>
</tr>
<tr>
<td>2,50 up to &lt; 3,20 mm</td>
<td>125</td>
<td>230</td>
</tr>
<tr>
<td>3,20 up to &lt; 3,70 mm</td>
<td>135</td>
<td>250</td>
</tr>
<tr>
<td>3,70 up to &lt; 4,00 mm</td>
<td>135</td>
<td>260</td>
</tr>
<tr>
<td>4,00 up to &lt; 4,50 mm</td>
<td>150</td>
<td>270</td>
</tr>
<tr>
<td>4,50 up to &lt; 5,50 mm</td>
<td>165</td>
<td>280</td>
</tr>
<tr>
<td>5,50 up to &lt; 6,00 mm</td>
<td>180</td>
<td>280</td>
</tr>
</tbody>
</table>

8.3  TESTING OF WIRE ROPES

The following tests are to be performed:

8.3.1  Testing of zinc coating

8.3.1.1  The specified weight of the zinc coating is to be determined an certified by the manufacturer by chemical-ly stripping the coating and measuring the weight loss of the stripped wires according to a recognized method, e.g. in accordance with DIN 51213. Wires of the various diameters shall be removed from the rope for this purpose.

8.3.2  Ductility test

8.3.2.1  At the option of the manufacturer, the ductility of the rope wires shall be tested either by the reverse bend test or by the twisting test specified in a recognized standard, e.g. DIN 51211 or DIN 51212. All the wires constituting a strand taken from the rope shall be subjected to this test. The test is considered successful if at least 95% of the wires withstand the bend or twisting test specified in the relevant standard without breaking.

8.3.3  Tensile test

8.3.3.1  From every manufactured length of rope up to 10000 m a test sample is to be tensile tested in its entirely to destruction. The test length shall be equal to 30 times the diameter of the rope, subject to a minimum of 600 mm. The minimum breaking load shall achieve the value specified for the rope in question in the standard. In the case of manufactured lengths of more than 10000 m, a second test sample is to be taken and tested.

8.3.3.2  Where the tensile loading capacity of the testing machine is insufficient to test the rope in its entirely, the breaking load of the rope shall be determined from the results of tests performed on the individual wires. For this purpose a strand is to be taken from every manufactured length of rope of 5000 m or less, and its constituent wires shall be individually subjected to the tensile test, e.g. to EN 12385. The wire test specimens shall have an initial measured length of 100 or 200 mm. The tensile strength is determined on the basis of the nominal wire diameter.

The test shall be deemed successful if at least 95% of the rope wires meet the requirements stated in 8.2.1 and the calculated breaking load achieves the values specified in the relevant standard. For this purpose, the individual test values are to be applied to the total number of wires in the rope and multiplied by the realization factor shown in Table 8.3.3.2.
### Table 8.3.3.2
Realization factors

<table>
<thead>
<tr>
<th>Rope construction</th>
<th>Ropes with fibre core</th>
<th>Ropes with steel core</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 x 7</td>
<td>0.9000</td>
<td>0.8379</td>
</tr>
<tr>
<td>6 x 19</td>
<td>0.8600</td>
<td>0.8007</td>
</tr>
<tr>
<td>6 x 24</td>
<td>0.8700</td>
<td>-</td>
</tr>
<tr>
<td>6 x 36</td>
<td>0.8400</td>
<td>0.7821</td>
</tr>
<tr>
<td>6 x 37</td>
<td>0.8250</td>
<td>0.7681</td>
</tr>
</tbody>
</table>

### 8.3.4 Dimensional check

8.3.4.1 The diameter of each rope is to be measured at two points located at least 1 m apart in two directions approximately perpendicular to each other. The difference between the smallest and the largest result may not be more than 4%.

The average value of the four measurements shall be considered to be actual rope diameter and shall lie within the permitted tolerances. The number and diameter of the individual wires shall also be verified.

### 8.4 MARKING

8.4.4.1 Wire ropes are to be provided with worked-in coloured threads as follows for the purpose of distinguishing the nominal strength of the wires:

- Nominal strength 1570 N/mm²: white
- Nominal strength 1770 N/mm²: green
- Nominal strength 1960 N/mm²: yellow

For special rope constructions in accordance with 8.1.4, the colour of the distinguishing thread shall be specially designated.

8.4.4.2 A tape shall also be worked into the ropes bearing the manufacturer’s name.

The coloured distinguishing thread may be dispensed with if the tape designating the company is of the colour specified in 8.4.4.1.

Ropes which have been tested in the presence of the Surveyor shall be marked with the Register’s stamp and number of certificate.
APPENDIX A

A1. Manufacturing Approval Scheme of Semi Finished Products for Hull Structural Steels

1. Scope of application

This document specifies, as given in 3.2.2.1, the scheme for the approval of the manufacturing process of semi-finished products such as ingots, slabs, blooms and billets for the structural steels.

The manufacturing approval scheme is valid for verifying the manufacturer’s capability to provide satisfactory products stably under effective process and production controls in which is required in 3.2.2.2.

2. Approval application

2.1 Documents to be submitted

The manufacturer has to submit to the Register, request of approval, proposed approval test program (see 3.1) and general information relevant to:

a) Name and site address of the manufacturer, location of the workshops, general indications relevant to the background, dimension of the works, estimated total annual production of finished products for shipbuilding and for other applications, as deemed useful.

b) Organization and quality:
   • organizational chart
   • staff employed
   • staff employed and organization of the quality control department
   • qualification of the personnel involved in activities related to the quality of the products
   • certification of compliance of the quality system with ISO 9001 or 9002, if any
   • approval certificates already granted by other Classification Societies, if any

c) Manufacturing facilities
   • flow chart of the manufacturing process
   • origin and storage of raw materials
   • storage of finished products
   • equipment for systematic control during fabrication

d) Details of inspections and quality control facilities
   • details of system used for identification of materials at the different stages of manufacturing
   • equipment for chemical analyses and relevant calibration procedures
   • list of quality control procedures

e) Type of products (ingots, slabs, blooms, billets); types of steel (normal or higher strength), range of thickness and aim material properties as follows:
   • range of chemical composition and aim analyses, including grain refining, micro alloying and residual elements, for the various grades of steel; if the range of chemical composition depends on thickness and supply condition, the different ranges are to be specified, as appropriate
   • aim maximum carbon equivalent according to IIW formula
   • aim maximum Pcm content for higher strength grades with low carbon content C<0.13 %
   • production statistics of the chemical composition and, if available at rolling mills, mechanical properties (ReH, Rm, A% and KV). The statistics are intended to demonstrate the capability to manufacture the steel products in accordance with the requirements.

f) Steelmaking
   • steel making process and capacity of furnace/s or converter/s
   • raw material used
   • deoxidation and alloying practice
   • desulphurisation and vacuum degassing installations, if any
   • casting methods: ingot or continuous casting. In the case of continuous casting, information relevant to type of casting machine, teeming practice, methods to prevent re-oxidation, inclusions and segregation control, presence of electromagnetic stirring, soft reduction, etc., is to be provided as appropriate.
   • ingot or slab size and weight
   • ingot or slab treatment: scarfing and discarding procedures

g) Approval already granted by other Classification Societies and documentation of approval tests performed.

2.2 Documents to be submitted for changing the approval conditions

The manufacturer has to submit to the Register the documents required in 2.1 together with the request of changing the approval conditions, in the case of the following a) through c):

a) Change of the manufacturing process (steel making process, casting method, steel making plant, caster)

b) Change of the thickness range (dimension)

c) Change of the chemical composition, added element, etc.
However, where the documents are duplicated by the ones at the previous approval for the same type of product, part or all of the documents may be omitted except the approval test program (see 3.1).

3. Approval tests

3.1 Extent of the approval tests

The extent of the test program is specified in 3.6, it may be modified on the basis of the preliminary information submitted by the manufacturer.

In particular a reduction of the indicated number of casts, product thicknesses and types to be tested or complete suppression of the approval tests may be accepted by the Register taking into account:

a) Approval already granted by other Classification Societies and documentation of approval tests performed.

b) Types of steel to be approved and availability of long term statistic results of chemical properties and of mechanical tests performed on rolled products.

c) Change of the approval conditions.

On the other hand, an increase of the number of casts and thicknesses to be tested may be required in the case of newly developed types of steel or manufacturing processes.

3.2 Approval test program

Where the number of tests differs from those shown in 3.6, the program is to be confirmed by the Register before the tests are carried out.

3.3 Approval survey

The approval tests are to be witnessed by the Surveyor at the manufacturer’s plant and the execution of the plant inspection in operation may be required by the Surveyor during the visit for the approval.

If the testing facilities are not available at the works, the tests are to be carried out at recognized laboratories.

3.4 Selection of the test product

For each type of steel and for each manufacturing process (e.g. steel making, casting), one test product with the maximum thickness and one test product with the minimum thickness to be approved are in general to be selected for each kind of product (ingots, slabs, blooms/billets).

