Rules for Classification and Construction

II Materials and Welding

1 Metallic Materials

2 Steel and Iron Materials
The following Rules come into force on April 1st, 2009

Alterations to the preceding Edition are marked by beams at the text margin.

Germanischer Lloyd Aktiengesellschaft

Head Office
Vorsetzen 35, 20459 Hamburg, Germany
Phone: +49 40 36149-0
Fax: +49 40 36149-200
headoffice@gl-group.com

www.gl-group.com

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# Table of Contents

## Section 1  Steel Plates, Strips, Sections and Bars

| A. General Rules | ................................................................. | 1- 1 |
| B. Normal and Higher Strength Hull Structural Steels | ...................................................... | 1- 5 |
| C. Unalloyed Steels for Welded Structures | ...................................................... | 1-16 |
| D. High-Strength Steels for Welded Structures | ...................................................... | 1-17 |
| E. Steels for Steam Boilers and Pressure Vessels | ...................................................... | 1-21 |
| F. Steels for Cargo Tanks | ................................................................. | 1-23 |
| G. Stainless Steels | ................................................................. | 1-28 |
| H. Clad Plates | ................................................................. | 1-30 |
| I. Steels with Through Thickness Properties | ...................................................... | 1-32 |
| J. Steel-Aluminium Welding Joints | ................................................................. | 1-34 |

## Section 2  Steel Pipes

| A. General Rules | ................................................................. | 2- 1 |
| B. Pipes for General Purpose | ................................................................. | 2- 5 |
| C. High-Temperature Steel Pipes | ...................................................... | 2- 7 |
| D. Pipes Tough at Sub-Zero Temperatures | ...................................................... | 2-10 |
| E. Stainless Steel Pipes | ................................................................. | 2-14 |

## Section 3  Forgings

| A. General Rules | ................................................................. | 3- 1 |
| B. Forgings for Machine Construction and Shipbuilding | ...................................................... | 3- 5 |
| C. Forgings for Crankshafts | ................................................................. | 3- 6 |
| D. Forgings for Gears | ................................................................. | 3-10 |
| E. Forgings for Boilers, Pressure Vessels, Process Equipment and Pipelines | ...................................................... | 3-13 |
| F. Steel Forgings Tough at Sub-Zero Temperatures | ...................................................... | 3-15 |
| G. Non-destructive Testing of Forged Components | ...................................................... | 3-17 |
| H. List of Forged Components for which Non-destructive Tests are Required | ...................................................... | 3-23 |
| I. Classifying of Inspection Zones for Magnetic Particle Testing (MT) | ...................................................... | 3-24 |
| J. Classifying of Inspection Zones for Ultrasonic Testing (UT) | ...................................................... | 3-29 |

## Section 4  Cast Steel

| A. General Rules | ................................................................. | 4- 1 |
| B. Steel Castings for Machine Construction and Shipbuilding | ...................................................... | 4- 5 |
| C. Steel Castings for Crankshafts and Connecting Rods | ...................................................... | 4- 8 |
| D. Steel Castings for Steam Boilers, Pressure Vessels and Pipelines | ...................................................... | 4- 8 |
| E. Steel Castings for Use at Low Temperatures | ...................................................... | 4-10 |
| F. Stainless Steel Castings | ................................................................. | 4-13 |
| G. Non-destructive Testing of Cast Steel Components | ...................................................... | 4-16 |
| H. List of Cast Steel Components for which Non-destructive Tests are Required | ...................................................... | 4-28 |
| I. Testing Instructions for Hull Structural Parts | ...................................................... | 4-29 |
| J. Testing Instruction for Diesel Engine Parts | ................................................................. | 4-37 |
Section 5  Cast Iron

A. General Rules ................................................................. 5- 1
B. Nodular Cast Iron ............................................................. 5- 3
C. Grey Cast Iron .............................................................. 5- 8

Section 6  Fittings and Pressed Parts, Bolts and Nuts

A. Pressed Parts ................................................................. 6- 1
B. Pipe Fittings ................................................................. 6- 4
C. Bolts and Nuts .............................................................. 6- 6
Section 1

Steel Plates, Strips, Sections and Bars

A. General Rules

1. Scope

1.1 General rules to be applied in the manufacture and testing of hot-rolled plates, strips, sections (including hollow sections), rods and bars are contained in A.

1.2 Hot-rolled round bars intended for the manufacture of shafts, tie rods and bolts are subject to Section 3, B.

1.3 Where stated in B. to J. of this Section, steels conforming to national or international standards may be used, provided that they satisfy the minimum requirements of these Rules.

2. Requirements to be met by manufacturers

Manufacturers wishing to supply products in accordance with these Rules shall fulfil the requirements set out in Chapter 1 – Principles and Test Procedures, Section 1, C., and shall demonstrate this to GL prior to commencing supplies. This applies also for manufacturers of semi-finished products such as ingots, slabs, blooms and billets.

3. Steelmaking process

3.1 The steels are to be manufactured by the basic oxygen process, the electric furnace process or by other methods approved by GL. On request, GL shall be informed of the steelmaking process used.

3.2 The steels may be cast in ingots (static casting) or continuously.

Special casting processes require initial appraisal by GL.

4. Condition of supply and heat treatment

4.1 All products are to be supplied in the heat treated conditions described in the following individual Sections, unless supply in the as-rolled condition is allowed.

This may be the case if, for instance, the product is to undergo further hot forming.

4.2 If the material is suitable, products may also be supplied in normalising rolled (controlled rolled) or thermo-mechanically rolled condition (see 4.3), provided that the processes have been checked and approved by GL on the manufacturer's premises.

4.3 Definitions

The processes mentioned in 4.2 are defined as follows:

4.3.1 Normalising rolling

Normalising rolling (controlled rolling) is a rolling process involving final forming in a specific temperature range which results in a material condition equivalent to that achieved by normalising treatment; thus the desired values of the mechanical properties are preserved even after an additional normalising treatment.

Products supplied in this condition are designated by the code NW.

4.3.2 Thermo-mechanical rolling

Thermo-mechanical rolling is a rolling process incorporating careful monitoring of both the rolling temperature and also the reduction per pass. The greater proportion of reductions per pass is generally carried out close to the upper transformation temperature $A_3$ where rolling in the two-phase temperature range may be incorporated. Unlike normalising rolling, the properties produced by thermo-mechanical rolling cannot be reproduced by subsequent normalising or other heat treatments.

Products supplied in this condition are designated by the code TM.

Accelerated cooling following TM rolling may take place if this process has been approved by GL. The same applies to tempering treatments following TM rolling.

Note on TM steels:

Any subsequent, continuous heating above 580 °C as well as significant long holding times at lower temperatures may impair the strength properties. The manufacturer shall be consulted where there is a requirement to use temperatures above 580 °C.

Flame straightening will generally be possible. To this effect flame straightening may be carried out by using flame lines/flame tracks on the surface up to 950 °C. A flame straightening by short time local through thick-
ness heating (hot wedge shapted spots, hot spots) may be carried out by a heating up to 700 °C.

5. General characteristics of products

5.1 All products shall have a smooth rolled surface and shall be free from any defects liable to have more than an insignificantly adverse effect on their workability and intended use, e.g. laminations, cracks, blow holes, scabs and seams.

5.2 Unless otherwise stipulated by the purchaser or prescribed by GL, hot-rolled plates, wide flats and sections shall be subject to the delivery conditions stipulated in EN 10163.

5.3 Unless otherwise specified or agreed, surface defects may only be removed by grinding within the permitted tolerance on the minimum thickness. The depressions caused by grinding shall have a smooth transition to the surrounding surface of the product.

6. Dimensions, dimensional and geometrical tolerances

6.1 Plates, strips and wide flats may be delivered with the minus tolerances shown in Table 1.1 or with no minus tolerance. Where no stipulations are made in the following individual rules, e.g. for shipbuilding steels in accordance with B., flat products for cargo tanks in accordance with F. and clad plates in accordance with H. the permitted minus tolerance is to be agreed when the order is placed.

6.2 The thickness is to be measured at points located at least 25 mm from the edge of the product. Local depressions due to flaws and grinding marks arising from the remedying of defects are not taken into account, provided that they do not exceed the tolerances.

6.3 Unless otherwise agreed in the order, the provisions regarding form tolerances according to EN 10029 apply.

6.4 For sections and bars, the dimensions and the dimensional and geometrical tolerances specified in the standards apply.

7. General technical requirements

7.1 Chemical composition

The limit values specified in these Rules for the chemical composition apply to the melt analysis. Minor positive or negative excesses beyond the limit values, established by analysis of the product, are acceptable provided that they do not impair the properties of the product and/or the tolerances specified in the other relevant standards are not exceeded.

<table>
<thead>
<tr>
<th>Nominal thickness [mm]</th>
<th>Permitted minus tolerances (^1) [mm] for class</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\geq 3 \leq 5)</td>
<td>(-0,4) (-0,3) (0)</td>
</tr>
<tr>
<td>(\geq 5 \leq 8)</td>
<td>(-0,4) (-0,3) (0)</td>
</tr>
<tr>
<td>(\geq 8 \leq 15)</td>
<td>(-0,5) (-0,3) (0)</td>
</tr>
<tr>
<td>(\geq 15 \leq 25)</td>
<td>(-0,6) (-0,3) (0)</td>
</tr>
<tr>
<td>(\geq 25 \leq 40)</td>
<td>(-0,8) (-0,3) (0)</td>
</tr>
<tr>
<td>(\geq 40 \leq 80)</td>
<td>(-1,0) (-0,3) (0)</td>
</tr>
<tr>
<td>(\geq 80 \leq 150)</td>
<td>(-1,0) (-0,3) (0)</td>
</tr>
<tr>
<td>(\geq 150 \leq 250)</td>
<td>(-1,2) (-0,3) (0)</td>
</tr>
</tbody>
</table>

\(^1\) See also EN 10029.

7.2 Weldability

Steels conforming to these Rules shall be weldable by established workshop methods. Where applicable, this includes the measures necessary to ensure the quality of the welds, e.g. preheating and/or post weld heat treatments.

7.3 Mechanical properties

The mechanical properties stated in these Rules shall be verified by means of tensile tests.

7.4 Notch impact energy

The notch impact energy specified for the individual steels shall be fulfilled by the average value of three specimens, one of which may produce a value below, though not less than 70 % of, the average value.

7.5 Other properties

Where special properties such as resistance to inter-crystalline corrosion, resistance to brittle fracture or high-temperature strength are prescribed for certain groups of products, these shall be proved by appropriate tests, as necessary.

8. General instructions for testing

8.1 Testing of chemical composition

The manufacturer shall determine the chemical composition of each melt and shall submit a corresponding certificate to the Surveyor. The chemical composition specified for the steel grade shall be shown in the certificate.
In the event of any doubt as to the composition of the products, a product analysis shall be carried out at the request of the Surveyor.

8.2 Testing of mechanical properties and position of specimen

8.2.1 From each test batch, at least one tensile test specimen shall be taken and tested. A test batch shall comprise either the rolled length (the unit subjected to the heat treatment) or the number of items from the same heat specified in the following Sections.

8.2.2 In the case of plates and wide flats with a width of \(\geq 600\) mm, the tensile test specimens shall be taken transverse, in all other products parallel to the rolling direction. The necessary test sections shall be taken from the products at the following points (see Fig. 1.1):

- plates, wide flats and strip \(\geq 600\) mm wide: from halfway between the centre line and a longitudinal edge
- wide flats and strip < 600 mm wide: from a position lying 1/3 of the product width from a longitudinal edge
- sections: wherever possible, from a flange at a position corresponding to 1/3 of the flange width from the longitudinal edge of the flange. In the case of channels and joists, test sections may also be taken from the web at a distance corresponding to 1/4 of the web height from the centre line of the web
- bulb flats: from the web at a distance from the edge of the web corresponding to 1/3 of the height of the section
- bars: from a position lying at a distance of 1/6 of the diameter or the diagonal from the surface or the corner respectively

8.2.3 Test sections may normally be taken from products only after the final heat treatment. Where products have to undergo further hot working and testing of the properties in the final heat-treated condition is required, the test sections may be subjected to separate heat treatment.

8.3 Determination of 0.2 % proof stress at elevated temperatures

For products intended 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 hot tensile test performed on at least one specimen from each heat. The test temperature shall be that specified in E.

The test may be dispensed with in the case of steels conforming to recognized standards whose mechanical characteristics at high temperature are considered to be already proven.

8.4 Notched bar impact tests

8.4.1 The tests shall be performed on Charpy V-notch specimens with the notch perpendicular to the
surface of the product. Where the thickness of the product is ≤ 40 mm, the specimens shall be located close to the rolled surface. Where the product thickness is > 40 mm, the specimens shall be so located that their longitudinal axis lies 1/4 of the product thickness from the surface. Furthermore, the test specimens shall be taken at a sufficient distance from flame-cut or sheared edges.

8.4.2 With products < 10 mm thick, specimens of reduced size are to be prepared with thicknesses of 7.5 or 5 mm. Unless otherwise specified, e.g. in B.6.3 and F.9.3, the requirements in respect of the impact energy shall be converted proportionally to the specimen cross-section in question:

For products < 6 mm thick the test is waived.

8.5 Testing of surface finish and dimensions

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

Any surface defects may be removed by grinding within the permitted tolerances, see 5. Any products which fail to meet the requirements in respect of surface finish and dimensional tolerances shall be rejected by the manufacturer.

8.5.2 Unless otherwise specified, all plates subject to individual testing shall be submitted to the Surveyor for final testing. The Surveyor may further require that products subject to batch testing be similarly submitted.

8.6 Ultrasonic tests

The tests shall be performed in accordance with EN 10160 or another standard accepted by GL. The testing staff shall be adequately qualified for this task and the Surveyor shall be furnished with proof thereof if he so requests. The Surveyor shall be permitted to take part in the tests at his request.

8.7 Retesting in the event of specimen failure

Where specimens subjected to tensile or impact testing fail to meet the requirements or where, in the impact test, one value is less than 70 % of the required average value, the retesting procedures described in Chapter 1 – Principles and Test Procedures, Section 2, H. may be applied before the unit test quantity is rejected. This also applies where specimens fail to meet the requirements in the testing of special characteristics such as shear strength, ductility as measured by the technological bend test applied to clad plates or reduction in area of through thickness tensile test specimens.

9. Marking of products

9.1 With the exception of the products with small dimensions specified in 9.2, every item shall be clearly identified by the manufacturer in at least one place with the following marks:

- steel grade
- manufacturer's mark
- heat number, manufacturing serial number
- specimen number (where necessary)

Plates and sections shall be marked with punches. Products with sensitive surfaces or with wall thicknesses of ≤ 10 mm may be marked by a different method, e.g. with a coloured impression or with a low-stress or a rubber stamp. Following agreement with the Surveyor, products may also be marked with code numbers, the meaning of which is explained in the covering certificate.

9.2 In the case of shapes and bars weighing ≤ 25 kg or less per metre which are bundled together, the marking specified in 9.1 may be applied on a tag.

9.3 Where individually tested rolled lengths (plates) are cut up into sections, each section shall be marked in a manner identifying its relationship to the original rolled length (plate).

10. Certificates

10.1 The Surveyor shall be given the test certificates or consignment lists for all the materials tested by him in at least three copies. The documents shall be issued separately for each grade or type of steel if necessary. The documents shall at least contain the following details:

- purchaser and order number
- where known, the newbuilding and project number respectively
- item number and quantities
- size and indication of products
- steel grade, type or brand name
- steel making process
- heat number
- chemical composition of the heat
- condition in which supplied if other than the as-rolled condition
- product identifying marks
- specimen number, where applicable

The certificate shall also state the results of the special tests carried out by the manufacturer, e.g. ultrasonic tests and tests of resistance to intercrystalline corrosion, together with details of the test method used.

10.2 Before the test certificates or consignment lists are countersigned by the Surveyor, the manufacturer shall confirm to the Surveyor in writing that the
material was manufactured by an approved process and tested in accordance with GL Rules for Materials, and the requirements were satisfied. The name "Germanischer Lloyd" (GL) shall be mentioned in the test certificate. The following wording of the declaration is adequate for this purpose if it is stamped or printed on every test certificate and/or consignment list together with the manufacturer's name and is certified on the manufacturer's behalf by a works employee appointed by him.

"We hereby declare that the material has been produced by an approved method and has satisfied Rules of GL for testing."

10.3 Where the steels are not produced and rolled by the same manufacturer, a certificate issued by the steelmaker specifying at least the heat numbers and the chemical compositions shall be handed to the Surveyor.

B. Normal and Higher Strength Hull Structural Steels

1. Scope

1.1 These requirements apply to weldable normal strength and higher strength hot-rolled plates, wide flats, sections and bars made of steel designed for shipbuilding use.

1.2 The requirements are primarily intended to apply to steel products with the following thicknesses:

- for plates and steel wide flats: all grades up to 150 mm thick
- for sections and steel bars: all grades up to 50 mm thick

For greater thicknesses certain variations in the requirements may be allowed or required in particular cases after consideration of the technical circumstances involved.

1.3 Provision is made for four grades of normal strength steel based on the impact test requirements. For higher strength shipbuilding steels provision is made for three strength levels (315, 355 and 390 N/mm²) each subdivided into four grades based on the impact test temperature.

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

Note

The attention of the users shall 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. Approval

2.1 All materials are to be manufactured at works which have been approved by GL for the grade of steel and the shape of the product which is being supplied.

2.2 The suitability of each grade for forming and welding is to be demonstrated during the initial approval tests at the steelworks. The type and extent of testing required is at the discretion of GL.

2.3 If the steel is not smelted in the mill where it was rolled, a certificate is to be given to the Surveyor in the rolling mill indicating the smelting process used, the name of the steel producer, the heat number and the smelt analysis (ladle analysis). The Surveyor shall be allowed access to the steel producing works.

3. Method of manufacture

3.1 The steel is to be manufactured by the basic oxygen process, in an electric furnace or by other processes specially approved by GL.

3.2 The deoxidation practice used for each grade is to comply with the appropriate requirements of Tables 1.2 and 1.3.

3.3 The definitions relating to the rolling process in question, such as normalising rolling or thermomechanical rolling, with or without subsequent accelerated cooling are stipulated in A.4.3.

4. Chemical Composition

4.1 The chemical composition of samples taken from each heat 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 1.2 and 1.3.

For plates and wide flats more than 50 mm thick, slight variations in the prescribed chemical composition may be permitted by arrangement with GL.

4.2 The manufacturer's declared analysis will be accepted subject to occasional checks if required by the Surveyor.

4.3 The following special rules apply to TM rolled steels:

4.3.1 The carbon equivalent value C eq shall be within the tolerances given in Table 1.4.

4.3.2 Rather than using the carbon equivalent value when assessing weldability, the P cm-value (susceptibility to cold cracking) may also be calculated based...
on the following formula:

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

In such cases, the \( P_{cm} \) value shall be agreed with GL.

5. Condition of supply

The condition in which all products are supplied shall correspond to the data given in Tables 1.5 and/or 1.6.

6. Mechanical properties

6.1 For tensile testing either the upper yield strength \( R_{yield} \) or, where this is not stipulated, the 0.2 per cent proof stress \( R_{0.2} \) is to be determined and the material is considered to satisfy the requirements if one of these values meets or exceeds the prescribed minimum value for the yield strength \( R_{yield} \).

6.2 The results obtained from tensile tests shall comply with the appropriate requirements of Tables 1.7 and 1.8.

---

Table 1.2 Chemical composition and deoxidation practice for normal strength steels

<table>
<thead>
<tr>
<th>Grade</th>
<th>GL–A</th>
<th>GL–B</th>
<th>GL–D</th>
<th>GL–E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deoxidation practice</td>
<td>For ( t \leq 50 \text{ mm} ) any method except 1 rimmed steel</td>
<td>For ( t \leq 50 \text{ mm} ) any method except rimmed steel</td>
<td>For ( t \leq 25 \text{ mm} ) killed,</td>
<td>Fully killed and fine grain treated</td>
</tr>
<tr>
<td>( t \text{ &gt; } 50 \text{ mm} ) killed</td>
<td>( t \text{ &gt; } 50 \text{ mm} ) killed</td>
<td>( t \text{ &gt; } 25 \text{ mm} ) fully killed an fine grain treated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemical composition (%) (ladle analysis)</td>
<td>Carbon plus 1/6 of the manganese content is not to exceed 0.40 %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( C_{max} )</td>
<td>0,21 2</td>
<td>0,21</td>
<td>0,21</td>
<td>0,18</td>
</tr>
<tr>
<td>( Mn_{min} )</td>
<td>2,5 \times C</td>
<td>0,80 3</td>
<td>0,60</td>
<td>0,70</td>
</tr>
<tr>
<td>( Si_{max} )</td>
<td>0,50</td>
<td>0,35</td>
<td>0,35</td>
<td>0,35</td>
</tr>
<tr>
<td>( P_{max} )</td>
<td>0,035</td>
<td>0,035</td>
<td>0,035</td>
<td>0,035</td>
</tr>
<tr>
<td>( S_{max} )</td>
<td>0,035</td>
<td>0,035</td>
<td>0,035</td>
<td>0,035</td>
</tr>
<tr>
<td>( Al \text{ (acid soluble)} ) min</td>
<td>—</td>
<td>—</td>
<td>0,015 5, 6</td>
<td>0,015 6</td>
</tr>
</tbody>
</table>

\( t \) = Material thickness

1. Grade GL–A sections up to a thickness of 12.5 mm may be accepted in rimmed steel subject to the special approval of GL.
2. Max. 0,23 % for sections.
3. When Grade GL-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.
5. For Grade GL–D steel over 25 mm thick.
6. For Grade GL-D steel over 25 mm thick and for Grade GL-E steel, the total aluminium content may be calculated in place of the acid soluble part. In such cases, the total aluminium content may not be less than 0.020 %. GL may also specify a maximum limit for aluminium. Other grain refining elements may also be permitted subject to approval.
7. In the melt, the maximum values of the following elements may not be exceeded:
   - \( Cu \) : 0,30 %
   - \( Cr \) : 0,20 %
   - \( Ni \) : 0,40 %
   - \( Mo \) : 0,08 %
8. Where the manufacturing process demands the addition of additional elements, their contents are to be indicated in the manufacturer's certificate.
### Table 1.3  Chemical composition and deoxidation practice for higher strength steels

<table>
<thead>
<tr>
<th>Grade 1</th>
<th>GL–A32, GL–D32, GL–E32</th>
<th>GL–F32</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GL–A36, GL–D36, GL–E36</td>
<td>GL–F36</td>
</tr>
<tr>
<td></td>
<td>GL–A40, GL–D40, GL–E40</td>
<td>GL–F40</td>
</tr>
<tr>
<td>Deoxidation practice</td>
<td>Killed and fine grain treated</td>
<td></td>
</tr>
<tr>
<td>Chemical composition (%) 5, 7 (ladle analysis)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C max.</td>
<td>0,18</td>
<td>0,16</td>
</tr>
<tr>
<td>Mn</td>
<td>0,90 – 1,60 2</td>
<td>0,90 – 1,60</td>
</tr>
<tr>
<td>Si max.</td>
<td>0,50</td>
<td>0,50</td>
</tr>
<tr>
<td>P max.</td>
<td>0,035</td>
<td>0,025</td>
</tr>
<tr>
<td>S max.</td>
<td>0,035</td>
<td>0,025</td>
</tr>
<tr>
<td>Al (acid soluble) min. 3, 4</td>
<td>0,015</td>
<td>0,015</td>
</tr>
<tr>
<td>Nb 4</td>
<td>0,02 – 0,05 4</td>
<td>0,02 – 0,05 4</td>
</tr>
<tr>
<td>V 4</td>
<td>0,05 – 0,10 4 total 0,12 max.</td>
<td>0,05 – 0,10 4 total 0,12 max.</td>
</tr>
<tr>
<td>Ti max.</td>
<td>0,02</td>
<td>0,02</td>
</tr>
<tr>
<td>Cu max.</td>
<td>0,30</td>
<td>0,30</td>
</tr>
<tr>
<td>Cr max.</td>
<td>0,20</td>
<td>0,20</td>
</tr>
<tr>
<td>Ni max.</td>
<td>0,40</td>
<td>0,80</td>
</tr>
<tr>
<td>Mo max.</td>
<td>0,08</td>
<td>0,08</td>
</tr>
<tr>
<td>N max.</td>
<td>—</td>
<td>0,009 (0,012 where Al is present)</td>
</tr>
</tbody>
</table>

**Carbon equivalent value 6**

---

1 The letter "H" may be added to the steel grade designation, e.g. GL–AH 36
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 calculated in place of the acid-soluble part. In such cases the total aluminium content may not be 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 the refining element is not applicable.
5 Where a higher strength steel is supplied in a thermo-mechanically rolled condition, variations in the chemical composition may be approved or required.
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 When the manufacturing process demands the addition of other elements, their content is to be indicated in the manufacturer's certificate.
### Table 1.4 Carbon equivalent values for TM rolled, higher strength shipbuilding steels up to a product thickness of 150 mm

<table>
<thead>
<tr>
<th>Steel grade</th>
<th>Carbon equivalent value [%], max. ¹</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Thickness of product t [mm]</td>
</tr>
<tr>
<td></td>
<td>t ≤ 50</td>
</tr>
<tr>
<td>GL–A 32, GL–D 32, GL–E 32, GL–F 32</td>
<td>0,36</td>
</tr>
<tr>
<td>GL–A 36, GL–D 36, GL–E 36, GL–F 36</td>
<td>0,38</td>
</tr>
<tr>
<td>GL–A 40, GL–D 40, GL–E 40, GL–F 40</td>
<td>0,40</td>
</tr>
</tbody>
</table>

¹ It is up to the manufacturer and material user (yard) to agree lower values in special cases.