The selection of the casts for the test product is to be based on the typical chemical composition, with particular regard to the specified Ceq or Pcm values and grain refining micro-alloying additions.

3.5 Position of the test samples

The test samples are to be taken, unless otherwise agreed, from the product (slabs, blooms, billets) corresponding to the top of the ingot, or, in the case of continuous casting, a random sample.

3.6 Tests on base material

3.6.1 Type of tests

The tests to be carried out for the approval of the manufacturing process of semi-finished products are:

- Chemical analysis. The analysis is to be complete and is to include micro alloying elements.
- Sulphur prints.

In addition, for initial approval and for any upgrade of the approval, the Register will require full tests indicated in Appendix A2.3 to be performed at rolling mill on the minimum thickness semi finished product.

In case of a multi-caster work, full tests on finished products shall be carried out for one caster and reduced tests (chemical analysis and sulphur print) for the others. The selection of the caster shall be based on the technical characteristics of the casters to be evaluated on case by case basis to be performed at rolling mill on products manufactured from the minimum thickness semi finished product.

3.6.2 Test specimens and testing procedure

The following tests and procedures apply:

a) Chemical analyses

Both the ladle and product analyses are to be reported. In general the content of the following elements is to be checked: C, Mn, Si, S, Ni, Cr, Mo, Al, N, Nb, V, Cu, As, Sn, Ti and, for steel manufactured from electric or open-hearth furnace, Sb and B.

b) Sulphur prints are to be taken from product edges which are perpendicular to the axis of the ingot or slab. These sulphur prints are to be approximately 600 mm long taken from the centre of the edge selected, i.e. on the ingot centreline, and are to include the full product thickness.

4. Results

All the results, which are in any case to comply with the requirements of the Rules, are evaluated for the approval; depending on the results, particular limitations or testing conditions, as deemed appropriate, may be specified in the approval document.

All the information required under Appendix A2.2, applicable to the products submitted to the tests, is to be collected by the manufacturer and put in the dossier which will include all the results of the tests and operation records relevant to steel making, casting and, when applicable, rolling and heat treatment of the test products.

5. Certification

5.1 Approval

Upon satisfactory completion of the survey, approval is granted by the Society.

On the approval certificate the following information is to be stated:
• Type of products (ingots, slabs, blooms, billets)
• Steelmaking and casting processes
• Thickness range of the semi-finished products
• Types of steel (normal or higher strength)

It is also to be indicated that the individual users of the semi-finished products are to be approved for the manufacturing process of the specific grade of rolled steel products they are going to manufacture with those semi-finished products.

5.2 List of approved manufacturers

The approved manufacturers are entered in a list containing the types of steel and the main conditions of approval.

6. Renewal of approval

The validity of the approval is to be a maximum of five years.

Renewal can be carried out by an audit and assessment on the result of satisfactory survey during the period. Where for operational reasons, the renewal audit falls outside the period of approval, the manufacturer will still be considered as approved if agreement to this audit date is made within the original period of approval, in this instance if successful, the extension of approval will be back dated to the original renewal date.

Manufacturers who have not produced the approved grades and products during the period between renewals may be required to either carry out approval tests or, on the basis of results of production of similar grades of products, at the discretion of the Register, be reapproved.

7. Reconsideration of the approval

During the period of validity the approval may be reconsidered in the following cases:

a) in service failures, traceable to product quality
b) non conformity of the product revealed during fabrication and construction
c) discovered failure of the Manufacturer’s quality system
d) changes brought by the Manufacturer, without preliminary agreement of the Register, to the extent of the approval defined at the time of the approval
e) evidence of major non conformities during testing of the products.

A2. Manufacturing Approval Scheme of Hull Structural Steels

1. Scope of application

This document specifies, as given in 3.2.2.1, the scheme for the approval of the manufacturing process of normal and higher strength hull structural steels, and also applies to the approval of semi-finished products such as slabs, blooms and billets for the structural steels.

The manufacturing approval scheme is valid for verifying the manufacturer’s capability to provide satisfactory products stably under effective process and production controls in operation including programmed rolling, which is required in 3.2.2.2 and 3.2.3.3.
steel products in accordance with the requirements.

f) Steelmaking
• steel making process and capacity of furnace/s or converter/s
• raw material used
• deoxidation and alloying practice
• desulphurisation and vacuum degassing installations, if any
• casting methods: ingot or continuous casting.
In the case of continuous casting, information relevant to type of casting machine, teeming practice, methods to prevent re-oxidation, inclusions and segregation control, presence of electromagnetic stirring, soft reduction, etc., is to be provided as appropriate.
• ingot or slab size and weight
• ingot or slab treatment: scarfing and discarding procedures

g) Reheating and rolling
• type of furnace and treatment parameters
• rolling: reduction ratio of slab/bloom/billet to finished product thickness, rolling and finishing temperatures
• descaling treatment during rolling
• capacity of the rolling stands

h) Heat treatment
• type of furnaces, heat treatment parameters and their relevant records
• accuracy and calibration of temperature control devices

i) Programmed rolling
For products delivered in the controlled rolling (CR) or thermo-mechanical rolling (TM) condition, the following additional information on the programmed rolling schedules is to be given:
• description of the rolling process
• normalizing temperature, re-crystallization temperature and Ar3 temperature and the methods used to determine them
• control standards for typical rolling parameters used for the different thickness and grades of steel (temperature and thickness at the beginning and at the end of the passes, interval between passes, reduction ratio, temperature range and cooling speed of accelerated cooling, if any) and relevant method of control
• calibration of the control equipment

j) Recommendations for working and welding in particular for products delivered in the CR or TM condition
• cold and hot working recommendations if needed in addition to the normal practice used in the shipyards and workshops
• minimum and maximum heat input if different from the ones usually used in the shipyards and workshops (15 - 50 kJ/cm)

k) Where any part of the manufacturing process is assigned to other companies or other manufacturing plants, additional information required by the Register is to be included.

l) For the approval of the semi-finished products such as ingots, slabs, blooms and billets for the structural steels, the above information a) through f) is to be given.
m) Approval already granted by other Classification Societies and documentation of approval tests performed.

2.2 Documents to be submitted for changing the approval conditions

The manufacturer has to submit to the Register the documents required in 2.1 together with the request of changing the approval conditions, in the case of the following a) through e) as applicable:

a) Change of the manufacturing process (steel making, casting, rolling and heat treatment)
b) Change of the maximum thickness (dimension)
c) Change of the chemical composition, added element, etc.
d) Subcontracting the rolling, heat treatment, etc.
e) Use of the slabs, blooms and billets manufactured by companies other than the ones verified in the approval tests.

However, where the documents are duplicated by the ones at the previous approval for the same type of product, part or all of the documents may be omitted except the approval test program (see 3.1).

3. Approval tests

3.1 Extent of the approval tests

The extent of the test program is specified in 3.6 and 3.7 of this Appendix, and it may be modified on the basis of the preliminary information submitted by the manufacturer.

In particular a reduction of the indicated number of casts, steel plate thicknesses and grades to be tested or complete suppression of the approval tests may be accepted by the Register taking into account:

a) Approval already granted by other Classification Societies and documentation of approval tests performed
b) Grades of steel to be approved and availability of long term statistic results of chemical and mechanical properties
c) Approval for any grade of steel also covers approval for any lower grade in the same strength level, provided that the aim analyses, method of manufacture and condition of supply are similar.
d) For higher tensile steels, approval of one strength level covers the approval of the strength level immediately below, provided the steelmaking process, deoxidation and fine grain practice, casting method and condition of supply are the same.
e) Change of the approval conditions
f) Approval of the semi-finished products such as slabs, blooms and billets.

On the other hand, an increase of the number of casts and thicknesses to be tested may be required in the case...
of newly developed types of steel or manufacturing processes.

In case of multi-source slabs or changing of slab manufacturer, the rolled steel manufacturer is required to obtain the approval of the manufacturing process of rolled steels using the slabs from each slab manufacturer and to conduct approval tests in accordance with 3.6 and 3.7 of this Appendix. A reduction or complete suppression of the approval tests may considered by the Register taking into account previous approval as follows:

- the rolled steel manufacturer has already been approved for the manufacturing process using other semi finished products characterised by the same thickness, steel grade, grain refining and micro-alloying elements, steel making and casting process;
- the semi finished products manufacturer has been approved for the complete manufacturing process with the same conditions (steelmaking, casting, rolling and heat treatment) for the same steel types.

3.2 Approval test program

Where the number of tests differs from those shown in pt. 3.6 and 3.7 of this Appendix, the program is to be confirmed by the Register before the tests are carried out.

3.3 Approval survey

The approval tests are to be witnessed by the Surveyor at the manufacturer’s plant and the execution of the plant inspection in operation may be required by the Surveyor or during the visit for the approval.