### Table 1.5 Condition of supply for normal strength steels

<table>
<thead>
<tr>
<th>Grade</th>
<th>Thickness of product t [mm]</th>
<th>Condition of supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>GL–A</td>
<td>≤ 50</td>
<td>any</td>
</tr>
<tr>
<td></td>
<td>50 &lt; t ≤ 150</td>
<td>normalised, normalising or TM-rolled ¹</td>
</tr>
<tr>
<td>GL–B</td>
<td>≤ 50</td>
<td>any</td>
</tr>
<tr>
<td></td>
<td>50 &lt; t ≤ 150</td>
<td>normalised, normalising or TM rolled ¹</td>
</tr>
<tr>
<td>GL–D</td>
<td>≤ 35</td>
<td>any</td>
</tr>
<tr>
<td></td>
<td>35 &lt; t ≤ 150</td>
<td>normalised, normalising or TM rolled ²</td>
</tr>
<tr>
<td>GL–E</td>
<td>≤ 150</td>
<td>normalised, or TM rolled ²</td>
</tr>
</tbody>
</table>

Notes

¹ Subject to the special approval of GL, plates in Grade GL–A and GL–B steel may also be supplied in the as-rolled condition, see 13.2.

² Subject to the special approval of GL, sections in Grade GL–D steel may be supplied in the as-rolled condition provided satisfactory results are consistently obtained from notch impact tests. Accordingly sections in Grade GL–E steel may be supplied in the as rolled or normalising rolled condition. The frequency of impact tests is to be determined in accordance with 13.2.2 and 13.3.3 respectively.

### Table 1.6 Condition of supply for higher strength steels

<table>
<thead>
<tr>
<th>Grades</th>
<th>Grain refining elements used</th>
<th>Thickness range t [mm]</th>
<th>Condition of supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>GL–A 32 GL–A 36</td>
<td>Nb or V</td>
<td>≤ 12,5</td>
<td>any</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12,5 &lt; t ≤ 150</td>
<td>normalised, normalising or TM rolled ²</td>
</tr>
<tr>
<td>GL–A 40</td>
<td>Al alone or with Ti</td>
<td>≤ 20</td>
<td>any</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20 &lt; t ≤ 35</td>
<td>any, but as-rolled subject to special approval of GL ¹</td>
</tr>
<tr>
<td></td>
<td></td>
<td>35 &lt; t ≤ 150</td>
<td>normalised, normalising or TM rolled ²</td>
</tr>
<tr>
<td>GL–D 32 GL–D 36</td>
<td>Nb or V</td>
<td>≤ 12,5</td>
<td>any</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12,5 &lt; t ≤ 150</td>
<td>normalised, normalising or TM rolled ²</td>
</tr>
<tr>
<td></td>
<td>Al alone or with Ti</td>
<td>≤ 20</td>
<td>any</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20 &lt; t ≤ 25</td>
<td>any, but as-rolled subject to special approval of GL ¹</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20 &lt; t ≤ 150</td>
<td>normalised, normalising or TM rolled ²</td>
</tr>
</tbody>
</table>
Table 1.6  Condition of supply for higher strength steels  (continued)

<table>
<thead>
<tr>
<th>Grades</th>
<th>Grain refining elements used</th>
<th>Thickness range ( t ) [mm]</th>
<th>Condition of supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>GL–D 40</td>
<td>any</td>
<td>( \leq 50 )</td>
<td>normalised, normalising or TM rolled</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( 50 &lt; t \leq 150 )</td>
<td>normalised, TM rolled or quenched and tempered</td>
</tr>
<tr>
<td>GL–E 32</td>
<td>any</td>
<td>( \leq 50 )</td>
<td>normalised or TM rolled (^2)</td>
</tr>
<tr>
<td>GL–E 36</td>
<td></td>
<td>( 50 &lt; t \leq 150 )</td>
<td>normalised or TM rolled</td>
</tr>
<tr>
<td>GL–E 40</td>
<td>any</td>
<td>( \leq 150 )</td>
<td>normalised, TM rolled or quenched and tempered</td>
</tr>
<tr>
<td>GL–F 32</td>
<td>any</td>
<td>( \leq 150 )</td>
<td>normalised, TM rolled or quenched and tempered (^3)</td>
</tr>
<tr>
<td>GL–F 36</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GL–F 40</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. The frequency of impact tests is to be in accordance with 13.2.2.
2. Subject to the special approval of GL, sections in Grade GL–A 32, GL–A 36, GL–D 32 and GL–D 36 steels may be supplied in as-rolled condition provided satisfactory results are consistently obtained from notch impact tests. Accordingly, sections in grade GL–E 32 and GL–E 36 steels may be supplied in as-rolled or normalising rolled condition. The frequency of notch impact tests is to be in accordance with 13.2.2 and 13.2.3 respectively.
3. Subject to special approval of GL, sections in Grade GL–F 32 and GL–F 36 steels with thickness \( \leq 50 \) may be supplied in as-rolled condition or normalising rolled condition. The frequency of notch impact tests is to be in accordance with 13.3.3.

Table 1.7  Mechanical properties for normal strength steels

<table>
<thead>
<tr>
<th>Grade</th>
<th>Yield strength ( R_{eH} ) ([\text{N/mm}^2]) min.</th>
<th>Tensile strength ( R_m ) ([\text{N/mm}^2])</th>
<th>Elongation (^1) ( \frac{A}{L_0 = 5.65 \cdot \sqrt{S_0}} ) [%] min.</th>
<th>Notched bar impact energy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Test temp. ( ^\circ \text{C} )</td>
<td>KV ([\text{J}]) min.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>long.</td>
<td>transv.</td>
<td>long.</td>
<td>transv.</td>
</tr>
<tr>
<td>GL–A</td>
<td>235</td>
<td>400–520 (^2)</td>
<td>22</td>
<td>+20</td>
</tr>
<tr>
<td>GL–B</td>
<td>0</td>
<td>27 (^3)</td>
<td>20 (^3)</td>
<td>34</td>
</tr>
<tr>
<td>GL–D</td>
<td>–20</td>
<td>27</td>
<td>20</td>
<td>34</td>
</tr>
<tr>
<td>GL–E</td>
<td>–40</td>
<td>27</td>
<td>20</td>
<td>34</td>
</tr>
</tbody>
</table>

\( t = \) thickness of product [mm]

1. Required elongation for flat tensile test specimens with gauge length \( L_0 = 200 \text{ mm} \), width = 25 mm and a thickness equal to the product thickness:

<table>
<thead>
<tr>
<th>Thickness of product ( t ) [mm]</th>
<th>( \leq 5 )</th>
<th>( &gt; 5 \leq 10 )</th>
<th>( &gt; 10 \leq 15 )</th>
<th>( &gt; 15 \leq 20 )</th>
<th>( &gt; 20 \leq 25 )</th>
<th>( &gt; 25 \leq 30 )</th>
<th>( &gt; 30 \leq 40 )</th>
<th>( &gt; 40 \leq 50 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elongation ( \frac{A}{200 \text{ mm}} ) [%]</td>
<td>14</td>
<td>16</td>
<td>17</td>
<td>18</td>
<td>19</td>
<td>20</td>
<td>21</td>
<td>22</td>
</tr>
</tbody>
</table>

2. For Grade GL–A sections the upper limit for the specified tensile strength range may be exceeded at the discretion of GL, irrespective of product thickness.
3. Notch impact tests are generally not required for Grade GL–B steels with thickness of 25 mm or less.
4. For Grade GL–A products with thickness in excess of 50 mm, notch impact tests are not required provided that the steel has been fine grain treated and normalised. TM rolled steels may also be supplied without notch impact testing provided that GL has waived the need.
Table 1.8 Mechanical properties for higher strength steels

<table>
<thead>
<tr>
<th>Grade</th>
<th>Yield strength $R_{eH}$</th>
<th>Tensile strength $R_m$</th>
<th>Elongation $A$</th>
<th>Notched bar impact energy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[N/mm²] min.</td>
<td>[N/mm²]</td>
<td>at $L_0 = 5,65 \cdot \sqrt{S_0}$</td>
<td>KV [J] min.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>[%]</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GL-A32</td>
<td>315</td>
<td>440–570</td>
<td>22</td>
<td>0</td>
</tr>
<tr>
<td>GL-D32</td>
<td></td>
<td></td>
<td></td>
<td>-20</td>
</tr>
<tr>
<td>GL-E32</td>
<td>GL-F32</td>
<td>355</td>
<td>490–630</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-20</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-40</td>
<td></td>
</tr>
<tr>
<td>GL-A36</td>
<td>GL-D36</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GL-E36</td>
<td>GL-F36</td>
<td>390</td>
<td>510–660</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-20</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-40</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-60</td>
<td></td>
</tr>
</tbody>
</table>

$t$ = thickness of product [mm]

1 Required elongation for flat tensile test specimens with gauge length $L_o = 200$ mm, width = 25 mm and a thickness equal to the product thickness:

<table>
<thead>
<tr>
<th>Thickness of product $t$ [mm]</th>
<th>5/6 of the tabulated value</th>
<th>2/3 of the tabulated value</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 5</td>
<td>&gt; 10</td>
<td>&gt; 15</td>
</tr>
<tr>
<td>GL-A32, -D32, -E32, -F32</td>
<td>14</td>
<td>16</td>
</tr>
<tr>
<td>GL-A36, -D36, -E36, -F36</td>
<td>13</td>
<td>15</td>
</tr>
<tr>
<td>GL-A40, -D40, -E40, -F40</td>
<td>12</td>
<td>14</td>
</tr>
</tbody>
</table>

2 For TM-rolled steels, the tensile strength may be up to 30 N/mm² below the lower limit for this value without giving cause for complaint.

6.3 The minimum impact energy requirements relate to Charpy V-notch impact test specimens, which are taken in either the longitudinal or transverse directions. Generally only longitudinal test specimens need be prepared and tested. For special applications, if required by GL or the purchaser, transverse specimens are to be tested. The requirements in respect of the transverse test specimens shall be guaranteed by the manufacturer.

The tabulated values are for standard specimens 10 mm × 10 mm. For plate thicknesses lower than 10 mm, the requirement for performing a notch impact test may be waived with the approval of GL or sub-size specimens with reduced requirements may be taken as follows:

Specimen dimensions 10 mm × 7,5 mm:
- 5/6 of the tabulated value

Specimen dimensions 10 mm × 5,0 mm:
- 2/3 of the tabulated value

6.4 The average notch impact energy value obtained from one set of three tests is to comply with the requirements given in Tables 1.7 or 1.8. One individual value only may be below the specified average value provided it is not less than 70 % of that value.

6.5 Notch impact tests are generally no longer required if the product is less than 6 mm thick.
7. **Freedom from defects and repair of surface defects**

7.1 **General characteristics**

7.1.1 All products shall satisfy the requirements applicable to general characteristics set out in A.5.1. Unless otherwise agreed, the surface finish of the products shall be subject to standard EN 10163, specifications relating to the surface finish of hot-rolled steel products (plate, steel wide flat and sections), Class A, or equivalent national or international standard, however, grinding of defects may only be carried out within the limits given in 7.2.

7.1.2 Notwithstanding the provisions of A.5.3, surface defects may be removed not only by grinding but also by welding according to the principles stated below, provided that the defects in question are isolated, of locally limited extent and the sum of the defective areas covers not more than 2% of the relevant face of the product.

7.2 **Repairs by grinding**

The manufacturer may, at his discretion, remove surface defects by grinding, provided that the depth of material ground away does not exceed 3 mm in relation to the nominal thickness of the product and provided also that at least 93% of the nominal thickness remains. In addition, the depressions caused by the grinding shall have a smooth transition to the surrounding surface of the product.

7.3 **Repairs by welding**

Defects which cannot be removed by grinding may be repaired by chipping and/or grinding with subsequent welding, provided that the Surveyor has consented to the repair and that the following requirements are met.

7.3.1 After chipping or grinding the defect, the remaining thickness shall be equal to at least 80% of the nominal thickness. The remaining thickness may be less than this limit value only in exceptional cases where the specific application of the product is not thereby impaired.

7.3.2 All welds shall be performed by trained welders using approved methods and electrodes with a controlled low hydrogen content. At least one layer of weld metal is to be welded in excess which shall thereafter be ground flush to the surface level.

7.3.3 Wherever possible, products which are to be supplied in the normalised condition shall be welded prior to the heat treatment. If welding is required after normalising an additional treatment may be requested. Products which are supplied thermo-mechanically treated or hot-rolled are to receive stress-relief heat treatment after welding, if appropriate further processing cannot be ensured.

7.3.4 The repaired items shall be submitted to the Surveyor for final inspection and freedom from defects shall be proved by a suitable non-destructive method.

7.3.5 For every repair weld, the manufacturer shall prepare a report containing details of the size and location of the defects, the welding method used and any heat treatment applied, and shall hand this report to the Surveyor.

8. **Dimensions, dimensional and geometrical tolerances**

The provisions of A.6. are applicable. With regard to flat products (plates and steel wide flat) for shipbuilding use, Class B given in Table 1.1 may be considered as the permitted lower deviation from the nominal thickness.

9. **Material identification**

9.1 The manufacturer is required to set up an identification system for ingots, slabs and finished products so that the material can be traced back as far as smelting.

9.2 The Surveyor is to be allowed every facility in order to carry out this trace-back procedure as appropriate.

10. **Testing and inspection**

10.1 **Test facilities**

The manufacturer is required to allow the Surveyor access to all works departments and to provide all the necessary facilities as may be required to establish the approved manufacturing process, the selection of test material, supervision of tests in accordance with the rules and also to establish the precision of the test equipment.

10.2 **Test methods**

The prescribed tests and surveys shall be conducted at the place of manufacture prior to despatch of products. The test specimens and test methods shall comply with the information given in Chapter 1 – Principles and Test Procedures, Section 2. Unless otherwise agreed with GL, the specimens shall be selected by the Surveyor, marked and tested in his presence.

10.3 **Tensile testing of specimens taken in the direction of thickness**

Where plates and steel wide flats with thicknesses ranging from 15 to 150 mm are ordered with requirements as to the direction of thickness, tensile test specimens shall be prepared and tested with their axis perpendicular to the surface of the product as described in 1.

10.4 **Non-destructive testing**

10.4.1 Where plates and steel wide flats are ordered with an ultrasonic test certificate, the tests are to be executed in accordance with a standard approved by...
GL, e.g. EN 10160. The quality class is to be stipulated when the order is placed.

10.4.2 The seams of welded hollow sections of hull structural steel are to be subjected to non-destructive testing over their entire length.

10.4.2.1 Electrical welded hollow sections

The weld seam of hollow sections is to be examined according to one of the following European standards:
- EN 10246-3, acceptance category E4, except that the technique of rotating pipes or with rotating saddle coils is not permitted
- EN 10246-5, acceptance category F5, or EN 10246-8, acceptance category U5

10.4.2.2 Submerged-arc welded hollow sections

The weld seam of hollow sections is to be examined according to acceptance category U4 in accordance with EN 10246-10, image quality class R2.

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

10.5 Testing of surface finish and dimensions

Inspections of surface finish and dimensional checks are the responsibility of the rolling mill. Acceptance testing by the Surveyor does not release the manufacturer from this responsibility.

11. Test material

11.1 Definitions

11.1.1 "Piece" denotes the rolled product which has been rolled directly from an ingot, billet or slab into a plate, section or bar.

11.1.2 "Batch" denotes a test batch, made up of products of the same kind and originating from the same heat, which has been submitted as a whole for testing.

11.2 Test section

11.2.1 The material which has been combined in one batch (one test batch) for testing shall have the same shape e.g. plate, steel wide flat, section, originate from the same heat and be delivered in the same condition.

11.2.2 The test sections shall be representative of the material and may only be cut from the test piece following the final heat treatment - unless there are technical reasons why they should not be.

11.2.3 Test sections may not be heat treated separately.

11.2.4 The removal of test sections is subject to the rules laid down in A.8.2.

12. Specimens for mechanical tests

12.1 Tensile test samples

The dimensions of the tensile test samples are to be selected from those given in Chapter 1 – Principles and Test Procedures, Section 2, D. Full thickness flat tensile test specimens should generally be selected as the test thickness for plates, steel wide flats and sections. Round tensile test specimens may be used where the thickness of the product exceeds 40 mm or in the case of bars and similar products. By way of an alternative to these specimens, full section specimens of a suitable length may also be tested in the case of small bars and sections.

12.2 Impact test specimens

Impact test specimens shall comply with the Charpy V specimen shape and be taken horizontally with the long side of the specimen 2 mm below the rolling surface. They shall be positioned so that their axes are either "longitudinal" or "transverse" to the main direction of rolling as shown in Tables 1.7 and 1.8. The notch shall be milled in the side of the specimen so that the latter’s axis is vertical to the surface of the product. The position of the notch may not be less than 25 mm from one flame-cut edge or one shear edge. Where the thickness of the product exceeds 40 mm, the impact test specimens shall be taken in such a way that the axis of the specimen is positioned at 1/4 of the product thickness.

13. Number of test specimens

13.1 Number of tensile tests

For each batch presented, except where specially agreed by GL, one tensile test specimen is to be taken from one piece (max. weight 50 t from the same heat). Where the weight of finished material is greater than 50 tonnes, one extra test specimen is to be taken from a different piece from each 50 tonnes or fraction thereof. Provision shall be made for additional specimens for every variation of 10 mm in the thickness or diameter of products from the same heat.


13.2.1 Except where otherwise specially agreed by GL, for each batch presented (max. 50 t from the same heat), at least one set of three Charpy V-notch test specimens is to be made from one piece. Where the weight of finished material is greater than 50 tonnes, one extra set of three test specimens is to be made from a different piece from each 50 tonnes or fractions thereof.
From plates of grades GL–A 40 and GL–D 40 in quenched and tempered condition, one set of impact tests per heat treatment length is to be taken.

Where plates, except for those in grade GL–A steel, are supplied in thicknesses greater than 50 mm in the normalising rolled condition, the test batch from which specimens are taken is no greater than 25 tonnes or fractions thereof.

13.2.2 When, subject to the special approval of GL, 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 fractions thereof. The same applies when plates of grade GL–A steel are supplied in thicknesses greater than 50 mm in the as rolled condition. In this case, one set of three impact test specimens shall be taken for each 50 tonnes or fractions thereof.

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

13.2.4 The test batch quantity depending on supply condition and thickness of product is shown in Tables 1.9 and 1.10.


13.3.1 For plates supplied in the normalised or TM-rolled condition, one set of specimens is to be taken from each rolled length. In the case of quenched and tempered plates, one set of specimens is to be taken from each heat treatment length.

13.3.2 For sections one set of specimens is to be taken from each test unit of 25 tonnes or fractions thereof.

13.3.3 When, subject to the special approval of GL, sections other than those in grade GL–E 40 and GL–F 40, are supplied in the as rolled or normalising rolled condition, one set of test specimens is to be taken from each batch of 15 tonnes or fractions thereof.

13.3.4 The specimens taken as described in 13.3.1 or 13.3.3 above are to be taken from the thickest piece in each batch.

13.3.5 The test batch quantity depending on supply condition and thickness of product is shown in Tables 1.9 and 1.10.

14. Re-tests

14.1 Where the requirements are not satisfied in a tensile test, or where the average from three impact test samples fails to meet the conditions, or where an individual value from a notch impact test does not meet the requirements, re-tests are to be carried out as stipulated in Chapter 1 – Principles and Test Procedures, Section 2, H. In this case, the conditions specified therein are to be satisfied.

15. Branding

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

– identification mark for the grade steel (e.g. GL–A, GL–A 36)

– Steels which have been specially approved by GL and which differ from these requirements (see 1.4) are to have the letter “S” after the above identification mark (e.g. GL–A36 S, GL–ES)

– Material supplied in the thermo-mechanically controlled processed condition is to have the letters TM added after the identification mark (e.g. GL–E 36 TM)

– name or initials to identify the steelworks

– heat or other number to identify the piece

– if required by the purchaser, his order number or other identification mark

15.2 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 recognizable.

15.3 Where a number of low-weight products are securely combined in packages or bundles, it is sufficient, subject to approval by GL, to mark only the uppermost piece in the package or robust tag which is securely fastened to the bundle.

15.4 When a product already bears GL brand but has not satisfied the test conditions, said brand shall be unequivocally removed by the manufacturer.