If the testing facilities are not available at the works, the tests are to be carried out at recognised laboratories.

3.4 Selection of the test product

For each grade of steel and for each manufacturing process (e.g. steel making, casting, rolling and condition of supply), one test product with the maximum thickness (dimension) to be approved is in general to be selected for each kind of product.

In addition, for initial approval, the Register will require selection of one test product of average thickness.

The selection of the casts for the test product is to be based on the typical chemical composition, with particular regard to the specified Ceq or Pcm values and grain refining micro-alloying additions.

3.5 Position of the test samples

The test samples are to be taken, unless otherwise agreed, from the product (plate, flat, section, bar) corresponding to the top of the ingot, or, in the case of continuous casting, a random sample.

The position of the samples to be taken in the length of the rolled product, "piece" defined in pt. 3.2.11.1 (a), (top and/or bottom of the piece) and the direction of the test specimens with respect to the final direction of rolling of the material are indicated in Table 1.

The position of the samples in the width of the product is to be in compliance with pt. 3.2.11.2 (d).

3.6 Tests on base material

3.6.1 Type of tests

The tests to be carried out are indicated in the following Table 1.

3.6.2 Test specimens and testing procedure

The test specimens and testing procedures are to be, as a rule, in accordance with Chapter 2 (Test specimens and mechanical testing procedures for materials).

In particular the following applies:

a) Tensile test

- for plates made from hot rolled strip one additional tensile specimen is to be taken from the middle of the strip constituting the coil.
- for plates having thickness higher than 40mm, when the capacity of the available testing machine is insufficient to allow the use of test specimens of full thickness, multiple flat specimens, representing collectively the full thickness, can be used. Alternatively two round specimens with the axis located at one quarter and at mid-thickness can be taken.

b) Impact test

- for plates made from hot rolled strip one additional set of impact specimens is to be taken from the middle of the strip constituting the coil.
- for plates having thickness higher than 40mm one additional set of impact specimens is to be taken with the axis located at mid-thickness.
- in addition to the determination of the energy value, also the lateral expansion and the percentage crystallinity are to be reported.

c) Chemical analyses

Both the ladle and product analyses are to be reported. The material for the product analyses should be taken from the tensile test specimen. In general the content of the following elements is to be checked: C, Mn, Si, P, S, Ni, Cr, Mo, Al, N, Nb, V, Cu, As, Sn, Ti and, for steel manufactured from electric or open-hearth furnace, Sb and B.

d) Sulphur prints are to be taken from plate edges which are perpendicular to the axis of the ingot or slab. These sulphur prints are to be approximately 600 mm long taken from the centre of the edge selected, i.e. on the ingot centrel ine, and are to include the full plate thickness.

e) Micrographic examination : the micrographs are to be representative of the full thickness. For thick products in general at least three examinations are to be made at surface, one quarter and mid-thickness of the product.
All photomicrographs are to be taken at x100 magnification and where ferrite grain size exceeds ASTM 10, additionally at x500 magnification. Ferrite grain size should be determined for each photomicrograph.
f) Drop weight test: the test is to be performed in accordance with ASTM E208. The NDTT is to be determined and photographs of the tested specimens are to be taken and enclosed with the test report.
g) Through thickness tensile test: the test is to be performed in accordance with Ch. 3.9 of this Rules.

### 3.6.3 Other tests

Additional tests such as CTOD test, large scale brittle fracture tests (Double Tension test, ESSO test, Deep Notch test, etc.) or other tests may be required in the case of newly developed type of steel, outside the scope of Ch.3 of this Rules, or when deemed necessary by the Register.

#### Table 1

<table>
<thead>
<tr>
<th>Type of test</th>
<th>Position of the samples and direction of the test specimens (1)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile test</td>
<td>Top and bottom transverse (2)</td>
<td>ReH, Rm, A5(%) , RA(%) are to be reported</td>
</tr>
<tr>
<td>Tensile test (stress relieved) only for TM steels</td>
<td>Top and bottom transverse (2)</td>
<td>Stress relieving at 600°C (2 min/mm with minimum 1 hour)</td>
</tr>
<tr>
<td>Impact tests (3) on non aged specimens for grades:</td>
<td>Top and bottom - longitudinal</td>
<td>Testing temperature (°C)</td>
</tr>
<tr>
<td>A, B, A32, A36, A40</td>
<td></td>
<td>+20 0 -20</td>
</tr>
<tr>
<td>D, D32, D36, D40</td>
<td></td>
<td>0 -20 -40</td>
</tr>
<tr>
<td>E, E32, E36, E40</td>
<td></td>
<td>0 -20 -40 -60</td>
</tr>
<tr>
<td>F32, F36, F40</td>
<td></td>
<td>-20 -40 -60 -80</td>
</tr>
<tr>
<td>A, B, A32, A36, A40</td>
<td>Top - transverse (4)</td>
<td>+20 0 -20</td>
</tr>
<tr>
<td>D, D32, D36, D40</td>
<td></td>
<td>0 -20 -40</td>
</tr>
<tr>
<td>E, E32, E36, E40</td>
<td></td>
<td>-20 -40 -60</td>
</tr>
<tr>
<td>F32, F36, F40</td>
<td></td>
<td>-40 -60 -80</td>
</tr>
<tr>
<td>Impact test (5) on strain aged specimens (5) for grades:</td>
<td>Top - longitudinal</td>
<td>Testing temperature (°C)</td>
</tr>
<tr>
<td>A32, A36, A40</td>
<td></td>
<td>+20 0 -20</td>
</tr>
<tr>
<td>D, D32, D36, D40</td>
<td></td>
<td>0 -20 -40</td>
</tr>
<tr>
<td>E, E32, E36, E40</td>
<td></td>
<td>-20 -40 -60</td>
</tr>
<tr>
<td>F32, F36, F40</td>
<td></td>
<td>-40 -60 -80</td>
</tr>
<tr>
<td>Chemical analyses (6)</td>
<td>Top</td>
<td>Complete analyses including micro alloying elements</td>
</tr>
<tr>
<td>Sulphur prints</td>
<td>Top</td>
<td></td>
</tr>
<tr>
<td>Micro examination</td>
<td>Top</td>
<td></td>
</tr>
<tr>
<td>Grain size determination</td>
<td>Top</td>
<td>only for fine grain steels</td>
</tr>
<tr>
<td>Drop weight test (4)</td>
<td>Top</td>
<td>only for grades E, E32, E36, E40, F32, F36, F40</td>
</tr>
<tr>
<td>Through thickness tensile tests</td>
<td>Top and bottom</td>
<td>only for grades with improved through thickness properties</td>
</tr>
</tbody>
</table>

1) For hot rolled strips see 3.6.2.
2) Longitudinal direction for sections and plates having width less than 600 mm.
3) One set of 3 Charpy V-notch impact specimens is required for each impact test.
4) Not required for sections and plates having width less than 600 mm.
5) Deformation 5% + 1 hour at 250°C.
6) Besides product analyses, ladle analyses are required.
3.7 Weldability tests

3.7.1 General

Weldability tests are required for plates and are to be carried out on samples of the thickest plate. Tests are required for normal strength grade E and for higher strength steels.

3.7.2 Preparation and welding of the test assemblies

The following tests are in general required:

a) 1 butt weld test assembly welded with a heat input approximately 15 kJ/cm
b) 1 butt weld test assembly welded with a heat input approximately 50 kJ/cm.

The butt weld test assemblies are to be prepared with the weld seam transverse to the plate rolling direction, so that impact specimens will result in the longitudinal direction.

The bevel preparation should be preferably 1/2V or K.

The welding procedure should be as far as possible in accordance with the normal welding practice used at the yards for the type of steel in question.

The welding parameters including consumables designation and diameter, pre-heating temperatures, interpass temperatures, heat input, number of passes, etc. are to be reported.

3.7.3 Type of tests

From the test assemblies the following test specimens are to be taken:

a) 1 cross weld tensile test
b) a set of 3 Charpy V-notch impact specimens transverse to the weld with the notch located at the fusion line and at a distance 2, 5 and minimum 20 mm from the fusion line. The fusion boundary is to be identified by etching the specimens with a suitable reagent. The test temperature is to be the one prescribed for the testing of the steel grade in question.

c) Hardness tests HV 5 across the weldment. The indentations are to be made along a 1 mm transverse line beneath the plate surface on both the face side and the root side of the weld as follows:
   - Fusion line
   - HAZ: at each 0.7 mm from fusion line into unaffected base material (6 to 7 minimum measurements for each HAZ)

The maximum hardness value should not be higher than 350 HV.

A sketch of the weld joint depicting groove dimensions, number of passes, hardness indentations should be attached to the test report together with photomacrographs of the weld cross section.

3.7.4 Other tests

Additional tests such as cold cracking tests (CTS, Cruciform, Implant, Tekken, Bead-on plate), CTOD, or other tests may be required in the case of newly developed type of steel, outside the scope of Chapter 3 of this Rules, or when deemed necessary by the Register.