16. Certificates

16.1 The manufacturer shall hand over to the Surveyor either works acceptance test certificates (e.g. in accordance with EN 10204-3.1) or despatch documents for the products accepted by him. Said documentation shall be in triplicate at least. Documentation is to be produced separately for each grade of steel and shall contain the following particulars:

– purchaser and order number

– where known, the newbuilding and project number respectively

– item numbers and quantities

– size and indication of products

– identification of rolling mill

– steel grade

– weight of products
– heat number or product number and, where appropriate, specimen number
– chemical composition of the melt for the elements shown in Tables 1.2 and 1.3
– delivery condition, where not supplied in the as-rolled condition, e.g. normalised, normalising rolled, thermo-mechanically rolled or quenched and tempered
– In the case of grade GL–A steel sections up to 12,5 mm, details of whether it is rimmed steel
– marking of the products
– test results

Table 1.9 Required condition of supply and number of impact tests for normal strength steels

<table>
<thead>
<tr>
<th>Grade</th>
<th>Deoxidation Practice</th>
<th>Product shape</th>
<th>Condition of supply (Test Batches for Impact Tests) 1, 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Thickness of product t [mm]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>12.5</td>
</tr>
<tr>
<td>GL-A</td>
<td>Rimmed</td>
<td>Sections</td>
<td>A (-)</td>
</tr>
<tr>
<td></td>
<td>For t ≤ 50 mm</td>
<td>Plates</td>
<td>A (-)</td>
</tr>
<tr>
<td></td>
<td>Any method except rimmed</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>For t &gt; 50 mm</td>
<td>Sections</td>
<td>A (-)</td>
</tr>
<tr>
<td></td>
<td>killed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GL-B</td>
<td>For t ≤ 50 mm</td>
<td>Plates</td>
<td>A (-)</td>
</tr>
<tr>
<td></td>
<td>Any method except rimmed</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>For t &gt; 50 mm</td>
<td>Sections</td>
<td>A (-)</td>
</tr>
<tr>
<td></td>
<td>killed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GL-D</td>
<td>Killed</td>
<td>Plates,</td>
<td>A (50)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sections</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fully killed and fine grain</td>
<td>Plates</td>
<td>A (50)</td>
</tr>
<tr>
<td></td>
<td>treated</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sections</td>
<td>A (50)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GL-E</td>
<td>Fully killed and fine grain</td>
<td>Plates</td>
<td>N (each rolled length)</td>
</tr>
<tr>
<td></td>
<td>treated</td>
<td></td>
<td>TM (each rolled length)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sections</td>
<td>N (25)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 Supply condition:
   A = any method
   N = normalised condition
   NW = normalising rolled condition
   TM = thermo-mechanically rolled condition
   W* = hot rolled condition subject to special approval of GL
   NW* = normalising rolled condition subject to special approval of GL

2 Number of impact tests:
   One set of test specimens is to be taken from each test batch or parts there of, the weight of the test batch being stated in ( ).
   Sign (-) means that the impact test is omitted.

3 Subject to special approval of GL, see Table 1.7 note 4.
Table 1.10  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>Product shape</th>
<th>Condition of Supply (Batch for Impact Tests)</th>
<th>Thickness of product t [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Plates</td>
<td>A (50)</td>
<td>12.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sections</td>
<td>A (50)</td>
<td>N (50)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Plates</td>
<td>A (50)</td>
<td>W* (25)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sections</td>
<td>A (50)</td>
<td>N (50)</td>
</tr>
<tr>
<td>GL-A32</td>
<td>Fully killed and fine grain treated</td>
<td>Al only or with Ti</td>
<td>Plates</td>
<td>A (50)</td>
<td>N (50)</td>
</tr>
<tr>
<td>GL-A36</td>
<td></td>
<td></td>
<td>Sections</td>
<td>A (50)</td>
<td>N (50)</td>
</tr>
<tr>
<td>GL-A40</td>
<td>Fully killed and fine grain treated</td>
<td>Any</td>
<td>Plates, Sections</td>
<td>A (50)</td>
<td>N (50)</td>
</tr>
<tr>
<td>GL-D32</td>
<td>Fully killed and fine grain treated</td>
<td>Al only or with Ti</td>
<td>Plates</td>
<td>A (50)</td>
<td>W* (25)</td>
</tr>
<tr>
<td>GL-D36</td>
<td></td>
<td></td>
<td>Sections</td>
<td>A (50)</td>
<td>N (50)</td>
</tr>
<tr>
<td>GL-D40</td>
<td>Fully killed and fine grain treated</td>
<td>Any</td>
<td>Plates, Sections</td>
<td>N (50)</td>
<td>NW (50), TM (50)</td>
</tr>
<tr>
<td>GL-E32</td>
<td>Fully killed and fine grain treated</td>
<td>Any</td>
<td>Plates</td>
<td>N (each rolled length)</td>
<td>TM (each rolled length)</td>
</tr>
<tr>
<td>GL-E36</td>
<td></td>
<td></td>
<td>Sections</td>
<td>N (25)</td>
<td>TM (25)</td>
</tr>
<tr>
<td>GL-E40</td>
<td>Fully killed and fine grain treated</td>
<td>Any</td>
<td>Plates</td>
<td>N (each rolled length)</td>
<td>TM (each rolled length)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sections</td>
<td>N (25)</td>
<td>TM (25)</td>
</tr>
</tbody>
</table>
### Table 1.10  Required condition of supply and number of impact tests for higher strength steels (continued)

<table>
<thead>
<tr>
<th>Grade</th>
<th>Deoxidation Practice</th>
<th>Grain Refining Elements</th>
<th>Product shape</th>
<th>Condition of Supply (Batch for Impact Tests)</th>
<th>Thickness of product t (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Plates</td>
<td>N (each rolled length)</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>TM (each rolled length)</td>
<td>150</td>
</tr>
<tr>
<td>GL-F32/36</td>
<td>Fully killed and fine grain treated</td>
<td>Any</td>
<td></td>
<td>V (for each unit heat treated)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sections</td>
<td>N (25)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>TM (25)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>V (25)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>NW* (15)</td>
<td>not applicable</td>
</tr>
<tr>
<td>GL-F40</td>
<td>Fully killed and fine grain treated</td>
<td>Any</td>
<td>Plates</td>
<td>N (each rolled length)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>TM (each rolled length)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>V (for each unit heat treated)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sections</td>
<td>N (25)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>TM (25)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>V (25)</td>
<td></td>
</tr>
</tbody>
</table>

1. Supply condition:
   A = any
   N = normalised condition
   NW = normalising rolled condition
   TM = thermo-mechanically rolled condition
   V = quenched and tempered condition
   W* = hot rolled and tempered condition
   NW* = normalising rolled subject to special approval of GL.

2. Number of impact tests:
   One set of impact test specimens is to be taken from each test batch or parts thereof, the weight of the test batch being stated in ( ).
   For grades GL-A 32 and GL-A 36 steels a relaxation in the number of impact tests may be permitted by special agreement with GL provided that satisfactory results are obtained from occasional check tests.

### 16.2 Before the acceptance test certificates or despatch documents are signed by the Surveyor, the manufacturer shall hand over written confirmation that the steel has been produced by an approved method and has successfully passed the tests prescribed in the presence of the Surveyor or his representative appointed by GL. In this regard, the following text may be also accepted, either stamped or printed on the certificate or despatch documents, and shall be verified by one of the manufacturer's authorised agents:

"We hereby declare that the material has been produced by an approved method and has satisfied the Rules of GL for testing".

### C. Unalloyed Steels for Welded Structures

#### 1. Scope

1.1 These Rules 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 or in shipbuilding.

#### 1.2 Rolled bars for the manufacture of shafts, shanks, studs, bolts and other rotating parts are governed by Section 3, B.

### 2. Suitable steels

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

**2.1 Steels conforming to EN 10025, EN 10210 and EN 10219 grades as follows:**

- S235: all grades
  
  **Note**
  The grades S235 JR and S235 JR G1 according to EN 10025 : 1990 + A1 : 1993 are excluded from application.

- S275: all grades

- S355: all grades
2.2 Weldable fine-grained structural steels conforming to EN 10025-3, in the grades:

- S275 N, S275 NL, S355 N, S355 NL (normalised or normalising rolled)

and conforming to EN 10025-4 in the grades:

- S275 M, S275 ML, S355 M, S355 ML (thermo-mechanically rolled)

2.3 Other steels after their suitability has been determined by GL, provided that they satisfy the following minimum requirements:

2.3.1 The chemical composition [%] of the ladle analysis shall not exceed the following limit values:

<table>
<thead>
<tr>
<th></th>
<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>max</td>
<td>0.22</td>
<td>1.70</td>
<td>0.55</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>
</tr>
</tbody>
</table>

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

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

2.3.3 For fine grain treated structural steels, an impact energy of not less than 27 J (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, normalising rolled or thermo-mechanically rolled condition
- 0 °C, for products supplied in as rolled condition.

3. Condition of supply and heat treatment

Flat products made of fine grain treated structural steels are to be supplied in normalised, normalising rolled or thermo-mechanically rolled condition. For all other products, the data in the standards apply, unless otherwise specified in the order.

4. Dimensions, dimensional and geometrical tolerances

A.6. applies, with the following addition:

For the minus tolerance applicable to the nominal thickness, the values stated under Class A in Table 1.1 apply to plates, strips and wide flats, unless otherwise specified in the purchase order.

5. Testing and scope of tests

The following tests shall be performed:

5.1 Test of chemical composition

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

5.2 Tensile test

5.2.1 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.

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

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 2.3.3. 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 5.2.1.

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

5.4 Testing of surface finish and dimensions

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

D. High-Strength Steels for Welded Structures

1. Scope

1.1 These Rules apply to plates and wide flats up to 70 mm thick made of weldable high-strength quenched and tempered steels. The application of these Rules to products with larger thicknesses shall be specially agreed with Germanischer Lloyd (GL). The same applies if products other than plates and wide flats, e.g. sections and pipes, are to be supplied in accordance with these Rules.

1.2 Steels falling within the scope of these Rules are classed into 6 groups indicated by the nominal
yield strengths 420, 460, 500, 550, 620 and 690 N/mm². Each group is further subdivided into the grades A, D, E and F based on the temperature for notched bar impact testing.

1.3 Steels which diverge from these Rules, e.g. with regard to their nominal yield strength, their mechanical properties and their chemical composition, may not be used without the special approval of GL.

1.4 Steels conforming to EN 10025-3 and -4 may also be used in place of grades GL–A 420, GL–D 420, GL–A 460 and GL–D 460, viz:

– for grades GL–A 420 and GL–D 420:
  S420 N and S420 NL, EN 10025-3
  S420 M and S420 ML, EN 10025-4

– for grades GL–A 460 and GL–D 460:
  S460 N and S460 NL, EN 10025-3
  S460 M and S460 ML, EN 10025-4

2. Approval

The steels shall be approved by GL. For this purpose, the steel manufacturer shall send GL a material specification containing the required information, such as chemical composition, manufacturing process, mechanical properties, condition of supply, as well as recommendations for welding, hot or cold forming, and heat treatment. GL reserves the right to require initial approval testing.

The material manufacturer shall verify the weldability of each grade of steel by appropriate documentation possibly in connection with welding tests.

3. Requirements

3.1 Manufacturing process

The steels shall be manufactured in works approved by GL by the basic oxygen process, in electric arc furnaces, or by another process approved by GL. They shall be cast in killed condition and fine grain treated.

3.2 Chemical composition

3.2.1 The chemical composition shall satisfy the requirements stated in the authorized specification and in Table 1.11.

Elements used for alloying and fine grain treatment are to be indicated in the manufacturer’s specification.

3.2.2 To assess weldability, sensitivity to cold cracking may be calculated from the ladle analysis according to 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 maximum permitted value is to be agreed with GL and shall be indicated in the authorised specification.

3.3 Heat treatment

The steels shall be supplied in quenched and tempered condition. However, for grades GL–A 420, GL–D 420, GL–E 420, GL–F 420 and also for GL–A 460, GL–D 460, GL–E 460 and GL–F 460, with product thicknesses up to 50 m, normalising or normalising rolling is permitted where the required properties can be achieved thereby. This is to be demonstrated for approval testing. The same applies to thermomechanically rolled steels up to 70 mm thickness with nominal yield strength up to 500 N/mm².

3.4 Mechanical properties

The requirements applicable to the mechanical properties and the impact energy shall conform to the data in Table 1.12.

3.5 General condition of products

A.5. applies. In addition, it should be noted that:

– Procedures for repair welding and reporting thereon shall be approved by GL.

– If defects are removed by grinding, the thickness remaining underneath the ground area shall be within the thickness tolerance.

3.6 Dimensions, dimensional and geometrical tolerances

A.6. applies, with the following addition:

For the minus tolerance applicable to the nominal thickness, the values stated under Class A in Table 1.1 apply, unless otherwise specified in the order.

4. Testing

4.1 Testing of chemical composition

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

4.2 Tensile test

4.2.1 From every piece heat-treated in a unit, at least one tensile test specimen shall be taken and tested. If plates are heat-treated by continuous processes, special arrangements may be made with regard to the number of tests required and the making of the test specimens.

In the case of products which are not quenched and tempered, one tensile test specimen is to be taken for each rolled length.

4.2.2 Test specimens are to be cut with their longitudinal axes perpendicular to the final direction of rolling, except in the case of sections and wide
flats < 600 mm in width, where longitudinal test specimens are to be taken. For other product forms, the tensile test specimens may be taken in either the longitudinal or the transverse direction as agreed with GL. Normally, flat tensile test specimens are to be used. The tensile-test specimens may be taken from the full or the half product thickness, however, one surface side shall be maintained. For thicknesses above 30 mm round tensile test specimens may be used, the axis of which shall lie at a distance of 1/4 of the product thickness from the surface.

4.3 Impact test

4.3.1 From each piece as heat treated or, in the case of products from each rolling length which have not been quenched and tempered, at least one set of three Charpy V-notch impact test specimens in accordance with Chapter 1 – Principles and Test Procedures, Section 2, E.2. is to be taken and tested. For continuous heat treated plates special consideration may be given to the number and location of test specimens required.

4.3.2 Unless otherwise accepted by GL, the V-notch impact test specimens for plates and wide flats ≥ 600 mm are to be taken with their axes transverse to the main rolling direction. For other product forms the impact tests are to be in the longitudinal direction. The specimens’ axes shall be positioned at a distance of 1/4 of the product thickness from the surface or as near as possible to this position.

4.3.3 For grade GL-A steel products, the number of impact test specimens may be reduced by agreement with GL, where equivalent results are obtained during testing.

4.4 Through thickness tensile test

If required by GL, through thickness tensile tests are to be performed using test specimens taken at right angles to the surface of the product in accordance with I.

4.5 Surface inspection and dimensions

The manufacturer shall inspect the condition of the surface and the dimensions of the product and shall then submit the products to the Surveyor for inspection.

4.6 Non-destructive testing

4.6.1 Where plates and wide flats are ordered with a certificate of ultrasonic examination, the tests are to be carried out according to a standard accepted by GL, e.g. EN 10160. The quality class is to be defined at the time of the order.

4.6.2 The seams of welded hollow sections of hull structural steel are to be subjected to non-destructive testing over their entire length.

4.6.2.1 Electrical welded hollow sections

The weld seam of hollow sections is to be examined according to one of the following European standards:

- EN 10246-3, acceptance category E4, except that the technique of rotating pipes or with rotating saddle coils is not permitted
- EN 10246-5, acceptance category F5, or EN 10246-8, acceptance category U5

4.6.2.2 Submerged-arc welded hollow sections

The weld seam of hollow sections is to be examined according to acceptance category U4 in accordance with EN 10246-10, image quality class R2.

Butt welds serving to connect strip or plate lengths by spiral submerged-arc welding have to be examined over their entire length according to the same test procedure and shall satisfy the same acceptance criteria as the main weld seam.
Table 1.12 Mechanical and technological properties for products with 70 mm maximum thickness

<table>
<thead>
<tr>
<th>Grades</th>
<th>Yield strength (R_{\text{eff}}) ([\text{N/mm}^2]) min.</th>
<th>Tensile strength (R_m) ([\text{N/mm}^2])</th>
<th>Elongation (3) (\text{at } L_o = 5.65 \cdot \sqrt{S_o}) (%) min.</th>
<th>Impact energy (KV) ([\text{J}]) min.</th>
</tr>
</thead>
<tbody>
<tr>
<td>GL–A 420</td>
<td>420</td>
<td>530 – 680</td>
<td>20</td>
<td>18</td>
</tr>
<tr>
<td>GL–D 420</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GL–E 420</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GL–F 420</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GL–A 460</td>
<td>460</td>
<td>570 – 720</td>
<td>19</td>
<td>17</td>
</tr>
<tr>
<td>GL–D 460</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GL–E 460</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GL–F 460</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GL–A 500</td>
<td>500</td>
<td>610 – 770</td>
<td>18</td>
<td>16</td>
</tr>
<tr>
<td>GL–D 500</td>
<td></td>
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</tr>
<tr>
<td>GL–E 500</td>
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<tr>
<td>GL–F 500</td>
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<td></td>
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<tr>
<td>GL–A 550</td>
<td>550</td>
<td>670 – 830</td>
<td>18</td>
<td>16</td>
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<tr>
<td>GL–D 550</td>
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<td>GL–F 550</td>
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<tr>
<td>GL–A 620</td>
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<td>720 – 890</td>
<td>17</td>
<td>15</td>
</tr>
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<tr>
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<td>690</td>
<td>770 – 940</td>
<td>16</td>
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<td></td>
</tr>
<tr>
<td>GL–F 690</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 Where the yield strength \(R_{\text{eff}}\) does not mark in the tensile test, the 0.2 % proof stress \(R_{p0.2}\) is applicable.
2 The permissible ratio between yield strength and tensile strength is to be agreed between the manufacturer and GL.
3 Where flat tensile test specimens 25 mm wide and with a gauge length of 200 mm are used, the minimum requirements in respect of elongation are to be obtained from Table 1.13.
Table 1.13 Minimum values in respect of elongation when using specimens 25 mm wide and with a gauge length of 200 mm

<table>
<thead>
<tr>
<th>Nominal yield strength</th>
<th>Elongation A₂₀₀ mm [%]</th>
<th>Thickness of product t [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>≤ 10</td>
<td>&gt; 10</td>
</tr>
<tr>
<td>RéH [N/mm²]</td>
<td>≤ 15</td>
<td>&gt; 15</td>
</tr>
<tr>
<td></td>
<td>≤ 20</td>
<td>&gt; 20</td>
</tr>
<tr>
<td>420</td>
<td>11</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>15</td>
</tr>
<tr>
<td>460</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td>500</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>550</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>620</td>
<td>9</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>690</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>12</td>
</tr>
</tbody>
</table>

4.7 Retest procedures

4.7.1 If one of the tensile tests fails to meet the requirements two additional test specimens are to be taken from the same position of the piece and subjected to the test. The piece will be accepted, if both additional tests are satisfactory.

4.7.2 When the average value of the impact test fails to meet the requirements or more than one value is below the required average value or when one value is below 70 % of the specified average value, the procedure described in Chapter 1 – Principles and Test Procedures, Section 2, H. is to be followed.

5. Marking

Every finished piece is to be clearly marked by the maker in at least one piece with GL brand and the following particulars:

– Marks of the manufacturer
– Unified identification mark for the grade of steel (e.g. GL–E 620) or manufacturer's trade name
– Heat number, plate number or equivalent identification mark.

The entire markings are to be encircled with paint or otherwise marked so as to be easily recognized.

2. Approved steel grades

The materials listed below may be used:

2.1 Flat products made of steels used for pressure vessels conforming to EN 10028-2 "Alloyed and Unalloyed High Temperature Steels".

2.2 Flat products made of steels used for pressure vessels conforming to EN 10028-3, "Weldable fine-grained structural steels, normalised".

2.3 Flat products made of GL-steels used for pressure vessels according to Table 1.14 and 1.15. For the 0,2 % proof stress at elevated temperatures, Table 1.16 applies.

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

2.4.1 The elongation (A) shall have the minimum values which characterise the grade of steel, as specified in the GL report, but shall be not less than 16 %.

2.4.2 The impact energy shall meet or exceed the requirements of EN 10028-2 and -3 respectively for flat products of the same strength, see Table 1.14. 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.

2.4.3 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.

2.4.4 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 Table 1.16.

E. Steels for Steam Boilers and Pressure Vessels

1. Scope

These Rules apply to flat products made from ferritic steels, which are intended for the manufacture of steam boilers, pressure vessels, heat exchangers and other process equipment.
Table 1.14 Mechanical and technological properties of flat products made of GL-steels used for pressure vessels

| Steel grade | Normal delivery condition | Yield strength $R_{eH}$ and $R_{p0.2}$ respectively $[N/mm^2]$ min. | Tensile strength $R_m$ $[N/mm^2]$ | Elongation $A$ [%] min. | Test temp. $[^\circ C]$ | KV $[J]$ min. | transv. |
|-------------|---------------------------|-------------------------------------------------------------|---------------------|----------------------|-----------------|--------------|
| GL-P235W N  | 235                       | 360 to 480                                                 | 25                  | 0                    | 34              |
| GL-P265W N  | 265                       | 410 to 530                                                 | 23                  | 0                    | 34              |
| GL-P295W N  | 295                       | 460 to 580                                                 | 22                  | 0                    | 34              |
| GL-P355W N  | 355                       | 510 to 650                                                 | 21                  | 0                    | 34              |

1 N = normalized, T = tempered.

Table 1.15 Chemical composition of GL-steels used for pressure vessels

<table>
<thead>
<tr>
<th>Steel grade</th>
<th>Chemical composition [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C</td>
</tr>
<tr>
<td>all</td>
<td>≤ 0,23</td>
</tr>
</tbody>
</table>

Table 1.16 0,2 %-Proof stress at elevated temperatures for flat products made of GL-steels used for pressure vessels

<table>
<thead>
<tr>
<th>Steel grade</th>
<th>$R_{p0.2}$-Yield strength $[N/mm^2]$ min.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Temperature $[^\circ C]$</td>
</tr>
<tr>
<td></td>
<td>50</td>
</tr>
<tr>
<td>GL-P235W</td>
<td>227</td>
</tr>
<tr>
<td>GL-P265W</td>
<td>256</td>
</tr>
<tr>
<td>GL-P295W</td>
<td>285</td>
</tr>
<tr>
<td>GL-P355W</td>
<td>343</td>
</tr>
</tbody>
</table>

2.5 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 thicknesses ≥ 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.

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

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 expert's report, unless they are to be further processed at elevated temperature.
4. **Dimensions, dimensional and geometrical tolerances**

A.6. applies with the following addition: The minus tolerances for the nominal thickness shall be as stated under Class B in Table 1.1. If lower minus tolerances are required for technical reasons, this shall be stated in the order.

5. **Testing and scope of tests**

The following tests shall be performed:

5.1 **Testing of chemical composition**

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

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:

- 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 with rolled length ≤ 7 m:
    - one specimen from one end, one specimen from each end if the rolled length is > 7 m.

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

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.

5.4 **Notched bar impact test**

5.4.1 All products with thicknesses ≥ 6 mm shall be impact tested using Charpy V-notch specimens at the test temperature of 0 °C. The specimens shall be taken from the products 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 5.2.

The test temperatures for flat products complying with EN 10025 are given in the standard.

For other steels as per 2.4, the test temperature will be stipulated in the GL approval.

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.

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 1., an ultrasonic test shall be carried out in accordance with A.8.6.

6. **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.

7. **Strength parameters for calculations**

The strength parameters for calculations are:

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

For flat products made of GL-steels used for pressure vessels according to 2.3, the values stated in Table 1.16.

7.2 For flat products made of other steels as per 2.4, the values approved by GL.

7.3 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 100 °C and 200 °C; rounding up is not allowed.

F. **Steels for Cargo Tanks**

1. **Scope**

1.1 These Rules apply to flat products made from

- fine-grained structural steels,
- high strength, quenched and tempered fine-grained structural steels,
2.1 Weldable, fine-grained structural steels conforming to EN 10028-3.

Note:
The use of steel grade P460 NH for tanks designed to carry pressure-liquefied ammonia at ambient temperatures is prohibited.

2.2 Fine-grained structural steels with nominal yield strengths above 335 N/mm² in accordance with EN 10028-3, -5 and -6.

2.3 Nickel alloy steels which are tough at low temperatures, conforming to EN 10028-4.

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

2.5 Other weldable steels conforming to other standards or to material specifications of the manufacturer or the purchaser, after initial approval testing by GL.