4 Results

All the results, which are in any case to comply with the requirements of the Rules, are evaluated for the approval; depending on the results, particular limitations or testing conditions, as deemed appropriate, may be specified in the approval document.

All the information required under pt. 2, of this Appendix applicable to the products submitted to the tests, is to be collected by the manufacturer and put in the dossier which will include all the results of the tests and operation records relevant to steel making, casting, rolling and heat treatment of the test products.

5 Certification

5.1 Approval

Upon satisfactory completion of the survey, approval is granted by the Register.

5.2 List of approved manufacturers

The approved manufacturers are entered in a list containing the types of steel and the main conditions of approval.

6 Renewal of approval

The validity of the approval is to be a maximum of four years.

Renewal can be carried out by an audit and assessment on the result of satisfactory survey during the period.

Where for operational reasons, the renewal audit falls outside the period of approval, the manufacturer will still be considered as approved if agreement to this audit date is made within the original period of approval, in this instance if successful, the extension of approval will be back dated to the original renewal date.

Manufacturers who have not produced the approved grades and products during the period between renewals may be required to either carry out approval tests or, on the basis of results of production of similar grades of products, at the discretion of the Register, be re-approved.

7 Reconsideration of the approval

During the period of validity the approval may be reconsidered in the following cases:

a) in service failures, traceable to product quality
b) non conformity of the product revealed during fabrication and construction
c) discovered failure of the Manufacturer’s quality system
d) changes brought by the Manufacturer, without preliminary agreement of the Register, to the extent of the approval defined at the time of the approval
e) evidence of major non conformities during testing of the products.
A3. Manufacturing Approval Scheme of High Strength Steels for Welded Structures

1. Scope of application

This appendix specifies the procedure for the approval of the manufacturing process of high strength steels for welded structures.

All materials are to be manufactured at works which have been approved by the Register for the type, delivery condition, grade and thickness of steel which is being supplied. The suitability of each grade of steel for forming and welding is to be demonstrated during the initial approval tests at the steelworks.

The manufacturing approval scheme is valid for verifying the manufacturer’s capability to provide satisfactory products stably under effective process and production controls in operation including programmed rolling, which is required in 3.4.1.2.2.

2. Approval application

2.1 Documents to be submitted

The manufacturer is to submit to the Register, a request for approval, a proposed approval test program (see 3.1) and general information relevant to:

a) Name and site address of the manufacturer, location of the workshops, general indications relevant to the background, dimension of the works, estimated total annual production of finished products, as deemed useful.

b) Organisation and quality
   - organisational chart
   - number of staff employed
   - staff employed and organisation of the quality control department
   - qualification of the personnel involved in activities related to the quality of the products
   - certification of compliance of the quality system with ISO 9001 or 9002, if any
   - approval certificates already granted by other Registers, if any

c) Manufacturing facilities
   - flow chart of the manufacturing process
   - origin and storage of raw materials
   - storage of finished products
   - equipment for systematic control during manufacturing

d) Details of inspections and quality control facilities

2.2 Manufacturing specification

a) Material to be approved, including type of products (plates, sections, bars and tubular), delivery condition, grades of steel, range of thickness and aim material properties as follows:

- range of chemical composition, aim analyses and associated control limits, including grain refining, nitrogen binding, micro alloying and residual elements, for the various grades of steel; if the range of chemical composition depends on thickness and delivery condition, the different ranges are to be specified, as appropriate.

- in addition, where zirconium, calcium and rare earth metals have been used during steelmaking for grain refinement and/or inclusion modification, the contents of these elements shall be specified in the manufacturing specification.

- aim carbon equivalent Ceq according to IIW formula or CET formula and/or aim Pcm content and associated control limits.

- production statistics of the chemical composition and mechanical properties (R_{eH}, R_{m}, A% and CVN). The statistics are intended to demonstrate the capability to manufacture the steel products.

b) Steelmaking (if applicable)

- steel making process and capacity of furnace/s or converter/s
- raw material used
- deoxidation, grain refining, nitrogen binding and alloying practice
- desulphurisation, dehydrogenation, sulphide treatment, ladle refining and vacuum degassing installations, if any
- casting methods: ingot or continuous casting. In the case of continuous casting, information relevant to type of casting machine, teeming practice, methods to prevent re-oxidation, inclusions and segregation control, presence of electromagnetic stirring, soft
reduction, etc., is to be provided as appropriate
- casting/solidification cooling rate control
- ingot or slab size and weight
- ingot or slab treatment: scarfing and discarding procedures
c) Reheating and rolling
- type of furnace and treatment parameters
- rolling: reduction ratio of ingot/slab/bloom/billet to finished product, rolling and finishing temperatures for each grade/thickness combination
- descaling treatment during rolling
- capacity of the rolling stands
d) Heat treatment
- type of furnaces, heat treatment parameters for products to be approved
- accuracy and calibration of temperature control devices
- the methods used to determine austenitizing temperature, recrystallization temperature and Ar3 temperature
- description of quenching and tempering process, if applicable
e) Programmed rolling
f) For products delivered in the Normalised rolling (NR) or thermo-mechanical rolling (TM) condition, the following additional information on the programmed rolling schedules is to be given:
- description of the rolling process
- the methods used to determine austenitizing temperature, recrystallization temperature and Ar3 temperature
- control standards for typical rolling parameters used for the different thickness and grades of steel (temperature and thickness at the beginning and at the end of the passes, interval between passes, reduction ratio, temperature range and cooling speed of accelerated cooling, if any) and relevant method of control
- calibration of the control equipment
g) Recommendations for fabrication and welding in particular for products delivered in the NR or TM condition:
- cold and hot working recommendations if needed in addition to the normal practice used in the shipyards and workshops
- minimum and maximum heat input and recommended pre-heat/interpass temperature
h) Where any part of the manufacturing process is assigned to other companies or other manufacturing plants, additional information required by the Register is to be included.
i) Approval already granted by other Registers and documentation of approval tests performed.

2.3 Documents to be submitted for changing the approval conditions

The manufacturer has to submit to the Register the documents required in 2.1 together with the request of changing the approval conditions, in the case of the following a) through e) as applicable:

a) Change of the manufacturing process (steel making, casting, rolling and heat treatment).
b) Change of the maximum thickness (dimension).
c) Change of the chemical composition, added element, etc.
d) Subcontracting the rolling, heat treatment, etc.
e) Use of the ingots, slabs, blooms and billets manufactured by companies other than the ones verified in the approval tests.

However, where the documents are duplicated by the ones at the previous approval for the same type of product, part or all of the documents may be omitted except the approval test program (see 3.1).

3. Approval tests

3.1 Extent of the approval tests

The extent of the test program is specified in 3.6 and 3.7; it may be modified on the basis of the preliminary information submitted by the manufacturer.

In particular a reduction of the indicated number of casts, steel plate thicknesses and grades to be tested or complete suppression of the approval tests may be accepted by the Register taking into account:

a) Approval already granted by other Registers and documentation of approval tests performed.
b) Grades of steel to be approved and where available the long term statistical results of chemical and mechanical properties.

An increase of the number of casts and thicknesses to be tested may be required in the case of newly developed types of steel or manufacturing processes.
In case of multi-source slabs or changing of slab manufacturer, the rolled steel manufacturer is required to obtain the approval of the manufacturing process of rolled steels using the slabs from each slab manufacturer and to conduct approval tests in accordance with 3.6 and 3.7. A reduction or complete suppression of the approval tests may be considered by the Register taking into account previous approval as follows:

- the rolled steel manufacturer has already been approved for the rolling process and heat treatment using approved other semi finished products characterized by the same thickness range, steel grade, grain refining and micro-alloying elements, steelmaking (deoxidation) and casting process.
- the semi finished products have been approved for the complete manufacturing process with the same conditions (steelmaking, casting, rolling and heat treatment) for the same steel types.

3.2 Approval test program

Where the number of tests differs from those shown in 3.6 and 3.7, the program is to be confirmed by the Register before the tests are carried out.

3.3 Approval survey

The approval tests are to be witnessed by the Surveyor at the manufacturer’s plant and the execution of the plant inspection in operation may be required by the Surveyor during the visit for the approval.

If the testing facilities are not available at the works, the tests are to be carried out at accredited laboratories.

3.4 Selection of the test product

For each grade of steel and for each manufacturing process (e.g. steel making, casting, rolling and condition of supply), one test product with the maximum thickness (dimension) to be approved is in general to be selected for each kind of product.

In addition, for initial approval, the Register will require selection of one test product of representative thickness.

The selection of the casts for the test product is to be based on the typical chemical composition, with particular regard to the aimed $C_{eq}$, $CET$ or $P_{cm}$ values and grain refining micro-alloying additions.

3.5 Position of the test samples and specimens

The test samples are to be taken, unless otherwise agreed, from the product (plate, flat, section, bar and tubular) corresponding to the top and bottom of the ingot as indicated in Table 1, or, in the case of continuous casting, a random sample.

The position of the samples to be taken in the length of the rolled product, “piece” defined in 3.2, (top and bottom of the piece) and the direction of the test specimens with respect to the final rolling direction of the material are indicated in Table 1.

The position of the samples in the width of the product is to be in accordance with 3.2.

The position of the tests with respect to the plate thickness is to be in accordance with Appendix 2 section 3.6.2 of W11.

3.6 Tests on base material

3.6.1 Type of tests

The tests to be carried out are indicated in the following Table 1.
<table>
<thead>
<tr>
<th>Type of test</th>
<th>Position and direction of test specimens</th>
<th>Remarks</th>
</tr>
</thead>
</table>
| 1 Chemical analysis (ladle and product\(^2\)) | Top                                      | a) Contents of C, Mn, Si, P, S, Ni, Cr, Mo, Al, N, Nb, V, Ti, B, Zr, Cu, As, Sn, Bi, Pb, Ca, Sb, O, H are to be reported.  
b) Carbon equivalent calculation, and/or  
c) \(P_{cm}\) calculation, as applicable. |
| 2 Segregation examination          | Top                                      | Sulphur prints\(^3\) are to be taken from plate edges which are perpendicular to the axis of the ingot or slab. These sulphur prints are to be approximately 600 mm long taken from the centre of the edge selected, i.e. on the ingot centreline, and are to include the full plate thickness. |
| 3 Micrographic examination\(^3\)  | Top                                      | a) Grain size determination. Ferrite and/or prior austenite grain size should be determined.  
b) All photomicrographs are to be taken at \(x\) 100 and 500 magnification.  
c) Non-metallic inclusion contents/Cleanliness  
The level of non-metallic inclusions and impurities in term of amount, size, shape and distribution shall be controlled by the manufacturer. The standards of the micrographic examination methods ISO 4967 or equivalent standards are applicable. Alternative methods for demonstrating the non-metallic inclusions and impurities may be used by the manufacturer. |
| 4 Tensile test                     | Top and bottom - longitudinal and transverse direction | Yield strength (\(R_{el}\)), Tensile strength (\(R_b\)), Elongation (A5), Reduction in Area (RA) and Y/T ratio are to be reported.                                                                 |
| 5a Charpy Impact tests on unstrained specimens for grades\(^4\) | Top and bottom - longitudinal and transverse direction | Testing temperature (\(^\circ\)C)                                                                                                                                                                          |
|                                  |                                          | +20  | 0  | -20  |
|                                  |                                          | 0   | -20 | -40  |
|                                  |                                          | 0   | -20 | -40  |
|                                  |                                          | -20 | -40 | -60  |
| 5b Charpy Impact tests on strain aged specimens for grades\(^5\) | Top                                      | Deformation of 5% + 1 hour at 250\(^\circ\)C                                                                                                                                                           |
|                                  |                                          | +20  | 0  | -20  |
|                                  |                                          | 0   | -20 | -40  |
|                                  |                                          | 0   | -20 | -40  |
|                                  |                                          | -20 | -40 | -60  |
| 6 Drop weight test               | Top                                      | The test is to be performed only on plates in accordance with ASTM E208. The NDTT is to be determined and photographs of the tested specimens are to be taken and enclosed with the test report. |
| 7 Through thickness tensile tests | Top and bottom                           | Optional for grades with improved through thickness properties, testing in accordance with UR W14.                                                                                                     |
Table 1  
Tests on base material (cont.)

<table>
<thead>
<tr>
<th>Type of test</th>
<th>Position and direction of test specimens</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>Weldability test(6)</td>
<td></td>
</tr>
<tr>
<td>a)</td>
<td>Butt Weld Assembly as-welded Top</td>
<td>Cross weld tensile, Charpy impact test on WM, FL, FL+2, FL+5, FL+20 Macro examination and hardness survey, CTOD at -10°C on Grain-coarsened HAZ.</td>
</tr>
<tr>
<td>b)</td>
<td>Butt Weld Assembly (PWHT), if applicable Top</td>
<td>Cross weld tensile, Charpy impact test on WM, FL, FL+2, FL+5, FL+20 Macro examination and hardness survey, CTOD at -10°C on Grain-coarsened HAZ.</td>
</tr>
<tr>
<td>c)</td>
<td>Y-shape weld crack test (Hydrogen crack test) Top</td>
<td></td>
</tr>
</tbody>
</table>

Notes:  
1) The product analyses should be taken from the tensile specimen. The deviation of the product analysis from the ladle analysis shall be permissible in accordance with the limits given in the manufacturing specification.  
2) Other tests than Sulphur prints for segregation examination may be applied and subject to acceptance by the Register.  
3) The micrographs are to be representative of the full thickness. For thick products in general at least three examinations are to be made at surface, 1/4t and 1/2t of the product.  
4) In addition to the determination of the absorbed energy value, also the lateral expansion and the percentage crystallinity are to be reported.  
5) Strain ageing test is to be carried out on the thickest plate.  
6) Weldability test is to be carried out on the thickest plate.

3.6.2 Test specimens and testing procedure  
The test specimens and testing procedures are to be in accordance with Chapter 2, where applicable.

3.6.3 Other tests  
Additional tests such as CTOD test on parent plate, large scale brittle fracture tests (Double Tension test, ESSO test, Deep Notch test, etc.) or other tests may be required in the case of newly developed type of steel, outside the scope of 3.4.1, or when deemed necessary by the Register.

3.7 Weldability tests - Butt weld test  
3.7.1 For H420 to H500 grade steels: Weldability tests are to be carried out on samples of the thickest plate. Testing on higher grades can cover the lower strength and toughness grades.  
- a) 1x butt weld test assembly welded with a heat input 15±2 kJ/cm is to be tested as-welded.  
- b) 1x butt weld test assembly welded with a heat input 50±5 kJ/cm for N/NR and TM and 35±3.5 kJ/cm for QT steels is to be tested as-welded.  
- c) 1x butt weld test assembly welded with the same heat input as given in b) is to be postweld heat treated (PWHT) prior to testing.  

Option: Steels intended to be designated as steels for high heat input welding are to be tested with 1x butt weld test assembly in the as-welded condition and 1x test assembly in the PWHT condition, both welded with the maximum heat input being approved.

3.7.2 For H550 to H960 grade steels:  
In general, the thickest plate with the highest toughness grade for each strength grade is to be tested. Provided the chemical composition of the higher grade is representative to the lower grade, testing requirements on the lower grades may be reduced at the discretion of the Register.  
- a) 1x butt weld test assembly welded with a heat input 10±2 kJ/cm is to be tested as-welded.  
- b) 1x butt weld test assembly welded with a maximum heat input as proposed by the manufacturer is to be tested as-welded. The approved maximum heat input shall be stated on the manufacturer approval certificate.  

Option: If the manufacturer requests to include the approval for Post Weld Heat Treated (PWHT) condition, 1x additional butt weld test assembly welded with a maximum heat input proposed by the manufacturer for the approval same as test assembly b) is to be post-weld heat treated (PWHT) prior to testing.
3.7.3 Butt weld test assembly

The butt weld test assemblies of N/NR plates are to be prepared with the weld seam transverse to the final plate rolling direction.

The butt weld test assemblies of TM/TM+AcC/TM+DQ and QT plates are to be prepared with the weld seam parallel to the final plate rolling direction. The butt weld test assemblies of long products, sections and seamless tubular in any delivery condition are to be prepared with the weld seam transverse to the rolling direction.

3.7.4 Bevel preparation

The bevel preparation should be preferably 1/2V or K related to thickness.

The welding procedure should be as far as possible in accordance with the normal welding practice used for the type of steel in question.

The welding procedure and welding record are to be submitted to the Register for review.

3.7.5 Post-weld heat treatment procedure

a) Steels delivered in N/NR or TM/TM+AcC/TM+DQ condition shall be heat treated for a minimum time of 1 hour per 25 mm thickness (but not less than 30 minutes and needs not be more than 150 minutes) at a maximum holding temperature of 580°C, unless otherwise approved at the time of approval.

b) Steels delivered in QT condition shall be heat treated for a minimum time of 1 hour per 25 mm thickness (but not less than 30 minutes and needs not be more than 150 minutes) at a maximum holding temperature of 550°C with the maximum holding temperature of at least 30°C below the previous tempering temperature, unless otherwise approved at the time of approval.

c) Heating and cooling above 300°C shall be carried out in a controlled manner in order to heat/cool the material uniformly. The cooling rate from the max. holding temperature to 300°C shall not be slower than 55°C/hr.