Table 1.17 Minimum design temperatures for steels used in the fabrication of cargo tanks

<table>
<thead>
<tr>
<th>Steel designation</th>
<th>References to standards and rules</th>
<th>Minimum design temperature [°C]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fine-grained structural steels for ammonia which has been liquefied under pressure</td>
<td>For chemical composition, see Table 1.18</td>
<td>0</td>
</tr>
<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 Section 8, D.</td>
<td>0</td>
</tr>
<tr>
<td>Other 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 1</td>
</tr>
<tr>
<td>Nickel alloy steels containing 0.5 % Nickel</td>
<td>Steels according to EN 10028-4</td>
<td>– 55</td>
</tr>
<tr>
<td>1.5 % Nickel</td>
<td>11MnNi5-3, 13MnNi6-3</td>
<td>– 60 2</td>
</tr>
<tr>
<td>3.5 % Nickel</td>
<td>12Ni14</td>
<td>– 90 2</td>
</tr>
<tr>
<td>5 % Nickel</td>
<td>X12Ni5</td>
<td>– 105 2</td>
</tr>
<tr>
<td>9 % Nickel</td>
<td>X7Ni9, X8Ni9</td>
<td>– 165</td>
</tr>
<tr>
<td>Austenitic steels</td>
<td>e.g. steels according to EN 10028-7</td>
<td>– 165</td>
</tr>
<tr>
<td></td>
<td>1.4306 (AISI 304 L)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.4404 (AISI 316 L)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.4541 (AISI 321)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.4550 (AISI 347)</td>
<td></td>
</tr>
</tbody>
</table>

1 GL 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 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 GL.
3. Approval test

3.1 On the subject of approval of materials, the material manufacturer or tank manufacturer shall provide GL 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 from defects
- heat treatments
- working method

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

The scope of the approval test is set down by GL 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.

4. Limits to use

For fabrication of cargo tanks and process pressure vessels, the limit values for the lowest design temperatures as per Table 1.17 shall apply.

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.

6. Dimensions, dimensional tolerances

For plates for parts of the tank 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 A.6., Table 1.1, Class A.

7. Freedom from defects and repair of surface defects

The provisions of A.5. 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.

8. Requirements applicable to the material

8.1 Chemical composition

8.1.1 The chemical composition shall conform to the data in the recognised standard or the material specification authorised by GL.

In addition the limiting values for the chemical composition of fine-grained structural steels with a nominal yield strength of up to 355 N/mm² used in the fabrication of tanks carrying pressure-liquefied ammonia as given in Table 1.18 are to be met.

8.1.2 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:

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

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

### Table 1.18 Chemical composition for fine-grained structural steels suitable for ammonia which has been liquefied under pressure (ladle analysis)

<p>| | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>Si</td>
<td>Mn</td>
<td>P</td>
<td>S</td>
<td>Al</td>
<td>Cr</td>
<td>Cu</td>
</tr>
<tr>
<td>0.18</td>
<td>0.10--0.50</td>
<td>1.65</td>
<td>0.030</td>
<td>0.025</td>
<td>min 0.020</td>
<td>0.20</td>
<td>0.35</td>
</tr>
<tr>
<td>Mo</td>
<td>Ni</td>
<td>V</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>min 0.04</td>
<td>0.40</td>
<td>0.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 For steels with nominal yield strengths of 355 N/mm², the chemical composition shall be set so that an upper yield strength figure of 440 N/mm² is not exceeded.

2 Where nickel is intentionally alloyed, the upper boundary value is 0.85 %.
8.2 Mechanical properties

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

8.2.2 The following also applies to fine-grained structural steels for pressure-liquefied ammonia:

The actual yield strength \(R_{xy}\) may not exceed 440 N/mm² or 470 N/mm² in the case of hot-formed dished ends.

Elongation \(A_5\) shall be at least 22 %.

8.3 Impact energy

The required impact energy values specified in Table 1.19 and 1.20 respectively for the steel grade concerned shall be achieved in tests on Charpy V-notch specimens at the prescribed test temperatures. This requirement also applies to comparable steels conforming to the standards or specifications, irrespective of the values stated therein.

8.4 Brittle fracture behaviour

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

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 \(C \leq 0.03\ %\).

9. Testing and scope of tests

The following tests are to be performed:

9.1 Test of chemical composition

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

9.2 Tensile test

9.2.1 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.

9.2.2 The number of specimens shall be determined as follows:

- normalised and TM-rolled plates: one specimen from one end of each rolled length. If this is greater than 15 m, one specimen shall be taken from each end.
- all quenched and tempered plates: one specimen from one end of each heat-treated length. If this is greater than 7 m, one specimen shall be taken from each end.
- sheets taken from hot-rolled wide strip which do not undergo individual heat treatment: one specimen each from the outer end of the coil.
- for plates of austenitic stainless steels one specimen of each heat treatment length. If this is greater than 15 m one specimen shall be taken from each end.

9.2.3 Specimens taken from the top and bottom ends of a rolled plate may not differ in tensile strength by more than the following amounts:

- rolled lengths of \(\leq 10\ m\): 60 N/mm²
- rolled lengths of \(> 10\ m\): 70 N/mm²

9.3 Notched bar impact test

9.3.1 All products with thicknesses of \(\geq 6\ mm\) shall be subjected to the notched bar impact test performed on Charpy V-notch specimens at the test temperatures specified in Table 1.19 and 1.20 respectively. In the case of plates and wide flats with a width of \(\geq 600\ mm\) 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 9.2.2.

9.3.2 Where the thickness of the products precludes the preparation of specimens with the standard dimensions (10 mm \(\times\) 10 mm), specimens measuring 7.5 mm \(\times\) 10 mm or 5 mm \(\times\) 10 mm should be used wherever possible. These specimens are subject to the requirements stated in Table 1.20.

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 of \(> 16\ mm\). It is to be conducted in accordance with a recognized standard, e.g. Stahl-Eisen-Prüfblatt (Steel-iron test specification) SEP 1325, EN 10274 or ASTM E-208, see also Chapter 1 – Principles and Test Procedures, Section 2, G.3.
### Table 1.19 Impact energy requirements for steels used for cargo tanks

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fine-grained structural steels for ammonia liquefied under pressure</td>
<td>≤ 40</td>
<td>−20</td>
<td></td>
</tr>
<tr>
<td>Fine-grained structural steels with yield strengths $R_{eH} \geq 355$ N/mm$^2$</td>
<td>≤ 40</td>
<td>−20</td>
<td></td>
</tr>
<tr>
<td>Other fine-grained structural steels, nickel alloy steel containing 0,5 % nickel</td>
<td>≤ 25 $^2$</td>
<td>5 K below minimum design temperature, not higher than −20 °C</td>
<td>41 (29) 27 (19)</td>
</tr>
<tr>
<td>Nickel alloy steels containing:</td>
<td>≤ 25 $^3$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1,5 % Nickel</td>
<td>−65</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3,5 % Nickel</td>
<td>−95</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 % Nickel</td>
<td>−110 (− 196) $^4$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 % Nickel</td>
<td>−196</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Austenitic steels</td>
<td>≤ 50</td>
<td>−196</td>
<td></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 thicknesses above 25 mm:

<table>
<thead>
<tr>
<th>Product thickness [mm]</th>
<th>Test temperature below minimum design temperature but not higher than −20 °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>25 &lt; $t$ ≤ 30</td>
<td>10 K</td>
</tr>
<tr>
<td>30 &lt; $t$ ≤ 35</td>
<td>15 K</td>
</tr>
<tr>
<td>35 &lt; $t$ ≤ 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 5 K 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 % Ni and 5 % Ni, the product thickness 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 GL.

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.
Table 1.20 Requirements applicable to specimens of reduced size according to impact energy for standard specimens

<table>
<thead>
<tr>
<th>Necessary impact acc. to Table 1.19 (standard specimens)</th>
<th>Necessary impact energy KV with specimens measuring</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7.5 mm × 10 mm</td>
</tr>
<tr>
<td>average value</td>
<td>average value</td>
</tr>
<tr>
<td>[J] min.</td>
<td>[J] min.</td>
</tr>
<tr>
<td>27 (19)</td>
<td>22</td>
</tr>
<tr>
<td>41 (29)</td>
<td>34</td>
</tr>
</tbody>
</table>

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

9.5 Test of resistance to intercrystalline corrosion

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

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 for final testing, and in the case of flat products the underside shall also be inspected by means of random sampling.

9.7 Non-destructive tests

9.7.1 The manufacturer shall carry out an ultrasonic test in accordance with A.8.6 on the following products and shall certify the result:
- plates for pressure-liquefied ammonia
- plates made from high-strength, quenched and tempered fine-grained structural steels
- plates which are loaded in the thickness direction, e.g. those used for the central longitudinal bulkheads of bilobe tanks,

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.

9.7.2 Ultrasonic testing is to be carried out according to EN 10160 or as stated in Stahl-Eisen-Lieferbedingungen SEL 072 (Steel-Iron Supply Specifications SEL 072) as follows:

Test grid ≤ 200 mm or in lines 100 mm apart.

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

Zones for longitudinal, circumferential and connection welds over a 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.

9.7.3 A non-destructive test shall be performed on products other than those mentioned in 9.7.1 if this is specified at the time of the order or called for by GL in special cases.

G. Stainless Steels

1. Scope

These Rules 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.

2. Selection of steels

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.

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.
2.3 In the light of 2.1 and 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 GL.

2.4 GL reserves the right to demand an approval test for the grade of steel in question.

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.

4. Dimensional tolerances

Unless otherwise stipulated in the order specification, plates are to be supplied in accordance with A.6., Class B as indicated in Table 1.1 (permitted thickness tolerance −0.3 mm). For all other products the values stated in the relevant standards shall apply.

5. General condition of products

The provisions of A.5. shall apply. Surface defects may generally only be repaired by grinding.

In doing so, the relevant minus tolerance shall not be exceeded at any point.

6. Requirements applicable to material properties

6.1 Chemical composition

6.1.1 The limit values for the chemical composition stated in the standards or in the specifications approved by GL shall apply.

6.1.2 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 $C \leq 0.03\%$.

6.2 Mechanical properties

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

6.3 Impact energy

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

7. Testing and scope of tests

The following tests shall be performed:

7.1 Testing of chemical composition

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

7.2 Testing of resistance to intercrystalline corrosion

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

- stabilized steels and steels with a carbon content $\leq 0.03\%$: sensitized (annealed at 700 °C for 30 minutes and quenched in water)

- all other steels: in the condition in which they are supplied

7.3 Tensile test

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

- plates > 20 mm thick: the rolled length

- plates $\leq 20$ 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.

- strip and plates taken therefrom: one specimen each from the beginning of the coil.

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

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

7.4 Notched bar impact test

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

- flat products with a thickness > 20 mm

- rods and bars with diameters or thicknesses > 50 mm

- flat products made of austenitic-ferritic steels with thicknesses $\geq 6$ mm

7.4.2 If the products are used for operating temperatures below $-10 \, ^\circ\mathrm{C}$, the impact test temperature shall be agreed with GL.
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.

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.

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 GL from case to case.

H. Clad Plates

1. Scope
These Rules 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.

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 8. and the required properties of the base material are preserved after cladding.

3. Suitable materials
Steels conforming to B., C. and E. shall be used as base materials. The stainless steels specified in G. and other materials approved by GL for the purpose may be used as cladding materials.

4. Method of manufacture and condition of supply
4.1 Cladding may be performed by rolling or explosive cladding or by a combination of the two methods.

4.2 Plates clad with austenitic materials shall normally be supplied in the as 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 GL.

5. Dimensions and tolerances
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 Table 1.21.

<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</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>

5.2 The tolerances for the base materials shall be governed by the requirements for the respective steel grades and product shapes.

6. Surface finish
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 A.5.

6.2 On the cladding material, the total surface area of all defects, with the exception of shallow defects as per 7.1, shall not exceed 20 % of the surface area of the cladding.

7. Repair of defects
7.1 Shallow defects in the cladding material, e.g. impressions, grooves and scratches, shall be removed by grinding within the tolerance specified in 5.

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.

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 subject to the following Rules:

7.3.1 All welds shall be made by qualified welders using a technique approved by GL.

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

7.3.3 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.

7.3.4 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.

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

8. Requirements applicable to the material

The clad steels shall satisfy the following requirements.

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 of at least 12% in a tensile test after the base metal has been removed by machining.

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.

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 dished ends, or while in use, e.g. in tubesheets, it may be necessary for the purchaser to impose more stringent requirements.

8.4 Mechanical properties

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

\[
\sigma_{pl} = \frac{\sigma_G \cdot S_G + \sigma_A \cdot S_A}{S_{pl}}
\]

\(\sigma = \) specified minimum value of tensile strength or yield strength or 0,2% proof stress [N/mm²]

\(S = \) nominal thickness [mm]

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.

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.

8.6 Impact energy

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

8.7 Resistance to intercrystalline corrosion

For austenitic or austenitic-ferritic cladding materials, the requirements applicable to the relevant grade of steel shall be satisfied.

9. Testing

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

9.1 Test of chemical composition

The manufacturer shall determine the chemical composition of each heat of base and cladding material and shall issue a relevant certificate.
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 shall be subjected to tensile stress.

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.

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 1.2.

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 1.3. Where the product thickness exceeds 80 mm, the specimens may be reduced to 80 mm by machining the base material side.

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.

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.

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.

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.

1. Steels with Through Thickness Properties

1. Scope

These Rules are supplementary to all Rules applying to plates, strips, wide flats and shapes made of fine-grained structural steels for which enhanced deformation properties in the direction of product thickness are required. They apply to products with thicknesses greater than or equal 15 mm. For smaller thicknesses these Rules may be applied at discretion of GL.
2. Requirements

2.1 Reduction in area

The average value of the reduction in area measured on 3 tensile test specimens (Z specimens) lying in the direction of the product thickness shall be at least 25 % for the grade Z25, including one test result which may be lower than 25 % but not less than 20 %. For the grade Z35 the reduction in area has to be at least 35 %, including one test result which may be lower than 35 % but not less than 25 %.

2.2 Freedom from defects

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

In addition, when subjected to ultrasonic testing flat products shall satisfy the Class 2 test requirements laid down in Stahl-Eisen-Lieferbedingung 072 (Iron and Steel Supply Conditions 072) or Class S2/E3 test requirements according to EN 10160. For sections Class 1.2/23 test requirements according to EN 10306 apply.

Note

Iron and Steel Supply Conditions 072 specify 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

2.3 Chemical composition

In addition to the requirements of the respective steel specification the sulphur content determined by heat analysis may not exceed 0,008 %.

3. Testing and scope of tests

The following tests shall be performed in addition to the tests prescribed for the product in question.

3.1 Tensile testing of Z specimens

3.1.1 The test shall be performed on at least 3 tensile test specimens taken from each unit testing quantity with their longitudinal axes perpendicular to the surface of the product (Z specimens). The unit testing quantities shall be taken from Table 1.22 and consist of products of the same heat, same thickness and same heat treatment.

<table>
<thead>
<tr>
<th>Table 1.22 Unit testing quantities</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Product</strong></td>
</tr>
<tr>
<td>Plates</td>
</tr>
<tr>
<td>Wide flats up to and including 25 mm thickness</td>
</tr>
<tr>
<td>Wide flats exceeding 25 mm thickness</td>
</tr>
</tbody>
</table>

3.1.2 In the case of flat products, the specimens shall be taken from one end in the longitudinal axis of the product, see Fig. 1.4. In both cases the centre of the product shall fall within the test length. In the case of sections, the specimens shall be taken from one end of the product at a distance of 1/3 of the flange width from the outside edge of the flange, see Fig. 1.4.

3.1.3 Tensile test with extension pieces

Steel extension pieces, e.g. studs, shall be welded to the two surfaces of the sample which lie perpendicular to the thickness direction of the steel product; see Fig. 1.5. Examples of permissible welding processes are stud or friction welding.

![Fig. 1.4 Sampling of Z specimens](image1)

![Fig. 1.5 Specimen blank, consisting of test piece and welded-on extension pieces](image2)
Before welding on the extension pieces, the abutting surfaces of the sample and the extension pieces shall be carefully cleaned to remove rust, scale and grease. The heat affected zone due to welding shall penetrate into the sample to the minimum possible depth.

The tensile test specimen shall be machined out of the specimen blank in accordance with Fig. 1.6.

The diameter $d_o$ of the tensile test specimen shall be as follows:

- $d_o = 6$ or 10 mm in the case of product thicknesses $s$ of $\leq 25$ mm,
- $d_o = 10$ mm in the case of product thicknesses $s$ of $> 25$ mm.

The test length $L_c$ of the tensile test specimen shall be at least $1.5 \cdot d_o$ and shall not exceed 150 mm.

**Note:**
For further details see EN 10164.

### 3.1.4 Tensile test specimen without extension pieces

If the tensile test specimen is machined out of the test section, in the case of product thicknesses $s$ of $\leq 150$ mm its total length $L_t$ is generally equal to the product thickness. The shape and dimensions of the tensile test specimen are shown in Fig. 1.7. The diameter $d_o$ of the tensile test specimen is 6 mm in the case of product thicknesses $s$ of $\leq 40$ mm and 10 mm in the case of product thicknesses $s$ of $> 40$ mm.

The test length $L_c$ of the tensile test specimen shall be at least $1.5 \cdot d_o$ and shall not exceed 150 mm.

### 3.1.5 If the required average value is not achieved under test or if one individual value is less than allowed, 3 further Z specimens shall be taken immediately next to the site of the first specimen and subjected to the tensile test. On the basis of the results obtained, a new average value for all 6 specimens shall be calculated. The test shall be regarded as successful if the new average value meets the requirements and no individual value yielded by the additional 3 specimens is below the required average value.

### 3.1.6 Ultrasonic testing

The manufacturer shall perform an ultrasonic test on the surfaces and edges of each product using a 50 mm grid for the testing of the surfaces. If indications are observed which exceed the permissible limits for flaws stated in 2.2, the decision of GL shall be obtained as to the serviceability of the product.

### 4. Marking

Products which meet these requirements shall be identified by adding the symbol Z25 and Z35 respectively to the designation of the material, e.g. Grade GL-E hull structural steel is given the designation GL-E Z25.

### J. Steel-Aluminium Welding Joints

#### 1. Scope

These requirements apply to explosion-bonded steel-aluminium joints for the connection of steel structures with aluminium structures.

#### 2. Manufacturing technique

The manufacturer shall demonstrate by means of an initial test of product suitability that the clad products satisfy the requirements stated in 8. and the required properties of the base material are preserved after cladding.

#### 3. Suitable materials

As base materials steels according to B., C. and E. are to be used. As cladding materials the aluminium alloys according to Chapter 3 – Non-Ferrous Metals, Section 1, A. are to be used. As cladding materials the aluminium alloys according to Chapter 3 – Non-Ferrous Metals, Section 1, A. are to be used.
Table 1.23 Permissible tolerances

<table>
<thead>
<tr>
<th>Product</th>
<th>Tolerance [mm]</th>
<th>lower</th>
<th>upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness</td>
<td>all</td>
<td>– 2</td>
<td>+ 1</td>
</tr>
<tr>
<td>Length</td>
<td>all</td>
<td>0</td>
<td>+ 10</td>
</tr>
<tr>
<td>Width</td>
<td>plates</td>
<td>0</td>
<td>+ 10</td>
</tr>
<tr>
<td>Width</td>
<td>rods ¹</td>
<td>&lt; 25 mm width</td>
<td>– 1,5</td>
</tr>
<tr>
<td>Width</td>
<td>rods ¹</td>
<td>&gt; 25 mm width</td>
<td>– 2</td>
</tr>
<tr>
<td>Diameter</td>
<td>circular blanks</td>
<td>&lt; 500 mm diameter</td>
<td>0</td>
</tr>
<tr>
<td>Diameter</td>
<td>circular blanks</td>
<td>&gt; 500 mm diameter</td>
<td>0</td>
</tr>
<tr>
<td>Rectangularity</td>
<td>plates (difference between the diagonals)</td>
<td>max. 10</td>
<td></td>
</tr>
<tr>
<td>Rectangularity</td>
<td>rods ¹ (perpendicular projection of a longitudinal edge or a transverse edge)</td>
<td>max. 1,5</td>
<td></td>
</tr>
<tr>
<td>Evenness (aluminium side)</td>
<td>≥ 1 m length</td>
<td>max. 5</td>
<td></td>
</tr>
<tr>
<td>Evenness (aluminium side)</td>
<td>&lt; 1 m length</td>
<td>max. 0,5 % of length</td>
<td></td>
</tr>
<tr>
<td>Straightness of longitudinal edges</td>
<td>rods ¹</td>
<td>max. 5</td>
<td></td>
</tr>
</tbody>
</table>

¹ Rods are contrary to plates flat products of a width ≤ 300 mm.

5.2 The tolerances for the base materials shall be governed by the requirements for the respective steel grades and product shapes.

6. Surface finish

The surface finish shall meet the respective requirements for the base materials.

7. Requirements applicable to the material

7.1 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.

7.2 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.

7.3 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.

7.4 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.

8. Testing

8.1 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 I. One specimen of each end is to be heated to 300 °C before testing.

8.2 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 recognized standard, e.g. DIN 50162. The dimensions of
One specimen of each end is to be heated to 300 °C before testing.

8.3 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 Fig. 1.3. Where the product thickness exceeds 80 mm, the specimens may be reduced to 80 mm by machining the base material side.

8.4 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.

8.5 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.

9. Marking
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.
Section 2

Steel Pipes

A. General Rules

1. Scope

1.1 The general Rules contained in A. to be observed in the manufacture of seamless and welded steel pipes apply in conjunction with the following individual requirements B. to E.

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

As regards steel pipes for structural applications, Section 1, B., C., D. and G. shall apply respectively.

Pipes which are individually manufactured and welded, such as masts, crane posts, pressure vessel shells etc. shall also comply with Part 3 –Welding.

1.2 Pipes conforming to national or international standards or to manufacturers’ 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.

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 W denoting high-temperature steel or T 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.

2. Requirements to be met by pipe manufacturers

2.1 Pipe manufacturers wishing to supply pipes in accordance with these Rules shall be approved by GL. Such approval is conditional upon their fulfilling the requirements stated in Chapter 1 – Principles and Test Procedures, Section 1, C. and demonstrating this to GL prior to the commencement of supplies.

2.2 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 GL on a case to case basis.

GL 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. Manufacturing process, condition of supply

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

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

3.3 Welded ferritic steel pipes may be manufactured by electrical induction or resistance pressure welding or by fusion welding of strip or 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 shall ensure a weld quality factor of $v = 1.0$.

3.4 All pipes shall be supplied in a properly heat-treated condition over their whole length according to the requirements of B. to E.

4. General characteristics of pipes

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.

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.
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.

4.4 On fusion-welded pipes, the inside and outside weld reinforcement shall not exceed a value of $1 + 0.1 \times \text{seam width (mm)}$.

5. Dimensions, dimensional and geometrical tolerances

The dimensions and the dimensional and geometrical tolerances of the pipes shall 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 shall 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.

6. Integrity of pipes

All pipes shall be leak proof at the specified test pressures.

7. General requirements applicable to the material

7.1 Chemical composition

The chemical composition of the pipe material (heat analysis) shall conform to the Tables contained in this Section or, where applicable, in the relevant standards.

7.2 Weldability

Pipes in accordance with these Rules shall be weldable by established workshop methods. Wherever necessary, appropriate measures to safeguard quality shall be taken, e.g. preheating and/or subsequent heat treatments, see Part 3 – Welding.