3.7.6 Type of tests

From the test assemblies the following test specimens are to be taken:

a) 1 cross weld tensile test - 1 full thickness test sample or sub-sized samples cover the full thickness cross section.

b) 1 set of 3 Charpy V-notch impact specimens transverse to the weld seam and 1-2 mm below the surface with the notch located at the fusion line and at a distance 2, 5 and 20 mm from the straight fusion line. An additional set of 3 Charpy test specimens at root is required for each aforementioned position for plate thickness t ≥ 50 mm. The fusion boundary is to be identified by etching the specimens with a suitable reagent. The test temperature is to be the one prescribed for the testing of the steel grade.

c) Hardness tests HV10 across the weldment. The indentations are to be made along a 1-2 mm transverse line beneath the plate surface on both the face side and the root side of the weld as follows:

- fusion line
- HAZ: at each 0.7 mm from fusion line into unaffected base material (6 to 7 minimum measurements for each HAZ)

The maximum hardness value should not be higher than 350HV for grade steels H420 to H460; not be higher than 420HV for H500 to H690; and not be higher than 450HV for H890 and H960.

A sketch of the weld joint depicting groove dimensions, number of passes, hardness indentations should be attached to the test report together with photomacrographs of the weld cross section.

d) CTOD test

CTOD test specimens are to be taken from butt weld test assembly specified in 3.7.1 b) or 3.7.2 b) in Appendix A of this UR. CTOD test is to be carried out in accordance with EN ISO 15653 or equivalent.

- the specimen geometry (B = W) is permitted for plate thickness up to 50 mm. For plate thicker than 50 mm, subsidiary specimen geometry (50x50 mm) is permitted, which is to be taken 50 mm in depth through thickness from the subsurface and 50 mm in width. See Figure 1 and 2 for more details
- the specimens shall be notched in through thickness direction
- grain-coarsened HAZ (GCHAZ) shall be targeted for the sampling position of the crack tip
- the test specimens shall be in as-welded and post-weld heat treated, if applicable
- three tests shall be performed at -10°C on each butt weld test assembly

For grades H690 and above, dehydrogenation of as-welded test pieces may be carried out by a low temperature heat treatment, prior to CTOD testing. Heat treatment conditions of 200°C for 4 h are recommended, and the exact parameters shall be notified with the CTOD test results.
3.7.7 Crack susceptibility weld test (Hydrogen crack test)

Testing in accordance with national and international recognised standards such as GB/T4675.1 and JIS Z 3158 for Y-groove weld crack test. Minimum preheat temperature is to be determined and the relationship of minimum preheat temperature with thickness is to be derived.

3.7.8 Other tests

Additional tests may be required in the case of newly developed types of steel, outside the scope of 3.4.1, or when deemed necessary by the Register.

4. Results

All the results are to comply with the requirements of the scheme of initial approval.

The subject manufacturer shall submit all the test results together with the manufacturing specification containing all the information required under this Appendix, Section 2, and manufacturing records relevant to steel making, casting, rolling and heat treatment, applicable to the product submitted to the tests.

5. Certification

5.1 Approval

Upon satisfactory completion of the survey, approval is granted by the Register.

5.2 List of approved manufacturers

The approved manufacturers are entered in a list containing the types of steel and the main conditions of approval.

6. Renewal of approval

The validity of the approval is to be a maximum of five years.

Renewal can be granted by a periodic inspection and evaluation of the result of the inspection to the surveyor’s satisfaction during the period.

Where for operational reasons, the renewal audit falls outside the period of approval, the manufacturer will still be considered as approved if agreement to this audit date is made within the original period of approval, in this instance if successful, the extension of approval will be back dated to the original renewal date.

Manufacturers who have not produced the approved grades and products during the period between renewals may be required to either carry out approval tests or, on the basis of the statistical data of results of production of similar grades of products, at the discretion of the Register, be reapproved.

7. Removal of the approval

During the period of validity the approval may be reconsidered in the following cases:
a) In service failures, traceable to product quality.
b) Non conformity of the product revealed during fabrication and construction.
c) Discovered failure of the Manufacturer’s quality system.
d) Changes brought by the Manufacturer, without preliminary agreement of the Register, to the extent of invalidating the approval.

e) Evidence of major non conformities during testing of the products.

* The provision for renewal of approval is also to be applied to all grades and products which were approved by the Register prior to an implementation of revision 3 of this section regardless of the validity of certificate in existing approvals. Such renewal is to be completed within five years after the revision 3 becomes effective.
APPENDIX B

Approval scheme for manufacturer of hull structural steels intended for welding with high heat input

1. Scope

This document specifies the weldability confirmation scheme of normal and higher strength hull structural steels stipulated in Chapter 3 of this Rules intended for welding with high heat input over 50 kJ/cm.

The weldability confirmation scheme is to be generally applied by manufacturer’s option and valid for certifying that the steel has satisfactory weldability for high heat input welding concerned under testing conditions.

Demonstration of conformance to the requirements of this document approves a particular steel mill to manufacture grade of steel to the specific chemical composition range, melting practice, and processing practice for which conformance was established. The approval scheme does not apply to qualification of welding procedures to be undertaken by the shipyards.

2. Application of certification

The manufacturer is to submit to the Register, request of certification, proposed weldability test program (see pt. 3.2 of this Appendix) and technical documents relevant to:

a) Outline of steel plate to be certified
   - grade
   - thickness range
   - deoxidation practice
   - fine grain practice
   - aim range of chemical composition
   - aim maximum Ceq and Pcm
   - production statistics of mechanical properties (tensile and Charpy V-notch impact tests), if any
b) Manufacturing control points to prevent toughness deterioration in heat affected zone when welded with high heat input, relevant to chemical elements, steel, making, casting, rolling, heat treatment etc.
c) Welding control points to improve joint properties on strength and toughness, if any.

3. Confirmation tests

3.1 Range of certification

Range of certification for steel grades is to be the following a) through c) unless otherwise agreed by the Register:

a) Approval tests on the lowest and highest toughness levels cover the intermediate toughness level.
b) Approval tests on normal strength level cover that strength level only.
c) For high tensile steels, approval tests on one strength level cover strength level immediately below.
d) Tests may be carried out separately subject to the same manufacturing process.
e) Certification and documentation of confirmation tests performed by other Classification Society may be accepted at the discretion of the Register.

3.2 Weldability test program

Extent of the program is specified in pt. 3.5 of this Appendix but it may be modified according to the contents of certification. In particular, additional test assemblies and/or test items may be required in the case of newly developed type of steel, welding consumable and welding method, or when deemed necessary by the Register.

Where the content of tests differs from those specified in pt. 3.5, the program is to be confirmed by the Register before the tests are carried out.

3.3 Test plate

The plate is to be manufactured by a process approved by the Register in accordance with the requirements of Appendix A.

For each manufacturing process route, two test plates with different thickness are to be selected. The thicker plate (t) and thinner plate (less than or equal to t/2) are to be proposed by the manufacturer.

Small changes in manufacturing processing (e.g. within the TMCP process) may be considered for acceptance without testing, at the discretion of the Register.

3.4 Test assembly

One butt weld assembly welded with heat input over 50 kJ/cm is to be generally prepared with the weld axis transverse to the plate rolling direction.

Dimensions of the test assembly are to be amply sufficient to take all the required test specimens specified in pt. 3.5.

The welding procedures should be as far as possible in accordance with the normal practices applied at shipyards for the test plate concerned.

Welding process, welding position, welding consumable (manufacturer, brand, grade, diameter and shield gas) and welding parameters including bevel preparation, heat input, preheating temperatures, interpass temperatures, number of passes etc. are to be reported.

3.5 Examination and tests for the test assembly

The test assembly is to be examined and tested in accordance with the following a) through h) unless otherwise agreed by the Register:

a) Visual examination
   Overall welded surface is to be uniform and free from injurious defects such as cracks, undercuts, overlaps etc.

b) Macroscopic test
   One macroscopic photograph is to be representative of transverse section of the welded joint and is to show absence of cracks, lack of penetration, lack of fusion and other injurious defects.

c) Microscopic test
   Along mid-thickness line across transverse section of the weld, one micrograph with x100 magnification is to be taken at
146 RULES FOR THE CLASSIFICATION OF SHIPS
PART 25, APPENDIX B

each position of the weld metal centre-line, fusion line and at a distance 2, 5, 10 and minimum 20 mm from the fusion line. The test result is provided for information purpose only.

d) Hardness test
   Along lines across transverse weld section 1 mm beneath plate surface on both face and root side of the weld, indentations by HV5 are to be made at weld metal centreline, fusion line and each 0.7 mm position from fusion line to unaffected base metal (minimum 6 to 7 measurements for each heat affected zone).
   The maximum hardness value should not be higher than 350HV.

e) Transverse tensile test
   Two transverse (cross weld) tensile specimens are to be taken from the test assembly. Test specimens and testing procedures are to comply with the requirements Chapter 2.
   The tensile strength is to be not less than the minimum required value for the grade of base metal.