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 shall conform to the Tables contained in this Section or, where applicable, in the relevant standards. Irrespective of the provisions contained in the standards, pipes made of steels tough at sub-zero temperatures shall at least meet the values specified in D. for the impact energy at the prescribed test temperature.

7.4 Technological properties

Pipes shall meet the requirements for the ring tests specified in 8.5.

8. General instructions for testing

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.

8.2 Test of mechanical properties

8.2.1 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 $\leq 500$ 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.

8.2.2 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.

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 the case of pipes to recognized standards, the high-temperature mechanical properties of which are regarded as proven.

8.4 Notch 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 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 specimens 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.
### Table 2.1 Types of ring test

<table>
<thead>
<tr>
<th>Outside diameter of pipe [mm]</th>
<th>Nominal wall thickness t [mm]</th>
<th>t &lt; 2</th>
<th>2 ≤ t ≤ 16</th>
<th>16 &lt; t ≤ 40</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 21.3</td>
<td>ring flattening test 1,3</td>
<td></td>
<td>ring flattening test 1,3</td>
<td>—</td>
</tr>
<tr>
<td>&gt; 21.3 ≤ 146</td>
<td>ring flattening test 1,3</td>
<td></td>
<td>ring expanding test 1,3</td>
<td>ring flattening</td>
</tr>
<tr>
<td>&gt; 146</td>
<td></td>
<td></td>
<td>ring tensile test 2</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.

### 8.5 Technological tests

#### 8.5.1
The pipes selected for testing shall be subjected to one of the ring tests specified in Table 2.1 provided that the wall thickness of the pipe does not exceed 40 mm. For the performance of the test, see Chapter 1 – Principles and Test Procedures, Section 2, F.

The number of test specimens depends on the application of the pipes and is stipulated in the requirements of B. to E.

#### 8.5.2
In the ring flattening test, the prescribed distance between the plates H is calculated by applying the following formula:

\[
H = \frac{(1 + C) a}{C + a/D}
\]

H = distance between the platens [mm]

a = nominal wall thickness [mm]

D = outside diameter of pipe [mm]

C = constant determined by the steel grade (see the provisions relating to technological tests according to B. to E.).

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

#### 8.5.3
In the ring expanding test, the change in the diameter of the specimen expanded to the point of fracture shall at least equal the percentages shown in Table 2.2, depending on the material.

#### 8.5.4
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.

#### 8.5.5
In the drift expanding test applied to 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 2.2 Diameter change in the ring expanding test

<table>
<thead>
<tr>
<th>Pipe material</th>
<th>Minimum expansion [%] for ID/OD ratios of</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>≥ 0.9 &amp; 0.8 ≤ 0.9 &amp; 0.7 ≤ 0.6 ≤ 0.5 ≤ 0.5</td>
</tr>
<tr>
<td>C- and CMn-steels</td>
<td>8 10 12 20 25 30</td>
</tr>
<tr>
<td>Mo-, CrMo- and Ni-steels</td>
<td>6 8 10 15 30 30</td>
</tr>
<tr>
<td>Austenitic steels</td>
<td>30</td>
</tr>
</tbody>
</table>

#### 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.

#### 8.7 Non-destructive tests

#### 8.7.1
The pipes shall be subjected to non-destructive tests of the extent specified in B. to E. Where tests of greater scope are prescribed in the order or in the relevant standards or specifications, these requirements shall be complied with.

#### 8.7.2
Other test specifications require special approval by GL.

#### 8.7.3
The test equipment used for the continuous inspection of pipes shall be regularly calibrated using
pipes with artificial defects. The efficiency of the equipment shall be demonstrated to the Surveyor.

8.8 Tightness test

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

8.8.2 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 \( \leq 25 \) 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.

8.8.3 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 shall 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 GL.

8.9 Retests 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 in Chapter 1 – Principles and Test Procedures, Section 2, H. may be applied.

9. Marking of pipes

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

– short designation or material number of the steel grade
– manufacturer's mark
– additionally, the heat number or a heat code

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 coloured imprint, electrical engraving or rubber stamps.

10. Certificates

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

– purchaser and order number
– newbuilding and project number respectively, where known
– quantity, dimensions and weight of delivered pipes
– strength category or pipe grade
– steel grade or material specification
– method of pipe manufacture
– heat numbers
– chemical composition of the heat
– condition in which supplied or heat treatment applied
– marking
– results of material testing

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.

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.

10.4 Where, in exceptional cases, pipes are tested on the premises of a stockist, the latter shall keep a clear record of the origin of the pipes, which shall bear the marking specified in 9. and, in the case of boiler tubes, the stamp of the works inspector as well. In addition, the Surveyor shall be furnished with a certificate issued by the pipe manufacturer and containing the following details:

– number, dimensions and weight of the pipes supplied
– steel grade or material specification
– method of pipe manufacture and condition in which supplied or method of heat treatment
– heat numbers and analyses
– confirmation that the tightness test and, where specified, the non-destructive test and test of resistance to intercrystalline corrosion have been carried out
– marking
B. Pipes for General Purpose

1. Scope

1.1 These Rules are applicable to seamless and welded pipes for use in pressure vessels, equipment, pipelines and pressure cylinders. Pipes conforming to these rules are intended for use at normal ambient temperatures.

In general for these applications pipe grades according to Table 2.3 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.

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

2. Heat treatment

The pipes shall be in a 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. Requirements applicable to the material

3.1 Chemical composition

The chemical composition of the pipe steels shall conform to the data given in Table 2.4 or, where appropriate, in the relevant standards or specifications.

3.2 Mechanical properties

The required values of tensile strength, yield strength and elongation specified in Table 2.5 or, where appropriate, in the relevant standards or specifications shall be met under test at room temperature.

3.3 Technological properties

When subjected to the ring tests, the pipes shall display a capacity for deformation which meets the requirements specified in A.8.5.

3.4 Impact energy

The pipes shall at least satisfy the impact energy requirements specified in Table 2.5.

4. Testing and scope of tests

The following tests are to be performed:

4.1 Test of chemical composition

The manufacturer shall determine the chemical composition of each heat in accordance with A.8.1.

---

Table 2.3 Standardized pipe grades

<table>
<thead>
<tr>
<th>Strength category or pipe grade to Table 2.5</th>
<th>Corresponding pipe grade to EN 10216-1 1 or EN 10217-1 2</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>GL–R 360</td>
<td>P235TR2</td>
<td>E235+N</td>
<td>E235+N</td>
<td>E235+N</td>
</tr>
<tr>
<td>GL–R 410</td>
<td>P265TR2</td>
<td>P275NL1</td>
<td>E275+N</td>
<td>E275+N</td>
</tr>
<tr>
<td>GL–R 490</td>
<td>P355N</td>
<td>E355+N</td>
<td>E355+N</td>
<td>E355+N</td>
</tr>
</tbody>
</table>

1 seamless
2 welded

---

Table 2.4 Chemical composition of unalloyed steel pipes

<table>
<thead>
<tr>
<th>Strength category or pipe grade</th>
<th>C max.</th>
<th>Si max.</th>
<th>Mn max.</th>
<th>P max.</th>
<th>S max.</th>
<th>Al tot.</th>
</tr>
</thead>
<tbody>
<tr>
<td>GL–R 360</td>
<td>0,17</td>
<td>0,35</td>
<td>1,20</td>
<td>0,025</td>
<td>0,020</td>
<td>≥ 0,020</td>
</tr>
<tr>
<td>GL–R 410</td>
<td>0,21</td>
<td>0,35</td>
<td>1,40</td>
<td>0,025</td>
<td>0,020</td>
<td></td>
</tr>
<tr>
<td>GL–R 490</td>
<td>0,22</td>
<td>0,55</td>
<td>1,60</td>
<td>0,025</td>
<td>0,020</td>
<td></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 2.5 Mechanical and technological properties of unalloyed steel pipes

<table>
<thead>
<tr>
<th>Strength category or pipe grade</th>
<th>Tensile strength $R_m$ [N/mm²]</th>
<th>Yield strength $R_{el}$ [N/mm²]</th>
<th>Elongation A [%] min.</th>
<th>Impact energy KV $^1$ at 0 °C [J] min.</th>
</tr>
</thead>
<tbody>
<tr>
<td>GL–R 360</td>
<td>360 – 500</td>
<td>235</td>
<td>25</td>
<td>23</td>
</tr>
<tr>
<td>GL–R 410</td>
<td>410 – 570</td>
<td>255</td>
<td>21</td>
<td>19</td>
</tr>
<tr>
<td>GL–R 490</td>
<td>490 – 650</td>
<td>310</td>
<td>19</td>
<td>17</td>
</tr>
</tbody>
</table>

$^1$ For pipes with wall thickness > 10 mm.

4.2 Tensile test

Specimens of the sample pipes selected in accordance with A.8.2 shall be subjected to the tensile test.

4.3 Technological test

4.3.1 Pipes with longitudinal weld seams and seamless pipes of grade GL–R490 are to be examined according to one of the ring tests specified in A.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 3 – Welding, Chapter 2 – Design, Fabrication and Inspection of Welded Joints, Section 5, D. may be carried out, applying a bending mandrel diameter of 3 t.

4.3.2 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 A.8.5.2:

Pipes of strength category 360: $C = 0,09$

Other pipe grades: $C = 0,07$

4.4 Notched bar impact test

On the pipes selected in accordance with A.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.

4.5 Test of surface finish and dimensions

The tests specified in A.8.6 are to be performed.

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.

4.6.1 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.

4.6.2 Non-destructive testing of pressure-welded pipes

GL-R360 and GL-R410:

The weld seam of pipe grades GL-R360 and GL-R410 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.

GL-R490:

Pipes of grade GL-R490 shall be subjected to an ultrasonic 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 in accordance with EN 10246-7, acceptance category U2, subcategory C or shall be cut off.
4.6.3 Non-destructive testing of fusion-welded pipes

GL-R360 and GL-R410:
The weld seam of SAW pipes of grades GL-R360 and GL-R410 shall be tested either according to EN 10246-9, acceptance category U3 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 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.

GL-R490:
The weld seam of pipes of grade GL-R490 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.

4.7 Tightness test

All pipes shall be tightness tested by the manufacturer in accordance with A.8.8

C. High-Temperature Steel Pipes

1. Scope

These Rules are applicable to seamless and welded pipes made of carbon steel, carbon-manganese steel, Mo steel and Cr Mo steel and intended for steam boilers, pressure vessels, 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 2.6.

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>
<thead>
<tr>
<th>Strength category or pipe grade</th>
<th>Corresponding pipe grade to EN 10216-2</th>
<th>Corresponding pipe grade to EN 10217-2</th>
<th>ISO 9329-2</th>
<th>ISO 9330-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>GL–R 360 W</td>
<td>P235GH</td>
<td>P235GH</td>
<td>PH 23</td>
<td>PH 23</td>
</tr>
<tr>
<td>GL–R 410 W</td>
<td>P265GH</td>
<td>P265GH</td>
<td>PH 26</td>
<td>PH 26</td>
</tr>
<tr>
<td>GL–R 460 W</td>
<td></td>
<td></td>
<td>PH 29</td>
<td></td>
</tr>
<tr>
<td>GL–R 510 W</td>
<td>20MnNb6</td>
<td></td>
<td>PH 35</td>
<td>PH 35</td>
</tr>
<tr>
<td>0.3Mo</td>
<td>16Mo3</td>
<td>16Mo3</td>
<td>16Mo3</td>
<td>16Mo3</td>
</tr>
<tr>
<td>1Cr05Mo</td>
<td>13CrMo4-5</td>
<td></td>
<td>13CrMo4-5</td>
<td>13CrMo4-5</td>
</tr>
<tr>
<td>2.25Cr1Mo</td>
<td>10CrMo9-10</td>
<td></td>
<td>11CrMo9-10</td>
<td>11CrMo9-10</td>
</tr>
</tbody>
</table>
3. Requirements applicable to the material

3.1 Chemical composition

The chemical composition shall conform to the data given in Table 2.7 or, where appropriate, the relevant standards or specifications.

3.2 Mechanical properties

The required values of tensile strength, yield strength and elongation specified in Table 2.8 or, where appropriate, in the relevant standards or specifications shall be met under test at room temperature.

### Table 2.7 Chemical compositions of high-temperature steel pipes

<table>
<thead>
<tr>
<th>Strength category or pipe grade</th>
<th>Chemical composition [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>---</td>
</tr>
<tr>
<td>GL–R 360 W</td>
<td>≤ 0,16</td>
</tr>
<tr>
<td>GL–R 410 W</td>
<td>≤ 0,20</td>
</tr>
<tr>
<td>GL–R 460 W</td>
<td>≤ 0,22</td>
</tr>
<tr>
<td>GL–R 510 W</td>
<td>≤ 0,23</td>
</tr>
<tr>
<td>0,3Mo</td>
<td>0,12 – 0,20</td>
</tr>
<tr>
<td>1Cr0,5Mo</td>
<td>0,10 – 0,17</td>
</tr>
<tr>
<td>2,25Cr1Mo</td>
<td>0,08 – 0,14</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. If titanium is used, the manufacturer shall demonstrate that

\[
\left(\frac{\text{Al} + \frac{\text{Ti}}{2}}{2}\right) \geq 0,20\%.
\]

### Table 2.8 Mechanical and technological properties of pipes made of high-temperature steel at room temperature

<table>
<thead>
<tr>
<th>Strength category or pipe grade</th>
<th>Tensile strength R m [N/mm²]</th>
<th>Yield strength R eH [N/mm²] min.</th>
<th>Elongation (\left(\text{at } L_0 = 5,65 \cdot \sqrt{\sigma_0}\right)) A [%] min.</th>
<th>Impact energy KV [J] min.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GL–R 360 W</td>
<td>360 – 500</td>
<td>235</td>
<td>25</td>
<td>23</td>
</tr>
<tr>
<td>GL–R 410 W</td>
<td>410 – 570</td>
<td>255</td>
<td>21</td>
<td>19</td>
</tr>
<tr>
<td>GL–R 460 W</td>
<td>460 – 580</td>
<td>270</td>
<td>23</td>
<td>21</td>
</tr>
<tr>
<td>GL–R 510 W</td>
<td>510 – 650</td>
<td>355</td>
<td>19</td>
<td>17</td>
</tr>
<tr>
<td>0,3Mo</td>
<td>450 – 600</td>
<td>270</td>
<td>22</td>
<td>20</td>
</tr>
<tr>
<td>1Cr0,5Mo</td>
<td>440 – 590</td>
<td>290</td>
<td>22</td>
<td>20</td>
</tr>
<tr>
<td>2,25Cr1Mo</td>
<td>480 – 630</td>
<td>280</td>
<td>20</td>
<td>18</td>
</tr>
</tbody>
</table>
Table 2.9 Minimum values of yield strength $R_{p0,2}$ at elevated temperatures

<table>
<thead>
<tr>
<th>Steel grade</th>
<th>Minimum yield strength $R_{p0,2}$ [N/mm²] at a temperature [°C] of</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100</td>
</tr>
<tr>
<td>GL-R360W</td>
<td>1.0345</td>
</tr>
<tr>
<td>GL-R410W</td>
<td>1.0425</td>
</tr>
<tr>
<td>GL-R460W</td>
<td>–</td>
</tr>
<tr>
<td>GL-R510W</td>
<td>1.0471</td>
</tr>
<tr>
<td>0,3Mo</td>
<td>1.5415</td>
</tr>
<tr>
<td>1Cr0,5Mo</td>
<td>1.7335</td>
</tr>
<tr>
<td>2,25Cr1Mo</td>
<td>1.7380</td>
</tr>
</tbody>
</table>

3.6 Dimensional tolerances for collectors

Seamless collector pipes and collectors with inside diameters ≤ 600 mm are subject to the following dimensional tolerances:
- 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
- 0 % to + 25 % on the wall thickness
- the lateral curvature of square pipes shall be as shown in Fig. 2.1

Fig. 2.1 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:

$$r \geq \frac{s}{3} \geq 8 \text{ mm}$$

4. Testing and scope of tests

The following tests are to be performed:

4.1 Test of chemical composition

The manufacturer shall determine the chemical composition of each heat in accordance with A.8.1.

4.2 Tensile test

Specimens of the sample pipes selected in accordance with A.8.2 shall be subjected to the tensile test.

4.3 Technological test

4.3.1 The pipes, namely two pipes of one test batch, shall undergo one of the ring tests specified in A., Table 2.1 as follows:

For fusion-welded pipes a weld seam bend test in accordance with Part 3 – Welding, Chapter 2 – Design, Fabrication and Inspection of Welded Joints, Section 5, D. is to be carried out, applying a bending mandrel diameter of 3 t.

4.3.2 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 A.8.5.2:

Pipes of strength categories 360: $C = 0,09$
Other pipe grades: $C = 0,07$

4.4 Notched bar impact test

The test is to be carried out at room temperature on the sample pipes selected in accordance with A.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.

4.5 High-temperature tensile test

Where stipulated in A.8.3 or in the purchase order, the 0,2 % proof stress shall be determined by a high-temperature tensile test.

4.6 Test of surface finish and dimensions

The tests specified in A.8.6 are to be performed.
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, cf. A.8.7.

4.7.1 Non-destructive testing of seamless and pressure-welded pipes
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 or shall be examined by means of radiographic testing according to the procedures specified above or shall be cut off.

4.7.2 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.

4.8 Tightness test
All pipes shall be tightness tested by the manufacturer in accordance with A.8.8.

D. Pipes Tough at Sub-Zero Temperatures
1. Scope
These Rules 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 process equipment of gas tankers with design temperatures below 0 °C.

For these applications, suitable standardized steel grades may also be used provided that they meet the requirements stated in these Rules, including especially those relating to impact energy at sub-zero temperatures. For the appropriate pipe grades see Table 2.10.

Table 2.10 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>EN 10216-4 1 or EN 10217-4 2</th>
<th>EN 10216-3 1 or EN 10217-3 2</th>
<th>DIN 17458 1 or DIN 17457 2</th>
<th>ISO 9329-3 1 or ISO 9330-3 2</th>
<th>ISO 9329-4 1 or ISO 9330-4 2</th>
<th>ASTM A312M 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>GL–R 360 T</td>
<td>P215NL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>PL25</td>
</tr>
<tr>
<td>GL–R 390 T</td>
<td>P265NL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GL–R 490 T</td>
<td>P355NL1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GL–R 0.5 Ni</td>
<td>13MnNi6-3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GL–R 3.5 Ni</td>
<td>12Ni14</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GL–R 9 Ni</td>
<td>X10Ni9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X10NiMn9</td>
</tr>
<tr>
<td>1.4306</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X2CrNi19-11</td>
</tr>
<tr>
<td>1.4404</td>
<td>X2CrNiMo17-13-2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X2CrNiMo17-12</td>
</tr>
<tr>
<td>1.4541</td>
<td>X6CrNiTi18-10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X6CrNiTi18-10</td>
</tr>
<tr>
<td>1.4550</td>
<td>X6CrNiNb18-10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X6CrNiNb18-10</td>
</tr>
<tr>
<td>1.4571</td>
<td>X6CrNiMoTi17-12-2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X6CrNiMoTi17-12</td>
</tr>
</tbody>
</table>

1 Seamless pipes
2 Welded pipes
3 The notched bar impact energies according to Table 2.14 are to be demonstrated.
Note: 
In the case of pipes and connections which are intended for liquefied ammonia at design temperatures above 0 °C, the boundary values applicable to chemical composition and strength properties as stated in Section 1, F.8.1.1 or 8.2.2 are to be maintained.

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

1.3 If the pipes are used for cargo and process equipment on gas tankers, the minimum design temperatures specified in Table 2.11 are applicable.

Table 2.11 Minimum design temperatures

<table>
<thead>
<tr>
<th>Strength category or pipe grade</th>
<th>Minimum design temperature [° C]</th>
</tr>
</thead>
<tbody>
<tr>
<td>GL-R 360 T</td>
<td>– 55</td>
</tr>
<tr>
<td>GL-R 390 T</td>
<td>– 55</td>
</tr>
<tr>
<td>GL-R 490 T</td>
<td>– 55</td>
</tr>
<tr>
<td>GL-R 0.5 Ni</td>
<td>– 55</td>
</tr>
<tr>
<td>GL-R 3.5 Ni</td>
<td>– 90</td>
</tr>
<tr>
<td>GL-R 9 Ni</td>
<td>– 165</td>
</tr>
<tr>
<td>Austenitic pipes</td>
<td>– 165</td>
</tr>
</tbody>
</table>

1 Only applicable if the required impact energy has been demonstrated at the time of the approval tests.

2. Heat treatment

Depending on the material, the pipes shall be supplied in one of the heat treated conditions specified in Table 2.12.

Table 2.12 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>GL-R 360 T</td>
<td>Normalized or quenched and tempered</td>
</tr>
<tr>
<td>GL-R 390 T</td>
<td>Normalized or quenched and tempered</td>
</tr>
<tr>
<td>GL-R 490 T</td>
<td>Normalized or quenched and tempered</td>
</tr>
<tr>
<td>GL-R 0.5 Ni</td>
<td>Normalized</td>
</tr>
<tr>
<td>GL-R 3.5 Ni</td>
<td>Normalized and tempered or quenched and tempered</td>
</tr>
<tr>
<td>GL-R 9 Ni</td>
<td>Double normalized and tempered quenched and tempered</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>

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.

3. Requirements applicable to the material

3.1 Chemical composition

The chemical composition of the pipe steels shall conform to the data in Table 2.13 or, where appropriate, to the other relevant standards or specifications.

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 ≤ 0.03 %, see Table 2.13.

3.3 Mechanical properties

The values for tensile strength, yield strength or 0.2 % or 1 % proof stress, and elongation specified in Table 2.14 or, where appropriate, in the other relevant standards or specifications shall be satisfied under test at room temperature.

3.4 Technological properties

In the ring tests, the pipes shall exhibit a capacity for deformation which satisfies the requirements stated in A.8.5.

3.5 Low-temperature impact energy

The required impact energy values specified in Table 2.14 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 standards or specifications, irrespective of the values specified therein.