f) Bend test
   Two transverse (cross weld) test specimens are to be taken from the test assembly and bent on a mandrel with diameter of quadruple specimen thickness. Bending angle is to be at least 120°. Test specimens are to comply with the requirements Chapter 2.
   For plate thickness up to 20 mm, one face-bend and one root-bend specimens or two side-bend specimens are to be taken. For plate thickness over 20 mm, two side-bend specimens are to be taken.
   After testing, the test specimens shall not reveal any crack nor other open defect in any direction greater than 3 mm.

g) Impact test
   Charpy V-notch impact specimens (three specimens for one set) are to be taken within 2 mm below plate surface on face side of the weld with the notch perpendicular to the plate surface.
   One set of the specimens transverse to the weld is to be taken with the notch located at the fusion line and at a distance 2, 5 and minimum 20 mm from the fusion line. The fusion boundary is to be identified by etching the specimens with a suitable reagent. The test temperature is to be the one prescribed for the testing of the steel grade in question.
   For steel plate with thickness greater than 20 mm, one additional set of the specimens is to be taken from the root side of the weld with the notch located at each the same position as for the face side.
   The average impact energy at the specified test temperature is to comply with the Tables 3.2.6.2-1 or 3.2.6.2-2 of Chapter 3 depending on the steel grade and thickness. Only one individual value may be below the specified average value provided it is not less than 70% of the value.
   Additional tests at the different testing temperatures may be required for evaluating the transition temperature curve of absorbed energy and percentage crystallinity at the discretion of the Register.

h) Other test
   Additional tests such as wide-width tensile test, HAZ tensile test, cold cracking tests (CTS, Cruciform, Implant, Tekken, and Bead-on plate), CTOD or other tests should be required at the discretion of the Register (see pt. 3.2).

4. Results
   The manufacturer is to submit to the Register the complete test report including all the results and required information relevant to the confirmation tests specified in pt. 3.
   The contents of the test report are to be reviewed and evaluated by the Register in accordance with this weldability confirmation scheme.

5. Certification
   The Register issues the certificate where the test report is found to be satisfactory.
   The following information is generally required to be included on the certificate:
   a) Manufacturer
   b) Grade designation with notation of heat input (see pt. 6)
   c) Deoxidation practice
   d) Fine grain practice
   e) Condition of supply
   f) Plate thickness tested
   g) Welding process
   h) Welding consumable (manufacturer, brand, grade), if desired
   i) Actual heat input applied.

6. Grade designation
   Upon issuance of the certificate, the notation indicating the value of heat input applied in the confirmation test may be added to the grade designation of the test plate, e.g. “CRS-E36-W300” (in the case of heat input 300 kJ/cm applied). The value of this notation is to be not less than 50 and every 10 added.
APPENDIX C

Procedure for Approval of Corrosion resistant steels for cargo oil tanks

Approval Procedure for Corrosion Resistant Steel

1. Scope
1.1 This document specifies, as given in 3.2.1, the scheme for the approval of corrosion resistant steels based upon corrosion testing.
1.2 The corrosion testing is to be carried out in addition to the approval testing specified in Appendix A1 and A2 for the approval of normal and higher strength hull structural steels.
1.3 The corrosion tests and assessment criteria are to be in accordance with the Appendix of the Annex to Performance Standard for Alternative Means of Corrosion Protection for Cargo Oil Tanks of Crude Oil Tankers (MSC.289 (87)).

2. Application for approval
2.1 The manufacturer is to submit to the Society a request for approval, which is to include the following:
a) Corrosion test plan and details of equipment and test environments.
b) Technical data related to product assessment criteria for confirming corrosion resistance.
c) The technical background explaining how the variation in added and controlled elements improves corrosion resistance.
d) The grades, the brand name and maximum thickness of corrosion resistant steel to be approved. Designations for corrosion resistant steels are given in Table 2.1.
e) The welding processes and the brand name of the welding consumables to be used for approval.

Table 2.1
Designations for Corrosion Resistant Steels

<table>
<thead>
<tr>
<th>Type of steel</th>
<th>Location where steel is effective</th>
<th>Corrosion Resistant Designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rolled steel for hull</td>
<td>For lower surface of strength deck and surrounding structures (ullage space)</td>
<td>RCU</td>
</tr>
<tr>
<td></td>
<td>For upper surface of inner bottom plating and surrounding structures</td>
<td>RCB</td>
</tr>
<tr>
<td></td>
<td>For both strength deck and inner bottom plating</td>
<td>RCW</td>
</tr>
</tbody>
</table>

3. Approval of test plan
3.1 The test program submitted by the manufacturer is to be reviewed by the Register, if found satisfactory, it will be approved and returned to the manufacturer for acceptance prior to tests being carried out. Tests that need to be witnessed by the Register’s Surveyor will be identified.
3.2 Method for selection of test samples is to satisfy the following:
3.2.1 The numbers of test samples is to be in accordance with the requirements of the Appendix of the Annex to Performance Standard for Alternative Means of Corrosion Protection for Cargo Oil Tanks of Crude Oil Tankers (MSC.289 (87)).
3.2.2 The number of casts and test samples selected are to be sufficient to make it possible to confirm the validity of interaction effects and/or the control range (upper limit, lower limit) of the elements which are added or intentionally controlled, for improving the corrosion resistance. Where agreed, this may be supported with data submitted by the manufacturer.
3.2.3 Additional tests may be required by the Register when reviewing the test program against the paragraph 3.2.2.

Remarks:
Considerations for additional tests may include but not be limited to:

a) When the Register determines that the control range is set by the theoretical analysis of each element based on existing data, the number of corrosion resistance tests conducted in accordance with the Appendix of the Annex to Performance Standard for Alternative Means of Corrosion Protection for Cargo Oil Tanks (MSC.289 (87)) is too few to adequately confirm the validity of the control range of chemical composition;
b) When the Register determines that the data of the corrosion resistance test result obtained for setting the control range of chemical composition varies too widely;
c) When the Register determines that the validity of the corrosion resistance test result for setting the control range of chemical composition is insufficient, or has some flaws;
d) When the Register’s Surveyor has not attended the corrosion resistance tests for setting the control range of chemical composition.
composition, and the Society determines that additional testing is necessary in order to confirm the validity of the test result data; and
e) When the Register determines that it is necessary, for reasons other than cases (a) to (d) above.

Remarks:
The chemical composition of the corrosion resistant steel is to be within the range specified for rolled steel for hull. Elements to be added for improving the corrosion resistance and for which content is not specified are to be generally within 1% in total.

4. Carrying out the approval test
4.1 The manufacturer is to carry out the approval test in accordance with the approved test.

5. Attendance of the Register's Surveyor for Test
5.1 The Register's Surveyor is to be present, as a rule, when the test samples for the approval test are being identified and for approval tests, see also 3.1.

6. Test Results
6.1 After completion of the approval test, the manufacturer is to produce the report of the approval test and submit it to the Register.
6.2 The Register will give approval for corrosion resistant steel where approval tests are considered by the society to have given satisfactory results based on the data submitted in accordance with the provisions of this Appendix.
6.3 The certificate is to contain the manufacturer's name, the period of validity of the certificate, the grades and thickness of the steel approved, welding methods and welding consumables approved.

7. Assessment Criteria for Results of Corrosion Resistance Tests of Welded Joint
7.1 The results will be assessed by the Register in accordance with the acceptance criteria specified in the Appendix of the Annex to Performance Standard for Alternative Means of Corrosion Protection for Cargo Oil Tanks (MSC.289 (87)).
APPENDIX D

ESSO test

1. Scope

1.1 The ESSO test method is used to estimate the brittle crack arrest toughness value $K_{ca}$ of rolled steel plates for hull of thickness 100 mm or less.

2. Symbols

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Unit</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>$t_s$</td>
<td>mm</td>
<td>Thickness of test specimen</td>
</tr>
<tr>
<td>$W_s$</td>
<td>mm</td>
<td>Width of test specimen</td>
</tr>
<tr>
<td>$L_s$</td>
<td>mm</td>
<td>Length of test specimen</td>
</tr>
<tr>
<td>$t_r$</td>
<td>mm</td>
<td>Thickness of tab plate</td>
</tr>
<tr>
<td>$W_r$</td>
<td>mm</td>
<td>Width of tab plate</td>
</tr>
<tr>
<td>$L_r$</td>
<td>mm</td>
<td>Length of tab plate</td>
</tr>
<tr>
<td>$L_p$</td>
<td>mm</td>
<td>Distance between pins</td>
</tr>
<tr>
<td>$a$</td>
<td>mm</td>
<td>Length of crack projected on surface normal to the line of load</td>
</tr>
<tr>
<td>$a_a$</td>
<td>mm</td>
<td>Maximum crack length at brittle crack arrest position</td>
</tr>
<tr>
<td>$T$</td>
<td>°C</td>
<td>Temperature of test specimen</td>
</tr>
<tr>
<td>$dT/da$</td>
<td>°C/mm</td>
<td>Temperature gradient of test specimen</td>
</tr>
<tr>
<td>$\sigma$</td>
<td>N/mm$^2$</td>
<td>Gross stress in tested part ($load/W_s, t_s$)</td>
</tr>
<tr>
<td>$K_{ca}$</td>
<td>N/mm$^{3/2}$</td>
<td>Brittle crack arrest toughness value</td>
</tr>
</tbody>
</table>

3 Purpose

3.1 The purpose of this test is to encourage the performance of a standard test for assessment of brittle crack arrest toughness with temperature gradient and to obtain the corresponding brittle crack arrest toughness value $K_{ca}$.