4. Testing and scope of tests

The following tests are to be performed:
Table 2.13  Chemical composition of steel pipes tough at sub-zero temperatures

<table>
<thead>
<tr>
<th>Strength category or pipe grade</th>
<th>C&lt;sub&gt;max.&lt;/sub&gt;</th>
<th>Si</th>
<th>Mn</th>
<th>P&lt;sub&gt;max.&lt;/sub&gt;</th>
<th>S&lt;sub&gt;max.&lt;/sub&gt;</th>
<th>Cr</th>
<th>Ni</th>
<th>Mo</th>
<th>Other elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>GL–R 360 T</td>
<td>≤ 0,16</td>
<td>≤ 0,40</td>
<td>0,40 – 1,20</td>
<td>0,025</td>
<td>≤ 0,30</td>
<td>≤ 0,3</td>
<td>≤ 0,08</td>
<td>Al&lt;sub&gt;net&lt;/sub&gt; ≥ 0,015&lt;sup&gt;1,2&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>GL–R 390 T</td>
<td>≤ 0,16</td>
<td>≤ 0,40</td>
<td>0,50 – 1,50</td>
<td>0,020</td>
<td>≤ 0,15</td>
<td>0,30 – 0,85</td>
<td>≤ 0,10</td>
<td>Al&lt;sub&gt;net&lt;/sub&gt; ≥ 0,015&lt;sup&gt;1,3&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>GL–R 0,5 Ni</td>
<td>≤ 0,40</td>
<td>≤ 0,50</td>
<td>0,85 – 1,70</td>
<td>0,025</td>
<td>0,020</td>
<td>3,25 – 3,75</td>
<td>0,025</td>
<td>V ≤ 0,05</td>
<td></td>
</tr>
<tr>
<td>GL–R 3,5 Ni</td>
<td>≤ 0,15</td>
<td>≤ 0,35</td>
<td>0,30 – 0,85</td>
<td>≤ 0,30</td>
<td>0,010</td>
<td>8,50 – 9,50</td>
<td>≤ 0,10</td>
<td>V ≤ 0,05</td>
<td></td>
</tr>
<tr>
<td>GL–R 9 Ni</td>
<td>≤ 0,13</td>
<td>≤ 1,00</td>
<td>≤ 2,00</td>
<td>0,040</td>
<td>0,030</td>
<td>17,0 – 19,0</td>
<td>2,0 – 2,5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.4306</td>
<td>0,030</td>
<td>≤ 1,00</td>
<td>≤ 2,00</td>
<td>0,040</td>
<td>0,030</td>
<td>17,0 – 19,0</td>
<td>2,0 – 2,5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.4404</td>
<td>0,030</td>
<td>≤ 1,00</td>
<td>≤ 2,00</td>
<td>0,040</td>
<td>0,030</td>
<td>17,0 – 19,0</td>
<td>2,0 – 2,5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.4541</td>
<td>0,08</td>
<td>≤ 1,00</td>
<td>≤ 2,00</td>
<td>0,040</td>
<td>0,030</td>
<td>17,0 – 19,0</td>
<td>2,0 – 2,5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.4550</td>
<td>0,08</td>
<td>≤ 1,00</td>
<td>≤ 2,00</td>
<td>0,040</td>
<td>0,030</td>
<td>17,0 – 19,0</td>
<td>2,0 – 2,5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.4571</td>
<td>0,08</td>
<td>≤ 1,00</td>
<td>≤ 2,00</td>
<td>0,040</td>
<td>0,030</td>
<td>17,0 – 19,0</td>
<td>2,0 – 2,5</td>
<td></td>
<td></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 2.14 Mechanical and technological properties of steel pipes tough at sub-zero temperatures

<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 or proof stress R&lt;sub&gt;el&lt;/sub&gt; or R&lt;sub&gt;p0,2&lt;/sub&gt;, R&lt;sub&gt;pL0&lt;/sub&gt;</th>
<th>Elongation A [%] min.</th>
<th>Impact energy KV&lt;sup&gt;2&lt;/sup&gt; [J] min.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>min. long.</td>
<td>transv.</td>
<td>min.</td>
<td>Test temperature [°C]</td>
</tr>
<tr>
<td>GL–R 360 T</td>
<td>360 – 490</td>
<td>255</td>
<td>25</td>
<td>23</td>
</tr>
<tr>
<td>GL–R 490 T</td>
<td>490 – 630</td>
<td>355</td>
<td>22</td>
<td>20</td>
</tr>
<tr>
<td>GL–R 0,5 Ni</td>
<td>490 – 610</td>
<td>355</td>
<td>22</td>
<td>20</td>
</tr>
<tr>
<td>GL–R 3,5 Ni</td>
<td>440 – 620</td>
<td>345</td>
<td>22</td>
<td>20</td>
</tr>
<tr>
<td>GL–R 9 Ni</td>
<td>690 – 840</td>
<td>510</td>
<td>20</td>
<td>18</td>
</tr>
<tr>
<td>1.4306</td>
<td>480 – 680</td>
<td>215</td>
<td>40</td>
<td>35</td>
</tr>
<tr>
<td>1.4404</td>
<td>490 – 690</td>
<td>225</td>
<td>40</td>
<td>35</td>
</tr>
<tr>
<td>1.4541</td>
<td>510 – 710</td>
<td>235</td>
<td>35</td>
<td>30</td>
</tr>
<tr>
<td>1.4550</td>
<td>510 – 740</td>
<td>240</td>
<td>35</td>
<td>30</td>
</tr>
<tr>
<td>1.4571</td>
<td>510 – 710</td>
<td>245</td>
<td>35</td>
<td>30</td>
</tr>
</tbody>
</table>

1. R<sub>p0,2</sub> or R<sub>el</sub> applies to ferritic steels, R<sub>pL0</sub> to austenitic steels.
2. Average value of 3 specimens; the values in brackets are the individual minima.
4.1 Test of chemical composition

The chemical composition of each heat shall be verified by the pipe manufacturer, or, where appropriate in the case of welded pipes, by the manufacturer of the starting material in accordance with A.8.1.

4.2 Test of resistance to intercrystalline corrosion

4.2.1 The resistance to intercrystalline 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 stabilization with titanium or niobium, see 3.2.

4.2.2 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 shall be treated as follows:

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

4.3 Tensile test

The tensile test shall be performed on the sample pipes selected in accordance with A.8.2.

4.4 Technological tests

4.4.1 The pipes shall undergo one of the ring tests specified in Table 2.1. For the performance of the tests, specimens shall be taken from one end of two pipes of a test batch.

4.4.2 To calculate the distance between the platens to be used in the ring flattening test, the values according to Table 2.15 shall be assigned to the constant C in the formula given in A.8.5.2:

Table 2.15

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

4.5 Notched bar impact test

4.5.1 On pipes with wall thicknesses ≥ 6 mm, the notched bar impact test shall be performed on Charpy V-notch specimens taken from each sample pipe selected in accordance with A.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.

4.5.2 If the wall thickness of the pipe does not allow the preparation of specimens with the standard dimensions (10 × 10 mm), specimens measuring 7,5 × 10 mm or 5 × 10 mm shall be used. The requirements applicable to these specimens as compared with the standard specimens are shown in Table 2.16.

4.6 Test of surface finish and dimensions

Tests shall be performed in accordance with A.8.6.

Table 2.16 Impact energy for specimens of reduced size

<table>
<thead>
<tr>
<th>Required impact energy (^1) in Table 2.14 (standard specimens)</th>
<th>Required impact energy KV with specimens measuring 7,5 mm × 10 mm</th>
<th>Required impact energy KV with specimens measuring 5 mm × 10 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>average value [J] min.</td>
<td>minimum individual value [J]</td>
</tr>
<tr>
<td>27 (19)</td>
<td>22</td>
<td>16</td>
</tr>
<tr>
<td>41 (29)</td>
<td>34</td>
<td>24</td>
</tr>
</tbody>
</table>

\(^1\) Average value of 3 specimens; values in brackets apply to the min. individual value.
4.7 Non-destructive tests
All pipes shall be subjected by the manufacturer to a non-destructive test over their whole length according to EN 10246.

4.7.1 Non-destructive testing of seamless and pressure-welded pipes
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 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.

4.7.2 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.

4.8 Tightness test
All pipes shall be tightness tested by the manufacturer in accordance with A.8.8.

E. Stainless Steel Pipes

1. Scope

1.1 These Rules 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 D., Table 2.13 are appropriate to these applications subject to the following conditions relating to manufacture and testing.

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.

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 D.2. are complied with.

3. Requirements applicable to the material

3.1 Chemical composition
The chemical composition of the pipe steels shall conform to recognized standards or specifications.

3.2 Resistance to intercrystalline corrosion
In the condition in which they are supplied, the pipes shall 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 %.

3.3 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.

3.4 Technological properties
In the ring tests, the pipes shall exhibit a capacity for deformation which satisfies the requirements stated in A.8.5.

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.

3.6 Impact energy
The required impact energy values shall be satisfied in tests at room temperature in accordance with the relevant standard or the recognized specification.
4. Testing and scope of tests

The following tests are to be performed:

4.1 Test of chemical composition

The chemical composition of each heat shall be demonstrated by the pipe manufacturer, or, where appropriate in the case of welded pipes, by the manufacturer of the starting material in accordance with A.8.1.

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:

- pipes for use on chemical tankers irrespective of the type of material
- pipes which do not meet the requirements in respect of stabilization or limited carbon content specified in 3.2
- pipes made of stabilized steels or steels with limited carbon contents intended for applications not covered, where such testing is specially prescribed in view of the anticipated corrosive attack

The test conditions shall be as prescribed in D.4.2.2.

4.3 Tensile test

The tensile test shall be performed on specimens of the sample pipes selected in accordance with A.8.2.

4.4 Technological tests

Unless more extensive testing is prescribed in the standards, one of the ring tests specified in A., Table 2.1 shall be performed on one end of 2 % of the pipes. To calculate the distance between the platens 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 A.8.5.2.

4.5 High-temperature tensile test

Where called for in A.8.3 or stipulated in the purchase order, the 0.2 % or 1 % proof stress shall be determined by a high-temperature tensile test.

4.6 Test of surface finish and dimensions

Tests shall be performed in accordance with A.8.6.

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 off.

4.8 Tightness test

All pipes shall be tightness tested by the manufacturer in accordance with A.8.8.
Section 3

Forgings

A. General Rules

1. Scope

This part contains general Rules to be applied in the manufacture and testing of forgings.

In conjunction with the individual Rules which follow, this part is also applicable to rolled steel bar, where it is to be used in place of forgings for the manufacture by machining of shafts, arbors, pins and similar parts.

2. Selection of steels

2.1 All steels shall be suitable for their application and shall satisfy the minimum requirements specified in the following individual Rules. Subject to these conditions, steels conforming to the relevant standards or to material specifications approved by GL may be used.

2.2 The steels shall be identified by the standardized designations or the designations given in the specifications.

3. Requirements to be met by manufacturers

3.1 Manufacturers wishing to produce forgings to these Rules shall fulfil the conditions stated in Chapter 1 – Principles and Test Procedures, Section 1 and shall prove this before the commencement of supplies. In addition, an approval test shall normally be performed on forgings selected for the purpose. The extent of the tests will be determined by GL on a case to case basis.

3.2 Forges without their own steelmaking facility may only use starting material supplied by producers who have been approved by GL.

4. Method of manufacture

4.1 Forging steel shall be produced by a basic oxygen process, in an electric furnace or by other methods approved by GL and shall be killed. On request, GL shall be informed of the steelmaking process used.

4.2 A sufficient amount of material shall be cropped from the top and bottom ends of ingots to ensure that the forgings are free from harmful segregations. This term includes all inhomogeneities liable to impair the required characteristics.

4.3 Given a reasonable machining allowance, workpieces shall as far as possible be forged to the final dimensions. Excessive machining to give the forging its final shape which may impair its character-istics, e.g. by laying open the core zone, is not allowed. Necks of shafts, pinions and journals exceeding 1/10 of the outer diameter shall be produced as far as possible by stepped forging. The degree of deformation shall be such that the core zone of the forging undergoes sufficient plastic deformation.

Unless otherwise approved the total reduction ratio is to be at least:

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

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

4.4 Annular and hollow shapes shall be produced from sections cut from the ingot or bloom which have been suitably punched, drilled or trepanned before the parts are rolled or expanded over a suitable mandrel.

4.5 The shaping of forgings or rolled products by flame cutting and flame scarfing and gouging shall be performed using established methods prior to the final heat treatment unless otherwise agreed with GL. Depending on its composition and/or thickness the workpiece shall be preheated. Where necessary, surfaces produced by flame cutting shall be machined.

4.6 Where two or more forgings are to be welded together, details of the welding method shall be submitted for approval. GL reserves the right to call for a welding procedure approval test in these cases.

5. Condition of supply and heat treatment

5.1 All forgings shall be suitably heat treated according to the material for obtaining a fine grain homogeneous microstructure condition as well as the required mechanical properties. Heat treatments shall be applied in suitable furnaces, which shall be properly and regularly maintained. They shall be fitted with devices for controlling and indicating the temperature; these devices are to be checked at regular intervals. The furnace dimensions shall enable the whole forging to be raised uniformly to the required heat treatment temperature.
5.2 All hot forming operations shall be concluded prior to the final heat treatment. Should it be necessary for some reason to reheat a forging for a further hot forming operation, then the final heat treatment shall be repeated.

5.3 Where a forging is subjected to hot or cold straightening after the final heat treatment, subsequent stress relief heat treatment to remove the residual stresses may be required.

5.4 Forgings whose section is substantially altered by machining after the forging operation may only be quenched and tempered after they have undergone adequate rough machining.

The weight of the quenched and tempered forging shall not exceed 1.25 times that of the finished part.

5.5 If the prescribed heat treatment is to be replaced by an equivalent temperature cycle during and after the hot forming process, appropriate tests shall be performed to prove to GL that the method is indeed equivalent.

6. General characteristics of forgings

6.1 All forgings shall be free from defects such as flakes, cracks, shrinkage cavities, segregation, peripheral blow holes and major non-metallic inclusions which are capable of having a more than insignificant adverse effect on their application and treatment. Forgings delivered in the unmachined condition shall have a smooth surface consistent with the method of manufacture.

6.2 Minor surface defects may be removed by grinding. The complete removal of the defects shall be proved by a magnetic particle or dye penetrant test. With the consent of the Surveyor, shallow depressions or indentations may be allowed to remain provided that they are ground out to accommodate them to the surrounding area and that their depth, in the case of surfaces which are to be machined, lies within the machining allowance.

6.3 The removal of defects by welding is permitted only in exceptional cases with the agreement of GL if the defects are of limited extent and occur at points which are subject to low operating loads.

In these cases, full details of the proposed repair and of the subsequent test method shall be submitted to GL for approval before the start of the repair. In addition, the test report shall be submitted with a description or sketch showing the position and extent of all repairs together with details of the subsequent heat treatment and non-destructive tests applied.

7. Dimensions; dimensional and geometrical tolerances

The dimensions and the dimensional and geometrical tolerances are governed by the values given in the drawings accompanying the order or, where applicable, in the relevant standards. Instructions on this point shall be given in the order documents and shall be made known to the Surveyor.

8. Tightness

Hollow forgings subjected to internal pressure by the operating medium shall be leakproof at the specified test pressure.

9. General requirements applicable to the material

9.1 Chemical composition

9.1.1 The chemical composition of forged steels shall conform to the limit values indicated in the Tables given in this section and/or in the relevant standards or specifications. If use is made of standardized steels whose nominal carbon contents agree with the limit values indicated in the Tables, the limits specified in the standards may be recognized. The steels shall also contain the quantities of deoxidizers needed to kill the steel.

Where steels are deoxidized by the vacuum-carbon method the lower limits for the Si and Al contents are inapplicable in all the rules specifying chemical composition.

9.1.2 The steelmaker shall take appropriate steps to ensure that elements liable to impair the characteristics of the products cannot enter the heat by way of scrap or other materials used in the steelmaking process.

9.2 Mechanical and technological properties

9.2.1 Tensile test

The requirements indicated in the Tables contained in these Rules or, where applicable, in the relevant standards or specifications shall be met under tensile test.

9.2.2 Notched bar impact test

The impact energy values specified for the various steel grades shall be met by the average result produced by 3 specimens, one of which may give a result below the specified average value although not lower than 70 % of the specified average value.

9.2.3 Other characteristics

Where special characteristics are specified for particular grades of steel, e.g. resistance to intercrystalline corrosion or 0,2 % proof stress at high temperatures, these characteristics shall be verified by appropriate tests.

10. Testing

10.1 Proof of chemical composition

The manufacturer shall determine the chemical composition of each heat and present a corresponding certificate to the Surveyor. The certificate shall indicate the chemical composition of the heat characteristic of the steel grade concerned.
Should there be any doubt as to the composition or where the connection between the certificate and the forgings cannot be proved, a product analysis shall be performed.

10.2 Test of mechanical properties and selection of specimens

10.2.1 The mechanical properties shall be ascertained by tensile test to determine tensile strength, yield strength or 0.2 % proof stress, elongation and reduction in area.

10.2.2 Unless otherwise specified, the impact energy shall be determined by notched bar impact tests on each forging or each test batch, as appropriate.

10.2.3 Unless otherwise specified, the following shall apply to the verification of the mechanical properties with regard to the test batches and the test specimens:

10.2.3.1 Forgings with similar dimensions which originate from the same heat and have been heat treated together shall be grouped into a test batch.

10.2.3.2 Testing of normalized forgings with unit weights of ≤ 1000 kg or quenched and tempered forgings with unit weights of ≤ 500 kg shall be performed in test batches. Unless otherwise agreed with GL, the size of the test batch shall be as detailed in Table 3.1.

Surplus quantities up to 10 % of the number of forgings per test batch can be allotted to a test batch

Forgings with unit weights > 1000 kg (normalized) and > 500 kg (quenched and tempered) shall be tested individually.

Table 3.1 Heat treatment weight of individual forging and number of forgings per test batch

<table>
<thead>
<tr>
<th>Heat treatment weight of individual forging [kg]</th>
<th>Number of forgings per test batch</th>
</tr>
</thead>
<tbody>
<tr>
<td>up to 15</td>
<td>≤ 300</td>
</tr>
<tr>
<td>&gt; 15 to 150</td>
<td>≤ 100</td>
</tr>
<tr>
<td>&gt; 150 to 300</td>
<td>≤ 50</td>
</tr>
<tr>
<td>&gt; 300 to 1000</td>
<td>≤ 25</td>
</tr>
</tbody>
</table>

10.2.3.3 The number of test sections required for the tensile test and the notched bar impact test is as follows:

 normalized forgings: one test section from one forging per test batch.

At least 5 % of all quenched and tempered forgings which undergo batchwise testing shall be subjected to a hardness test.

In the case of products ≥ 3 m in length and weighing over 4 000 kg in heat-treated condition which do not undergo heat treatment in a continuous furnace, one test section shall be taken from each end of the forging to be tested.

10.2.3.4 Depending on the conditions agreed on placing the order, the test sections shall be taken as follows:

 normalized forgings: one test section from one forging (which is then destroyed in its entirety)

 from additional material provided on the forging

 from a sample of similar dimensions from the same heat, which has been forged in the same way as the other forgings and heat treated together with them

10.2.3.5 The location of the test specimens in the cross section of the heat-treated region shall be as follows:

 The specimens shall be taken starting from the surface at a distance of 1/4 of the diameter or the (wall) thickness, but max. 80 mm, and at a corresponding distance from a further, adjacent surface.

10.2.3.6 It may be necessary to distinguish between the geometrical position of the specimens in the forging and their location in relation to the direction of the fibre.

For forgings, the references in the tables to longitudinal, tangential and transverse orientations refer to the position of the specimen in relation to the direction of the fibre and should be understood as follows:

Longitudinal: The longitudinal axis of the specimen is parallel to the main direction of elongation of the non-curved fibre pattern;

Tangential: The longitudinal axis of the specimen traverses the curved fibre pattern in the form of a chord (and thus "slopes", so to speak, in relation to it);

Transverse: The longitudinal axis of the specimen traverses the fibre pattern at right angles. Specimens with a longitudinal axis lying in the direction of an additional compression (perpendicular to an expansion) of the fibre pattern (so-called location "in the thickness direction") are not covered by the specimen positions termed "transverse".
10.2.3.7 Normally, test specimens shall be taken from the test sections forged together with the workpieces. This test section may normally be separated from the forging only after the latter has undergone final heat treatment. In this context, subsequent heat treatment for stress relief may be disregarded. Prior separation is permitted only where the manufacturing process makes this unavoidable. In these circumstances, the forging and the test section shall be heat treated together.

10.2.3.8 All test sections shall be forged with the same degree of deformation to a cross section corresponding to the relevant cross section of the forging. The test sections shall be large enough to provide material not only for the specimens required for the initial test but also for specimens needed for possible retests.

All test sections and samples shall be so marked that they can be clearly related to the forgings or test batches which they represent.

10.2.4 For forgings whose method of manufacture is subject to special approval by GL, see 5.5, the number and position of the test sections shall be specially determined with regard to the method of manufacture.

10.3 Test of surface finish and dimensions

10.3.1 The manufacturer shall inspect each forging for surface finish and compliance with the dimensional and geometrical tolerances and shall then submit the forgings to the Surveyor for final inspection. The inner surfaces of hollow forgings and bores are to be included in these inspections.

10.3.2 The surface of the forgings shall be clean and properly prepared for inspection. Surface defects are to be removed. Where necessary this condition shall be achieved by pickling, local grinding, shot or sand blasting, cleaning with wire brushes or by chemical means, unless the parts are submitted in the rough machined condition.

10.3.3 If the surface condition suggests that welds have been carried out on the forging, the Surveyor may demand local etching to reveal possible welds.

10.4 Non-destructive tests

10.4.1 Where non-destructive tests are called for, these are to be performed by the manufacturer and/or finishing plant. Tests may also be arranged by the Society.

10.4.2 Non-destructive tests are to be performed in accordance with the specifications stated in G. in consideration of the specifications in Chapter 1 – Principles and Test Procedures, Section 3.

10.5 Retests in the event of failure of specimens

If the required values of tensile strength or notched bar impact tests are not achieved or if a notched bar impact test produces an individual value which is lower than 70 % of the required average value, then, before the forging or the unit test quantity is rejected, the procedure for repeat tests prescribed in Chapter 1 – Principles and Test Procedures, Section 2, H. may be applied. The additional test specimens shall be taken either from the same test section as the original specimen or from other test sections or samples which are representative of the test batch concerned.

11. Identification and marking

11.1 The manufacturer shall institute a monitoring system enabling all forgings to be traced back to the original heat, and this shall be demonstrated to the Surveyor on request.

11.2 Prior to final inspection, all forgings shall be stamped by the manufacturer in at least one place with the following marks:
- steel grade
- manufacturer's mark
- item or heat number, or another mark enabling the manufacturing process to be traced back
- specimen number
- date of test

The area receiving the stamp marks shall be ground.

11.3 In the case of small, series-manufactured forgings, agreement may be reached with the Surveyor to apply stamp marks other than those stated in 11.2.

12. Certificates

For each consignment the manufacturer shall supply to the Surveyor a certificate containing at least the following details:
- purchaser and order number
- newbuilding number and project number, if known
- nature of forging and grade of steel
- purpose and drawing number, if necessary
- weight of the forging
- method of forging
- item number and number of units
- heat number
- chemical composition of the heat
- condition of supply
- details of heat treatment
results of the mechanical tests
results of any special tests applied, e.g. test of resistance to intercrystalline corrosion, determination of proof stress at elevated temperatures or non-destructive tests

B. Forgings for Machine Construction and Shipbuilding

1. Scope

These Rules are applicable to forgings made of unalloyed and low alloy steels intended for the manufacture of components and structural parts in machine construction and shipbuilding, e.g. shafts, piston rods, connecting rods, rudderstocks and heel pintles. They are also applicable to rolled round bars for the manufacture of shafts, pins, tie-rods and similar components which are given their final shape by machining.

2. Suitable grades of steel

On condition that they meet the requirements specified in 4., the following steels may be used:

2.1 Suitable grades of forging steel conforming to recognized standards, e.g. EN 10083, EN 10250-2, EN 10250-3 and SEW 550.

2.2 Other unalloyed and low alloy steels conforming to other standards or material specifications, provided that their suitability has been confirmed by GL. An initial test of product suitability may be required for this purpose.

3. Condition of supply and heat treatment

3.1 All forgings shall be properly heat treated. Acceptable methods of heat treatment are:
- for carbon and carbon-manganese steels:
  - normalizing
  - normalizing and tempering (air quenching and tempering)
  - quenching and tempering
- for alloy steels:
  - quenching and tempering

3.2 Large forgings of complex shape made of carbon or carbon-manganese steel which are to be supplied in normalized condition shall undergo additional stress-relieving heat treatment if they have been extensively machined subsequent to normalizing.

4. Requirements applicable to the material

4.1 Chemical composition

4.1.1 The chemical composition of the forging steels is subject to the limit values in Table 3.2.

<table>
<thead>
<tr>
<th>Table 3.2 Limit values for the chemical composition of forging steels</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>C- and CMn steels</strong></td>
</tr>
<tr>
<td><strong>Chemical composition</strong></td>
</tr>
<tr>
<td>C&lt;sub&gt;max.&lt;/sub&gt;</td>
</tr>
<tr>
<td>Si&lt;sub&gt;max.&lt;/sub&gt;</td>
</tr>
<tr>
<td>Mn</td>
</tr>
<tr>
<td>P&lt;sub&gt;max.&lt;/sub&gt;</td>
</tr>
<tr>
<td>S&lt;sub&gt;max.&lt;/sub&gt;</td>
</tr>
</tbody>
</table>

1 Where necessary, grain-refining elements, e.g. aluminium, may be added.
2 For the alloying elements the data given in the standards or approved specifications are applicable.
3 The use of steels with carbon contents of C > 0,50 % and C > 0,45 %, respectively, shall be specially authorized by GL.
4 For welded constructions, rudderstocks and pintles: max. 0,23 % C.

4.1.2 Where forgings are to be used in welded assemblies, the composition shall be specially determined by reference to the welding method used and shall be submitted to GL for approval.

4.2 Mechanical and technological properties

4.2.1 The required values of yield strength, reduction in area and elongation shown in Tables 3.5 and 3.6 respectively in relation to the prescribed minimum tensile strength shall be met.

4.2.2 The strength levels of 40 and 50 N/mm<sup>2</sup> stated in Tables 3.5 and 3.6 respectively should not be regarded as minimum tensile strengths for certain grades of forging steel, but are intended to enable the required property values (yield strength, elongation, reduction in area and impact energy) to be determined by interpolation in relation to the prescribed minimum tensile strengths.

4.2.3 If two test specimens are taken from forgings, the difference between the measured tensile strength values may not exceed the magnitudes stated in Table 3.3.
Table 3.3 Differences permitted between tensile strength values

<table>
<thead>
<tr>
<th>Minimum tensile strength $R_m$ [N/mm²]</th>
<th>Difference permitted between tensile strength values [N/mm²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 600</td>
<td>70</td>
</tr>
<tr>
<td>≥ 600 &lt; 900</td>
<td>100</td>
</tr>
<tr>
<td>≥ 900</td>
<td>120</td>
</tr>
</tbody>
</table>

4.3 Impact energy

The required impact energy values shown in Tables 3.5 and 3.6 in relation to the specified minimum tensile strength shall be met. Irrespective of this, for heel pintles and rudderstocks an impact energy of at least 27 J shall be attained with longitudinal Charpy V-notch specimens measured at 0 °C for ships with ice class symbols E3 and E4 and at –20 °C for ships with the arctic ice class symbols ARC1 to ARC4. One individual value may be below the average value but shall not be less than 19 J.

For propeller shafts intended for ships with ice class an impact energy of at least 27 J with longitudinal Charpy V-notch specimens measured at –10 °C shall be attained.

4.4 Hardness

4.4.1 The hardness values prescribed in the approval drawings or specifications of the forgings are mandatory. The figures shown in Tables 3.5 and 3.6 are guide values only.

4.4.2 Where a hardness test is stipulated, the hardness values measured at different points on the forging or on different units within a unit test quantity respectively may not differ by more than the amounts stated in Table 3.4.

If the hardness is measured in other units, the values shall be converted into the corresponding Brinell units.

Table 3.4 Differences permitted between hardness values

<table>
<thead>
<tr>
<th>Minimum tensile strength $R_m$ [N/mm²]</th>
<th>Difference in hardness Brinell units</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 600</td>
<td>up to 25</td>
</tr>
<tr>
<td>≥ 600 &lt; 900</td>
<td>up to 35</td>
</tr>
<tr>
<td>≥ 900</td>
<td>up to 42</td>
</tr>
</tbody>
</table>

5. Testing

5.1 Mechanical testing

5.1.1 Testing shall be accomplished by tensile tests and notched bar impact tests in accordance with A. 10.2. Quenched and tempered forgings grouped into test batches shall be subjected to additional hardness testing.

5.1.2 Notched bar impact testing of propeller shafts, rudderstocks and heel pintles for ships with ice class symbols shall be carried out with Charpy V-notch specimens. For all other products, the selection of the specimen shape according to Chapter 1 – Principles and Test Procedures, Section 2, E.1. and E.2. shall be at the manufacturer’s discretion.

5.1.3 The test specimens may be taken from the samples in longitudinal, tangential or transverse direction in relation to the fibre pattern; cf. Figures 3.1 to 3.3.

5.2 Non-destructive tests

The specifications in G. do apply. The components indicated in H. are to be tested according to the scope prescribed there.

5.3 Test of surface finish and dimensions

All forgings shall be presented to the Surveyor in the condition in which they are delivered for testing of the surface finish and the dimensions.

C. Forgings for Crankshafts

1. Scope

These Rules are applicable to solid forged crankshafts and to the forged throws, webs and pins of semi-built crankshafts of unalloyed and low alloy steels.

2. Approved materials

Only materials which have been approved by GL as suitable for the intended application may be used. To this end, the engine manufacturer shall submit to GL for approval specifications and/or drawings containing...
all the data required for evaluating the material, e.g. method of manufacture, chemical composition, heat treatment and mechanical properties. The minimum requirements as per Tables 3.5 and 3.6 are to be satisfied.

3. Requirements applicable to the material

3.1 With regard to the chemical composition, mechanical properties and required impact energy and hardness values of the steel, the data contained in the approved specification or drawing are applicable.

3.2 The steel shall undergo vacuum degassing following its production to ensure that the hydrogen content of the heat does not exceed 2 ppm.

4. Manufacture and condition of supply

4.1 Wherever possible, the throws of built crankshafts shall be preforged as a flat semi-finished product and then folded in a press to produce a rough forging having a fibre pattern with favourable loading characteristics. However, other processes may be used if they achieve the required characteristics. GL shall be advised of the method of manufacture.

4.2 Where crankshaft webs are produced by thermal cutting from forged or rolled flat products, the heat-affected area at the cut faces shall be completely removed by machining. This Rule does not apply to webs which are cut out of the starting material before the specified heat treatment is applied.

4.3 Crankshafts shall normally be supplied in quenched and tempered condition. However, crankshafts and their components which are made of carbon and carbon-manganese steels may also be normalized or normalized and tempered. Where crankshafts are to be surface-hardened, the nature of the heat treatment shall be stated in the manufacturer’s specification.

5. Testing

5.1 Tensile test

The mechanical properties shall be verified by tensile test. Test specimens shall be taken for this purpose in accordance with 5.1.1 to 5.1.4.
Table 3.5 Mechanical and technological properties of carbon and carbon manganese steel forgings in normalized or quenched and tempered condition for room temperature

<table>
<thead>
<tr>
<th>Minimum tensile strength $^{1,2}$ $R_m$ $[N/mm^2]$</th>
<th>Relevant heat treatment diameter $[mm]$</th>
<th>Yield strength $R_{yH}$ $[N/mm^2]$ min.</th>
<th>Elongation ( A = 5.65 \cdot \sqrt{S_o} ) [%] min.</th>
<th>Reduction in area $Z$ [%] min.</th>
<th>Impact energy $K_V$ $[J]$ min.</th>
<th>$K_U$ $[J]$ min.</th>
<th>Brinell hardness $HB$ (Guide values)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\leq 360$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>95 – 125</td>
</tr>
<tr>
<td>$&gt; 250 \leq 500$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$&gt; 500 \leq 1000$</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>$\leq 400$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>110 – 150</td>
</tr>
<tr>
<td>$&gt; 250 \leq 500$</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$&gt; 500 \leq 1000$</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>$\leq 440$</td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td>125 – 160</td>
</tr>
<tr>
<td>$&gt; 250 \leq 500$</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>$&gt; 500 \leq 1000$</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>$\leq 480$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>135 – 175</td>
</tr>
<tr>
<td>$&gt; 250 \leq 500$</td>
<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>$&gt; 500 \leq 1000$</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\leq 520$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>150 – 185</td>
</tr>
<tr>
<td>$&gt; 250 \leq 500$</td>
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<tr>
<td>$&gt; 500 \leq 1000$</td>
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<tr>
<td>$\leq 560$</td>
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<td>160 – 200</td>
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<tr>
<td>$&gt; 250 \leq 500$</td>
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<tr>
<td>$&gt; 500 \leq 1000$</td>
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<tr>
<td>$\leq 600$</td>
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<td></td>
<td></td>
<td>175 – 215</td>
</tr>
<tr>
<td>$&gt; 250 \leq 500$</td>
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<tr>
<td>$&gt; 500 \leq 1000$</td>
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<tr>
<td>$\leq 640$</td>
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<td></td>
<td>185 – 230</td>
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<tr>
<td>$&gt; 250 \leq 500$</td>
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<td>$&gt; 500 \leq 1000$</td>
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<tr>
<td>$\leq 680$</td>
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<td>200 – 240</td>
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<td>$&gt; 250 \leq 500$</td>
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<td>$&gt; 500 \leq 1000$</td>
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<tr>
<td>$\leq 720$</td>
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<td>210 – 250</td>
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<td>$&gt; 500 \leq 1000$</td>
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<tr>
<td>$\leq 760$</td>
<td></td>
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<td></td>
<td></td>
<td>225 – 265</td>
</tr>
<tr>
<td>$&gt; 250 \leq 500$</td>
<td></td>
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<td></td>
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<tr>
<td>$&gt; 500 \leq 1000$</td>
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</tr>
</tbody>
</table>

1. Where the minimum tensile strength of a steel grade falls between two of the graduated values, the requirements are to be determined by interpolation, see 4.2.2.
2. The tensile strength determined by testing may not exceed the specified minimum tensile strength, if less than 600 N/mm², by more than 120 N/mm². Where the minimum tensile strength is ≥ 600 N/mm² not more than 150 N/mm² may be exceeded.
3. The propeller shafts, rudderstocks and heel pintles of ships with ice class symbols are subject to the impact energy values stipulated in 4.3.
Table 3.6 Mechanical and technological properties of alloy steel forgings in quenched and tempered condition for room temperature

<table>
<thead>
<tr>
<th>Minimum tensile strength $R_m$ [N/mm²]</th>
<th>Relevant heat treatment diameter $R_{H}$ [mm]</th>
<th>Yield strength $R_{eh}$ [N/mm²]</th>
<th>Elongation $A$ [%] min.</th>
<th>Reduction in area $Z$ [%] min.</th>
<th>Impact energy $K_U$ [J] min.</th>
<th>Impact energy $K_V$ [J] min.</th>
<th>Brinell hardness HB (Guide values)</th>
</tr>
</thead>
<tbody>
<tr>
<td>550 ≤ 250</td>
<td>≤ 250 ≤ 500</td>
<td>0,6 × minimum tensile strength</td>
<td>20 18 16</td>
<td>50 45 35</td>
<td>41 32 24</td>
<td>35 30 24</td>
<td>160 – 200</td>
</tr>
<tr>
<td>600 &gt; 250 ≤ 500</td>
<td>20 18 16</td>
<td>50 45 35</td>
<td>41 32 24</td>
<td>35 30 24</td>
<td>175 – 215</td>
<td></td>
<td></td>
</tr>
<tr>
<td>650 &gt; 250 ≤ 500</td>
<td>18 16 14</td>
<td>50 45 35</td>
<td>32 28 22</td>
<td>30 27 23</td>
<td>190 – 235</td>
<td></td>
<td></td>
</tr>
<tr>
<td>700 &gt; 250 ≤ 500</td>
<td>17 15 13</td>
<td>50 45 35</td>
<td>25 18 13</td>
<td>25 20 15</td>
<td>205 – 245</td>
<td></td>
<td></td>
</tr>
<tr>
<td>750 &gt; 250 ≤ 500</td>
<td>17 15 13</td>
<td>45 40 30</td>
<td>25 18 13</td>
<td>25 20 15</td>
<td>215 – 260</td>
<td></td>
<td></td>
</tr>
<tr>
<td>800 &gt; 250 ≤ 500</td>
<td>15 14 12</td>
<td>45 40 30</td>
<td>25 18 13</td>
<td>25 20 15</td>
<td>235 – 275</td>
<td></td>
<td></td>
</tr>
<tr>
<td>850 &gt; 250 ≤ 500</td>
<td>14 13 11</td>
<td>45 40 30</td>
<td>25 18 13</td>
<td>25 20 15</td>
<td>245 – 290</td>
<td></td>
<td></td>
</tr>
<tr>
<td>900 &gt; 250 ≤ 500</td>
<td>14 13 11</td>
<td>40 35 27</td>
<td>25 18 13</td>
<td>25 20 15</td>
<td>260 – 320</td>
<td></td>
<td></td>
</tr>
<tr>
<td>950 &gt; 250 ≤ 500</td>
<td>13 11 10</td>
<td>40 35 27</td>
<td>25 18 13</td>
<td>25 20 15</td>
<td>275 – 340</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1000 &gt; 250 ≤ 500</td>
<td>12 10 10</td>
<td>40 35 27</td>
<td>25 18 13</td>
<td>25 20 15</td>
<td>290 – 365</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1050 &gt; 250 ≤ 500</td>
<td>11 10 8</td>
<td>40 35 27</td>
<td>25 18 13</td>
<td>25 20 15</td>
<td>310 – 375</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1100 &gt; 250 ≤ 500</td>
<td>11 10 8</td>
<td>40 35 27</td>
<td>25 18 13</td>
<td>25 20 15</td>
<td>320 – 385</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 Where the minimum tensile strength of a steel grade falls between two of the graduated values, the requirements are to be determined by interpolation, see 4.2.2.
2 The tensile strength determined by testing may not exceed the specified minimum tensile strength, if less than 900 N/mm², by more than 150 N/mm². Where the minimum tensile strength is 900 N/mm² not more than 200 N/mm² may be exceeded.
3 For case-hardening steels a value of 60 % of the specified minimum tensile strength is sufficient irrespective of the value of the tensile strength.
4 Where the heat treatment diameter is > 500 mm, the requirements shall be agreed with GL.
5.1.1 Independently of the selection of test specimens according to test batches as prescribed in 5.1.3, at least one longitudinal or transverse tensile test specimen shall be taken from the driven side of each crankshaft. Where a solid forged crankshaft weighs more than 3000 kg, test specimens shall be taken from both ends, on the driven side as a transverse specimen. The weight applicable is the weight of the crankshaft in the heat-treated condition minus the weight of the test sections.

5.1.2 Where the throws are machined or flame cut from a preforged crankshaft, a second set of test specimens shall be taken in the transverse direction from the material removed from the throw furthest from the driven side, cf. Fig. 3.4.

The test sections may not be removed prior to quenching and tempering.

Fig. 3.4 Location of test specimens in crankshafts

5.1.3 Crankshafts of the same dimensions up to a weight in heat-treated condition of 500 kg which originate from the same heat and form part of the same heat treatment batch may be grouped into test batches in accordance with Table 3.1, A.10.2.3. For quenched and tempered crankshafts, two tensile test specimens shall be taken from each test batch; for normalized shafts, one specimen is sufficient.

5.1.4 Transverse test specimens shall be taken from forged throws. Unless otherwise agreed with GL, at least one specimen shall be taken from each forging.

5.1.5 Where two test specimens are taken from large crankshafts, the difference between the measured tensile strength values may not exceed the magnitudes stated in B.4.2.3.

5.2 Notched bar impact test

Each forging or unit test quantity, as applicable, shall be subjected to the notched bar impact test. The number of sets of specimens (each comprising 3 specimens) and their position are subject to the conditions stated in 5.1.1 to 5.1.4 for tensile test specimens.

5.3 Hardness testing

5.3.1 Where testing is performed in test batches, at least 10 % of the crankshafts shall be subjected to hardness tests.

The method of hardness testing and the position of the hardness testing impressions on the forgings shall be agreed with GL.

5.3.2 The differences in the hardness values measured at different points on the forging or on different units within a test batch may not exceed the magnitudes stated in B.4.4.2.

5.4 Test of surface finish and dimensions

The crankshaft manufacturer shall test the surface finish and dimensions of the crankshafts and give the measurement records to the Surveyor. He shall also present the crankshafts to the Surveyor for final inspection and hold in readiness the measuring instruments required for checking the dimensions.

5.5 Non-destructive testing

Crankshafts shall be subjected to non-destructive testing according to the scope stipulated in G.

D. Forgings for Gears

1. Scope

These Rules are applicable to forgings made of carbon, carbon-manganese and low alloy steels which are intended for the manufacture of wheels and wheel rims for the gears of the main engine and auxiliary equipment.

2. Suitable grades of steel

On condition that they satisfy the requirements of 6., the following grades of steel may be used:

2.1 Quenched and tempered steels conforming to EN 10083-1, case hardening steels conforming to EN 10084 and nitriding steels conforming to EN 10085, provided that proof has been furnished of the suitability of the individual grade of steel for the intended purpose. Table 3.7 contains a selection of suitable steel grades.

2.2 Steels conforming to other standards, provided that they are comparable with the steel grades specified in 2.1 and proof has been furnished of their suitability for the intended purpose.

Table 3.7 Suitable steel grades for gears

<table>
<thead>
<tr>
<th>Steel grade</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>42CrMo4</td>
<td>EN 10083-1</td>
</tr>
<tr>
<td>16MnCr5</td>
<td>EN 10084</td>
</tr>
<tr>
<td>20MnCr5</td>
<td></td>
</tr>
<tr>
<td>18CrNiMo7-6</td>
<td></td>
</tr>
</tbody>
</table>
2.3 Steels conforming to particular material specifications, provided that GL has authorised their use. To this end, the gear manufacturer shall submit the corresponding specifications for approval. These specifications shall contain all the data required for their evaluation, e.g. method of manufacture, chemical composition, heat treatment, surface hardening and mechanical properties.

3. Welded wheels

Where gear wheels are made up of components welded together, full details of the welding process, the scope of non-destructive testing and the acceptability criteria for welding defects shall be submitted to GL for approval. The characteristics of the welds shall first be demonstrated by a welding procedure specification test.

4. Heat treatment

4.1 Forgings for which surface hardening after the cutting of the teeth is not specified shall be quenched and tempered. Carbon and carbon-manganese steels may also be normalized and tempered.

4.2 In the case of forgings which undergo surface hardening after the cutting of the teeth, the heat treatment depends on the nature of the surface hardening process, as follows:

4.2.1 After carburization, case-hardening steels are to be hardened and then tempered at low temperature. The depth of case hardening, the time-temperature cycle and the hardness range (min/max) shall be stated in the specification.

4.2.2 Steels for induction hardening shall normally be quenched and tempered prior to hardening. Carbon and carbon-manganese steels may also be normalized instead of quenching and tempering. The nature of the heat treatment, the depth of hardening, the hardening temperatures, the quenching media and the hardness range (min/max) shall be stated in the specification.

4.2.3 Nitriding steels shall be quenched and tempered prior to nitriding. Where possible, nitriding shall be effected by the action of gases. The nature of the heat treatment, the nitriding depth and the hardness range (min/max) shall be stated in a specification.

4.3 The heat treatments and surface hardening processes referred to in 4.2 shall be carried out in such a way as to produce uniform hardening of the depth and hardness stipulated in the specification. GL reserves the right to require the manufacture of samples on which the uniformity, depth and hardness of the surface layer shall be demonstrated.

5. Dimensions, dimensional and geometrical tolerances

The data shown in the drawings relating to the order are applicable.

6. Requirements applicable to the material

6.1 Chemical composition

6.1.1 The chemical composition is subject to the limit values specified in the relevant standard or the approved specification.

6.1.2 Where forgings are to be used for welded wheel assemblies, their composition shall be specially determined to suit the method of welding and shall be submitted to GL for approval.

6.2 Mechanical and technological properties

For quenched and tempered steels, the minimum required values for the yield strength, elongation and reduction in area specified in Tables 3.5 and 3.6 in C. shall be met in relation to the prescribed minimum tensile strength.

For case-hardening steels, the requirements specified in Table 3.8 apply to specimens which have undergone heat treatment together with the forging (coupons).

<table>
<thead>
<tr>
<th>Steel grade</th>
<th>Sample dia. Ø [mm]</th>
<th>Yield strength ReH [N/mm²] min.</th>
<th>Tensile strength Rm [N/mm²]</th>
<th>Elongation A¹ [%] min.</th>
<th>Reduction in area Z¹ [%] min.</th>
<th>Impact energy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>KV¹ [J] min.</td>
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<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>l t, q</td>
</tr>
<tr>
<td>16MnCr5</td>
<td>30</td>
<td>590</td>
<td>780 –1080</td>
<td>10</td>
<td>8</td>
<td>40</td>
</tr>
<tr>
<td>20MnCr5</td>
<td>690</td>
<td>980</td>
<td>1280</td>
<td>8</td>
<td>6</td>
<td>35</td>
</tr>
<tr>
<td>18CrNiMo7-6</td>
<td>785</td>
<td>1080 –1320</td>
<td>8</td>
<td>6</td>
<td>35</td>
<td>27</td>
</tr>
<tr>
<td>16MnCr5</td>
<td>63</td>
<td>440</td>
<td>640 –940</td>
<td>11</td>
<td>9</td>
<td>40</td>
</tr>
<tr>
<td>20MnCr5</td>
<td>540</td>
<td>780 –1080</td>
<td>10</td>
<td>8</td>
<td>35</td>
<td>27</td>
</tr>
<tr>
<td>18CrNiMo7-6</td>
<td>685</td>
<td>980 –1280</td>
<td>8</td>
<td>6</td>
<td>35</td>
<td>27</td>
</tr>
</tbody>
</table>

¹ Orientation of specimen axis: l = longitudinal, t = tangential, q = transverse
6.3 Hardness
For all gear components, the hardness values prescribed for the tooth area in the specification or approval drawing are mandatory.

7. Testing
The following tests shall be performed:

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

7.2 Tensile test on finally heat-treated, induction-hardened and nitrided forgings
The mechanical properties shall be verified by tensile test. Test specimens shall be taken as follows:

7.2.1 Pinions over 200 mm in diameter:
If the diameter in the area of the teeth is greater than 200 mm, a tangential test specimen shall be taken from a position adjoining the tooth area, see Fig. 3.5. If the dimensions of the blank do not allow a specimen to be taken from this position, then a transverse specimen may be taken from an extension of the bearing journal. If the diameter of the bearing journal is 200 mm or less, then a longitudinal specimen may be taken. If the length of the finished tooth system is more than 1250 mm, test specimens shall be taken from both ends of the blank.

7.2.2 Pinions up to 200 mm in diameter:
In the case of small pinions with diameters of up to 200 mm in the area of the teeth, a longitudinal test specimen shall be taken from the bearing journal, see Fig. 3.5.

7.2.3 Gear wheels:
A tangential test specimen shall be taken from gear wheel blanks, see Fig. 3.6.

7.2.4 Wheel rims:
In the case of wheel rims which are normally made by piercing a bar and enlarging the hole by forging or rolling, a tangential test specimen shall be taken, see Fig. 3.7.

7.2.5 Pinion blanks:
From hollow pinion blanks, the length of whose finished tooth system is 1 250 mm or less, a test specimen shall be taken from one end at right angles to the longitudinal axis of the workpiece; where the length of the tooth system is more than 1 250 mm, specimens shall be taken from both ends, see Fig. 3.8.