4 Standard test specimen

4.1 Fig.2 shows the shape and size of the standard test specimen.
4.2 The thickness and width of the test specimen are to be in accordance with Table 2.

Table 2
Thickness and width of test specimen

<table>
<thead>
<tr>
<th>Thickness, ( t_s )</th>
<th>100 mm and below</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width of test specimen, ( W_s )</td>
<td>500 mm</td>
</tr>
</tbody>
</table>

Note:
If the width of the test specimen cannot be made at 500 mm, it may be taken as 600 mm.

4.3 The test specimens are to be taken from the same steel plate.

4.4 Test specimens are to be taken in such a way that the axial direction of the load is parallel to the rolling direction of the steel plate.

4.5 The thickness of the test specimen is to be the same as the thickness of the steel plate to be used in the vessel structure.

5 Test equipment

5.1 The test equipment to be used is to consist of pin load type hydraulic test equipment capable of tensile tests.

5.2 The distance between the pins is to be not less than 2,000 mm. The distance between pins refers to the distance between the centres of the pin diameters.

5.3 Drop weight type or air gun type impact equipment may be used for the impact energy required for generating brittle cracks.

5.4 The wedge is to have an angle greater than the upper notch of the test specimen, and an opening force is to be applied on the notch.

6 Test preparations

6.1 The test piece is to be fixed directly to the pin load jig or by means of weld joint through the tab plate. The overall length of the test specimen and tab plate is to be not less than 3\( W_s \).

The thickness and width of the tab plate are to be in accordance with Table 3.

Table 3
Allowable dimensions of tab plate

<table>
<thead>
<tr>
<th>Dimensions of tab plate</th>
<th>Thickness ( t_s )</th>
<th>Width ( W_s )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( 0.8t_s^{(1,2)} \leq t_s \leq 1.5t_s )</td>
<td>( W_s \leq W_s \leq 2W_s )</td>
</tr>
</tbody>
</table>

Note:
(1) \( t_s \) – thickness of test specimen
(2) If the tab plate has a thickness smaller than the test specimen, the reflection of stress wave will be on the safer side for the assessment; therefore, considering the actual circumstances for conducting the test, the lower limit of thickness is taken as 0.8\( t_s \).
6.2 Thermocouples are to be fitted at 50 mm pitch on the notch extension line of the test specimen.

6.3 If the brittle crack is estimated to deviate from its presumed course, thermocouples are to be fitted at two points separated by 100 mm on the line of load from the notch extension line at the centre of width of the test specimen.

6.4 If dynamic measurements are necessary, strain gauges and crack gauges are to be fitted at specific locations.

6.5 The test specimen is to be fixed to the testing machine together with the tab plate after welding and the pin load jig.

6.6 The impact equipment is to be mounted. The construction of the impact equipment is to be such that the impact energy is correctly transmitted. An appropriate jig is to be arranged to minimize the effect of bending load due to the impact equipment.

7 Test method

7.1 To eliminate the effect of residual stress or correct the angular deformation of tab welding, a preload less than the test load may be applied before cooling.

7.2 Cooling and heating may be implemented from one side on the side opposite the side on which the thermocouple is fitted, or from both sides.

7.3 The temperature gradient is to be controlled in the range of 0.25°C/mm to 0.35°C/mm in the range of width from 0.3Ws to 0.7Ws at the central part of the test specimen.

7.4 When the specific temperature gradient is reached, the temperature is to be maintained for more than 10 minutes, after which the specified test load may then be applied.

7.5 After maintaining the test load for at least 30 seconds, a brittle crack is to be generated by impact. The standard impact energy is taken as 20 to 60 J per 1 mm plate thickness. If the brittle crack initiation characteristics of the base metal are high, and it is difficult to generate a brittle crack, the impact energy may be increased to the upper limit of 120 J per 1 mm plate thickness.

7.6 Loading is stopped when the initiation, propagation, and arrest of crack have been confirmed. Normal temperature is restored, and if necessary, the ligament is broken by gas cutting and forcibly the specimen is broken by using the testing machine. Or, after the ductile crack has been propagated to an adequate length with the testing machine, the ligament is broken by gas cutting.

7.7 After forcing the fracture, photos of the fractured surface and the propagation route are to be taken, and the crack length is to be measured.

8 Test results

8.1 The distance from the top of the test specimen including the notch to the maximum length in the plate thickness direction of the arrested crack tip is to be measured. If the crack surface deviates from the surface normal to the line of load of the test specimen, the projected length on the surface normal to the line of load is to be measured. In this case, if the trace of brittle crack arrest is clearly visible on the fractured surface, the first crack arrest position is taken as the arrest crack position.

8.2 From the results of thermocouple measurement, the temperature distribution curve is to be plotted, and the arrest crack temperature is to be measured corresponding to the arrest crack length.

8.3 The brittle crack arrest toughness value (Kca value) of each test is to be determined by using the following formula:

\[ K_{ca} = \sigma \sqrt{\pi a} \left(\frac{2W}{\pi a}\right) \tan \left(\frac{\pi a}{2W}\right) \]

9 Report

9.1 The following items are to be reported:

a) Testing machine specifications; testing machine capacity, distance between pins (Lp),

b) Load jig dimensions; tab plate thickness (t), tab plate width (W), test specimen length including tab plate (L_p + 2L_r),

c) Test specimen dimensions; plate thickness (t), test specimen width (W) and length (L),

d) Test conditions; preload stress, test stress, test temperature, temperature gradient at arrest position, brittle crack arrest toughness (Kca),

f) Dynamic measurement results (if measurement is carried out); crack growth rate, strain change,

g) Test specimen photos; fracture route, fractured surface.

9.2 If the conditions below are not satisfied, the test results are to be treated as reference values.

a) The brittle crack arrest position is to be in the range of the hatched part shown in Fig.3. In this case, if the brittle crack arrest position is more than 50 mm away from the centre of the test specimen in the longitudinal direction of the test specimen, the temperature of the thermocouple at the ±100 mm position is to be within ±3°C of the thermocouple at the centre.

b) The brittle crack should not have a distinctive crack bifurcation while it propagates.

9.3 From effective test results measured at more than 3 points, the linear approximation equation is to be determined on the Arrhenius plot, and Kca at the desired temperature is to be calculated. In this case, data should exist on both sides, that is, the high temperature and low temperature sides around the assessed temperature.
Figure 3
Necessary conditions of arrest crack position
APPENDIX E
Chafing Chain for Emergency Towing Arrangements

1. Scope
These requirements apply to the chafing chain for chafing gear of two types Emergency Towing Arrangement (ETA) with specified safe working load (SWL) of 1000 kN (ETA 1000) and 2000 kN (ETA 2000). Chafing chains other than those specified can be used subject to special agreement with the Register.

2. Approval of manufacturing
The chafing chain is to be manufactured by works approved by the Register according to Chapter 6.1.3.

3. Materials
The materials used for the manufacture of the chafing chain are to satisfy the requirements of Chapter 6.2.

4. Design, manufacture, testing and certification of chafing chain

4.1 The chafing chain is to be designed, manufactured, tested and certified in accordance with the requirements of Chapter 6.3, 6.4 and 6.5.

4.2 The arrangement at the end connected to the strongpoint and the dimensions of the chafing chain are determined by the type of ETA. The other end of the chafing chain is to be fitted with a pear-shaped open link allowing connection to a shackle corresponding to the type of ETA and chain cable grade. A typical arrangement of this chain end is shown in Figure 1.

4.3 The common link is to be of stud link type grade CRS-L2 or CRS-L3.

4.4 The chafing chain is to be able to withstand a breaking load not less than twice the SWL. For each type of ETA, the nominal diameter of common link for chafing chains is to comply with the value indicated in Table 1.

<table>
<thead>
<tr>
<th>Type of ETA</th>
<th>Nominal diameter of common link, d min.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grade CRS-L2</td>
</tr>
<tr>
<td>ETA 1000</td>
<td>62 mm</td>
</tr>
<tr>
<td>ETA 2000</td>
<td>90 mm</td>
</tr>
</tbody>
</table>

Figure 1
Typical outboard chafing chain end