A distinction is to be made here according to whether the workpiece has been forged as a solid blank and then drilled or has been produced by piercing a rough forging and opening up the hole over a mandrel.

Where the workpiece is drilled, the specimens are considered to be transverse, but where the blank is expanded over a mandrel the specimens are considered to be tangential.
7.3 Tensile test on case-hardening steels

7.3.1 The respective test sections are to be heat-treated together with the associated gear component or the test batch. For this purpose, the test sections are to be machined to a diameter corresponding to the smaller of the following two values:

- \(0.25 \times \text{diameter of tooth system}\)
- 63 mm diameter

If the diameter of the test specimen is less than 63 mm, in agreement with the surveyor a test specimen with standardized dimensions may be used (e.g. 30 mm diameter according to DIN 17210).

Tensile test specimens shall then be taken from the test sections and tested.

7.3.2 The gear manufacturer has the option of producing test sections with a cross section greater than that specified in 7.3.1. However, for the final hardening and tempering the pieces shall be given the specified dimensions.

7.4 Strength differences in the forging

Where two test specimens are taken from large forgings, the difference between the measured tensile strength values may not exceed the magnitudes specified in B.4.2.3.

7.5 Notched bar impact test

Each forging or unit test quantity, as applicable, shall be subjected to the notched bar impact test. The number of sets of specimens (each comprising 3 specimens), the positions in the forgings or test sections from which the specimens are taken and their heat treatment are subject to the provisions of 7.2 and 7.3, as appropriate.

The test may be carried out on Charpy V- or Charpy U-notch samples as chosen by the manufacturer.

7.6 Hardness test

7.6.1 After heat treatment but before the cutting of the teeth, hardness tests are to be carried out on all forgings at the points specified in the approval drawings. Where the length L of the teeth of a gear component exceeds 500 mm, testing shall be performed at both ends of the tooth system.

7.6.2 On all surface-hardened gear parts, additional hardness tests are to be carried out on the teeth after hardening and grinding. The number of measuring points shall be such that compliance with the specified hardness values can be verified over the periphery and the width of the tooth system.

7.6.3 The differences in the values measured at the prescribed points on a forging or on different units within a test batch may not exceed the magnitudes specified in B.4.4.2.

7.7 Test of surface finish and dimensions

The gear manufacturer shall check the surface finish and dimensions of the tooth system. The products shall then be presented to the Surveyor for final inspection and he shall be given the measurement records. For retests by the Surveyor, the gear manufacturer shall hold the necessary measuring instruments in readiness.

7.8 Batchwise testing

Forgings with similar dimensions up to a weight in heat-treated condition of 300 kg which originate from the same heat and form part of the same heat treatment batch may be grouped into test batches in accordance with A.10.2, Table 3.1. Two test sections shall be taken from each test batch for the tensile test and the notched bar impact test. Every forging shall be subjected to a hardness test.

7.9 Non-destructive tests

7.9.1 The manufacturer shall carry out an ultrasonic test on the tooth area of all forgings where the diameter of the tooth system exceeds 200 mm.

7.9.2 The entire tooth system of gear parts with surface-hardened teeth shall be tested for cracks using the magnetic particle or dye penetrant method. The welds of gear wheels built up of separate parts shall be subjected to non-destructive testing of the scope specified at the time of the process approval.

The tests shall be performed in compliance with G.

E. Forgings for Boilers, Pressure Vessels, Process Equipment and Pipelines

1. Scope

1.1 These Rules are applicable to unalloyed and alloy steel forgings for the manufacture of flanges, nozzles, valve housings, socket welding and welding neck components. Steel forgings tough at sub-zero temperatures are subject to F.

1.2 In the case of forgings for steam boilers on vessels sailing under the German flag, the "Technical Rules for Steam Boilers" of series TRD 100 shall be complied with.

2. Suitable grades of steel

The following materials may be used:

2.1 Weldable unalloyed structural steels conforming to EN 10250-2 up to an operating temperature of 300 °C.

2.2 Forgings made of ferritic and martensitic steels with specified properties at elevated temperatures conforming to EN 10222-2.
2.3 Forgings made of weldable fine-grained structural steels conforming to EN 10222-4.

2.4 Austenitic or austenitic-ferritic stainless steel forgings conforming to DIN 17440, EN 10222-5 or "Stahl-Eisen-Werkstoffblatt" (Iron and Steel Material Specification) SEW 400.

2.5 Steel flanges conforming to DIN 2528.

2.6 Steels conforming to other standards or material specifications, provided that they are comparable to the steel grades listed in 2.1 to 2.5 and proof has been furnished of their suitability for the intended application. An initial test of product suitability may be requested for this purpose. Ferritic steels shall additionally satisfy the following minimum requirements.

2.6.1 The elongation (A) shall have the characteristic minimum values for the respective steel grades as specified by GL; however, it shall be not less than 14 % in transverse and tangential direction and not less than 16 % in longitudinal direction.

2.6.2 The impact energy shall have the characteristic minimum values for the respective steel grades as specified by GL; however, it shall be not less than 27 J in transverse and tangential direction and 39 J in longitudinal direction at room temperature in tests conducted with Charpy V-notch specimens. This value is an average value from three tests, in which one individual value may be below the prescribed average value but not less than 70 % of the average value.

3. Heat treatment and condition of supply

All forgings shall be supplied in a heat treated condition appropriate to the grade of steel. In the case of unalloyed steel grades, normalizing may be replaced by an equivalent method of temperature control during or after forging or rolling, provided that GL has approved the method.

If parts are manufactured from bars or plates by machining, heat treatment of the starting material is sufficient.

4. Requirements applicable to the material

4.1 General requirements

The chemical composition, mechanical properties, and impact energy and hardness values of the steel shall conform to the standards stated in 2.1 to 2.5 or, where applicable, the data contained in the approved specifications.

4.2 Weldability

Steels conforming to these Rules shall be weldable by established workshop methods. Depending on the chemical composition, preheating and/or post-weld heat treatments may be required for this purpose.

4.3 Resistance to intercrystalline corrosion

Austenitic steel grades shall be resistant to intercrystalline corrosion in the condition in which they are supplied. If forgings for welded assemblies (e.g. weld-on valves, flanges) are to be used without post-weld heat treatment, steel grades which are corrosion-resistant in this condition as well shall be selected, e.g. steels stabilized with Ti or Nb or steels with carbon contents of C \( \leq 0.03 \) %.

5. Testing

The forgings shall be presented for testing in finished condition (condition of supply) and shall undergo the following tests. With regard to forgings for steam boilers, 1.2 shall be complied with.

5.1 Tensile testing

5.1.1 The mechanical properties shall be verified by a tensile test. For preparing the test specimens, forgings with similar dimensions and nominal weights up to 1 000 kg which originate from the same heat and form part of the same heat treatment batch may be grouped into test batches in accordance with A.10.2, Table 3.1. For normalized forgings, one specimen shall be taken from each test batch, while for forgings in other heat-treated conditions, 2 specimens shall be taken from each test batch. For quantities of \( \leq 10 \), and \( \leq 30 \) in the case of nominal weights not exceeding 15 kg, one specimen is sufficient.

5.1.2 For batchwise testing, the hardest and softest forgings in each batch shall be selected for testing, see 5.3.

5.1.3 In the case of forgings with unit weights of more than 1 000 kg, a test specimen shall be taken from every forging.

5.2 Notched bar impact test

The forgings shall be subjected to the notched bar impact test. The number of sets of test specimens (3 Charpy V-notch specimens per set) shall be determined in the same way as the number of tensile test specimens.

5.3 Hardness tests

5.3.1 In the case of quenched and tempered forgings, with the exception of flanges with standardized dimensions, a hardness test shall be performed on each forging.

5.3.2 Flanges with standardized dimensions shall be subjected to the following scope of testing:

- normalized steels: at least 3 %,
- quenched and tempered, and austenitic-ferritic steels: at least 10 % of the same test batch

5.3.3 In the case of parts not mentioned in paragraphs 5.3.1 and 5.3.2, at least 20 % of each test batch shall be tested.
5.4 Test of surface finish and dimensions
The manufacturer shall test the surface finish and dimensions of the products and shall then present the parts to the Surveyor for final acceptance testing.

5.5 Test for use of correct material
Alloy steel forgings shall be subjected by the manufacturer to appropriate tests to ensure that the correct material has been used.

5.6 Non-destructive testing
Forgings with a nominal weight of over 300 kg shall be subjected by the manufacturer to an ultrasonic test and, where necessary, a supplementary test for surface cracks. The tests shall be performed in compliance with G.

5.7 Testing of resistance to intercrystalline corrosion
The manufacturer shall check the resistance to intercrystalline corrosion of austenitic and austenitic-ferritic steel forgings intended for welded assemblies and, where stipulated in the order, of other austenitic steels as well. Testing shall be carried out in the following conditions:

- steels containing $C \leq 0.03\%$ and stabilized steels: after sensitizing heat treatment (700 °C, 30 min, quenching in water)
- all other steels: in the condition of supply. At least two specimens from each heat shall be tested in accordance with a recognized standard (e.g. ISO 3651-2).

F. Steel Forgings Tough at Sub-Zero Temperatures

1. Scope

1.1 These Rules are applicable to steel forgings tough at sub-zero temperatures and high-strength, quenched and tempered steel forgings which are intended for cargo and processing equipment on gas tanks, e.g. flanges, valve parts, weld-on and socket welding parts.

1.2 In the case of forgings which are intended for pressure-liquefied ammonia at design temperatures not lower than 0 °C, e.g. forged flanges, rings and connections, the boundary values given in Section 1, F.8.1.1, Table 1.18 for chemical composition and in Section 1, F.8.2.2 for mechanical properties are to be observed. The required values for impact energy given in Section 1, F.8.3 shall also apply.

1.3 In the case of high-strength, quenched and tempered fine-grained structural steel forgings having nominal yield strengths of between 420 and 690 N/mm² which are designed for gas tanks with design temperatures no lower than 0 °C, the requirements according to 1.2 apply.

2. Approved steel grades
The following grades of steel may be used within the minimum design temperature limits specified in Table 3.9, provided that they satisfy the requirements of 5.

2.1 Standardized steels conforming to Table 3.9.

2.2 Other steels conforming to other standards or material specifications, provided that they are comparable with the steel grades specified in 2.1 and proof has been furnished of their suitability for the intended application. An initial approval test may be required for this purpose.

3. Heat treatment and condition of supply
All forgings shall be supplied in a heat-treated condition appropriate to the grade of steel, i.e. normalized, quenched and tempered, or solution-annealed and quenched.

If parts are manufactured from bars or plates by machining, heat treatment of the starting material is sufficient.

4. Dimensions, dimensional and geometrical tolerances
The data in the standards or specifications are applicable.

5. Requirements applicable to the material

5.1 General requirements
The chemical composition, the mechanical properties and the hardness shall conform to the data contained in the relevant standards or approved specifications.

5.2 Weldability
Steels conforming to these Rules shall be weldable by established workshop methods.

5.3 Impact energy at low temperatures
The required impact energy values specified in Table 3.10 for the grade of steel concerned shall be met at the test temperatures specified in the table, using Charpy V-notch specimens.

5.4 Resistance to intercrystalline corrosion
Austenitic steel grades shall be resistant to intercrystalline corrosion in the condition in which they are supplied. If forgings are to be used for welded assemblies (e.g. weld-on valves, flanges) without post-weld heat treatment, steel grades which are corrosion-resistant in this condition as well shall be selected, e.g. steels stabilized with Ti or Nb or steels with carbon contents of $C \leq 0.03\%$. 
### Table 3.9  Approved grades of forging steels tough at sub-zero temperatures

<table>
<thead>
<tr>
<th>Type of steel</th>
<th>Approved minimum design temperature</th>
<th>Steel grade or Material no.</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weldable fine-grained structural steels</td>
<td>–20 °C ¹</td>
<td>P285NH</td>
<td>EN 10222-4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>P285QH</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>P355N</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>P355QH</td>
<td></td>
</tr>
<tr>
<td>0.5 % nickel steel</td>
<td>–55 °C</td>
<td>13MnNi6-3</td>
<td>EN 10222-3</td>
</tr>
<tr>
<td>2.25 % nickel steel</td>
<td>–65 °C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.5 % nickel steel</td>
<td>–90 °C</td>
<td>12Ni14</td>
<td>EN 10222-3</td>
</tr>
<tr>
<td>5 % nickel steel</td>
<td>–105 °C</td>
<td>12Ni19</td>
<td></td>
</tr>
<tr>
<td></td>
<td>–165 °C</td>
<td>X12Ni5</td>
<td></td>
</tr>
<tr>
<td>9 % nickel steel</td>
<td>–165 °C</td>
<td>X8Ni9</td>
<td></td>
</tr>
<tr>
<td>Austenitic steel</td>
<td>–165 °C</td>
<td></td>
<td>EN 10222-5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.4301 (304)³</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.4307 (304 L)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.4401 (316)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.4404 (316 L)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.4541 (321)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.4550 (347)</td>
<td></td>
</tr>
</tbody>
</table>

¹ Lower design temperatures may be established by means of an approval test.
² The minimum design temperature of –165 °C is only valid if this has been demonstrated by an approval test.
³ The numbers in brackets denote comparable steels conforming to AISI standards.

### Table 3.10  Required impact energy values for steel forgings tough at sub-zero temperatures

<table>
<thead>
<tr>
<th>Type of steel</th>
<th>Test temperature</th>
<th>Impact Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weldable fine-grained structural steels and 0.5 % nickel steel</td>
<td>5 K below minimum design temperature but at least –20 °C</td>
<td>KV [J]¹ min.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>longitudinal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>27 (19)</td>
</tr>
<tr>
<td>2.25 % nickel steel</td>
<td>–70 °C</td>
<td></td>
</tr>
<tr>
<td>3.5 % nickel steel</td>
<td>–95 °C</td>
<td></td>
</tr>
<tr>
<td>5 % nickel steel</td>
<td>–110 °C</td>
<td>34 (24)</td>
</tr>
<tr>
<td>5 % nickel steel</td>
<td>–196 °C</td>
<td></td>
</tr>
<tr>
<td>9 % nickel steel</td>
<td>–196 °C</td>
<td></td>
</tr>
<tr>
<td>Austenitic steels</td>
<td>–196 °C</td>
<td>41 (27)</td>
</tr>
</tbody>
</table>

¹ Average value measured on 3 Charpy V-notch specimens; the figures in brackets indicate the minimum individual value.
² The test temperature of –196 °C applies if the 5 % nickel steel has been approved for a minimum design temperature of –165 °C.
6. **Testing**

The forgings shall be presented for testing in the finished condition (condition of supply) and subjected to the tests specified below.

6.1 **Tensile test**

6.1.1 The mechanical properties shall be tested by tensile test. For preparing the test specimens, forgings with similar dimensions and nominal weights up to 1 000 kg which originate from the same heat and form part of the same heat treatment batch may be grouped into test batches in accordance with A.10.2, Table 3.1.

For normalized forgings, one specimen shall be taken from each test batch, while for forgings in other heat-treated conditions, 2 specimens shall be taken from each test batch. For quantities of ≤ 10 - and ≤ 30 in the case of nominal weights not exceeding 15 kg - one specimen is sufficient.

6.1.2 For the batchwise testing, the hardest and softest forgings in each batch shall be selected for testing, see 6.3.

6.1.3 In the case of forgings with unit weights of more than 1 000 kg, a test specimen shall be taken from every forging.

6.2 **Notched bar impact test**

The forgings shall be subjected to the notched bar impact test using Charpy V-notch specimens. The number of sets of test specimens (3 specimens per set) shall be determined in the same way as the number of tensile test specimens. The tests shall be performed at the test temperatures specified in Table 3.10.

6.3 **Hardness testing**

6.3.1 In the case of forgings in quenched and tempered condition, with the exception of flanges with standardized dimensions, a hardness test shall be performed on every forging.

6.3.2 Flanges with standardized dimensions shall be subjected to the following scope of testing:

- Normalized steels: at least 3 %,
- quenched and tempered, austenitic and austenitic-ferritic steels: at least 10 % of the same test batch

6.3.3 In the case of parts not mentioned in 6.3.1 and 6.3.2, at least 20 % of each test batch shall be tested.

6.4 **Test of surface finish and dimensions**

The manufacturer shall test the surface finish and dimensions of the products and then present the parts to the Surveyor for final acceptance testing.

6.5 **Test for use of correct material**

Alloy steel forgings shall be subjected by the manufacturer to appropriate tests to ensure that the correct material has been used.

6.6 **Non-destructive testing**

Forgings with a nominal weight of over 300 kg shall be subjected by the manufacturer to an ultrasonic test and, where necessary, a supplementary test for surface cracks. The test shall be performed in compliance with G.

6.7 **Test of resistance to intercrystalline corrosion**

The manufacturer shall check the resistance to intercrystalline corrosion of austenitic steel forgings intended for welded assemblies and - where stipulated in the order - other austenitic steels as well. Testing shall be carried out in the following conditions:

- steels containing C ≤ 0,03 % and stabilized steels: after sensitizing heat treatment (700 °C, 30 min, quenching in water)
- all other steels: in the condition of supply. At least two specimens from each heat shall be tested in accordance with a recognized standard (e.g. ISO 3651-2).

G. **Non-destructive Testing of Forged Components**

1. **Scope of validity**

1.1 These Rules apply to the non-destructive testing of forged components for which in B. to F. appropriate requirements are prescribed, and for which no other regulations or manufacturer specifications are agreed upon.

A list containing the forged components for which non-destructive testing is required and the specific tests to be performed is contained in H.

1.2 The general requirements for inspection bodies, inspection personnel, testing methods and certification of the results are prescribed in Chapter 1 – Principles and Test Procedures, Section 3 and are mandatory for all tests.

1.3 The methods indicated in these Rules concerning the magnetic particle test and ultrasonic tests are limited to the application of forged components made of ferritic steel grades.

For forged components made of austenitic or austenitic-ferritic steel grades the methods and acceptance criteria for the ultrasonic and penetrant tests shall be agreed upon with GL individually. This may be performed based on standards or specifications from the manufacturer or the orderer.

1.4 Taking into account the prescriptions in 1.3, in these Rules the following testing methods are described, see Table 3.11.
Table 3.11 Test methods

<table>
<thead>
<tr>
<th>Testing of</th>
<th>Method</th>
<th>Short name (^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>External condition</td>
<td>Visual testing</td>
<td>VT</td>
</tr>
<tr>
<td></td>
<td>Magnetic particle testing (^1)</td>
<td>MT</td>
</tr>
<tr>
<td></td>
<td>Penetrant testing</td>
<td>PT</td>
</tr>
<tr>
<td>Internal condition</td>
<td>Ultrasonic testing</td>
<td>UT</td>
</tr>
</tbody>
</table>

\(^1\) only for forged components made of ferritic steel grades
\(^2\) definition according to DIN EN 473

1.5 The methods and testing criteria indicated in G. are to be employed by the manufacturers and companies performing the further processing.

In case the orderer wants further regulations to be applied on specific forged components e.g. for engines and turbines, he shall state this in a test specification and make this known to the GL Surveyor.

Alternatively, non-destructive testing may be performed in accordance with test specifications from the manufacturer or the orderer on condition that the methods and acceptance criteria fulfill the following requirements.

1.6 For testing, the forged components shall be classified in inspection zones of type I, II and III, according to the possible effects of defects on the structural integrity. For magnetic particle testing there will be the addition of type IV. In inspection zone I the allowable number and size of indications are the smallest.

For classifying in inspection zones the following principles are decisive:

- the operation loads to be expected
- the effects of the defects on the reliability of the component
- possible risk of damage if the component fails
- Freedom of defects and surface condition after the final machining

For the most important forged components of the propulsion plant the classifying in inspection zones is prescribed in I. and J.

1.7 For forgings where in I. for magnetic particle testing and in J. for ultrasonic testing no classifying in inspection zones is indicated, the manufacturer or orderer shall prescribe the inspection zones in a test specification taking into consideration the principles in 1.6 and shall be make them known to the GL Surveyor.

Further, the test specification shall contain details concerning the required acceptance criteria (e.g. quality class according to EN 10228-1, -2, -3).

2. Performing the tests

2.1 After the inspector of the internal or external inspection body in charge of testing has performed the prescribed tests, the final machined forged components shall be presented to the GL-Surveyor for visual testing.

2.2 Concerning the tests it shall be differentiated between pre-testing and acceptance testing. With pretests, where decisions concerning the testability and the employability of the forged component are made, they are in general the business of the manufacturer.

Acceptance tests shall be performed preferably on the final machined component after the heat treatment appropriate for the required properties has been performed.

If necessary acceptance tests may be performed at a production stage with little machining allowance, and for ultrasonic testing after pre-machining in a condition with less contours.

Details for this are to be prescribed in a test specification and to be made known to GL.

2.3 The Surveyor shall be informed by the manufacturer or the company performing the further processing about the intended tests. It is up to the discretion of the Surveyor to attend the tests.

2.4 The tests shall be performed for the zones described for the forged components in H. and J., or for those indicated in the test specification. In case the results indicate that further defects are present in the forged component, the test scope shall be extended according to agreement with the Surveyor.

2.5 Indications exceeding the allowable size, number and position indicated in the tables shall be removed if technically possible. Excavated areas at the surface are to be subjected to retesting.

2.6 In case internal defects or defects close to the surface cannot be removed by grinding with satisfactory results, the manufacturer, the orderer and the GL-Surveyor shall decide on the employability of the forged component.

3. Visual testing (VT)

3.1 The manufacturer shall verify for each production stage of the forged components the external condition and the compliance of the dimensions. Forging defects are to be removed, unless they are removed by the following machining.

3.2 For the acceptance test the forged component are to be presented to the Surveyor in final machined condition.
If necessary an inspection of forged components in raw condition or in premachined condition by the GL-Surveyor can be agreed on.

3.3 Discontinuities of the material such as cracks, forging laminations or inclusions open towards the surface are not allowed and shall be repaired. The repaired areas shall be subjected to additional surface crack detection.

3.4 The Surveyor certifies the visual inspection on the GL acceptance test certificate. E.g. the following text can be typed in the test certificate:

"The aforementioned forged components were visually tested.

The prescribed requirements are fulfilled."

3.5 On demand of the orderer the manufacturer shall issue an inspection certificate according to EN 10204-3.1 containing the details of the tests and the test results.

4. Magnetic particle testing (MT)

4.1 The surfaces to be tested shall be free of scale, grease, dirt and protecting paint as well as other contaminations which may affect the detection of indications.

4.2 The roughness of the machined test areas shall not exceed an average roughness of Ra = 12,5 μm for premachined surface, and Ra = 6,3 μm for final machined surface.

4.3 Contact points visible on the surface are to be ground and to be retested by yoke magnetization if they will not be removed by the following machining. It is not allowed to employ prods on final machined surfaces.

4.4 In case deviant of 2.1, tests have to be performed before final machining, e.g. before bore holes or lubricating oil channels are realized. This shall be indicated in the test instructions. The acceptance test will be performed by the Surveyor after the final machining of the component.

4.5 The indications of magnetic particle testing shall be evaluated depending on the specific inspection zone I to IV (cf. 1.6) concerning their size and number in accordance with Table 3.12. The reference area for this shall be a rectangle with 148 mm × 105 mm (size DIN A6) and shall be placed on the specific most unfavourable area for each case (area with the highest number of indications).

4.6 Concerning the evaluation it shall be differentiated between isolated and aligned indications. These terms are explained in Fig. 3.9.

4.7 All indications exceeding the registration levels indicated in Table 3.12 are to be reported.

Where indications concerning their size and number exceed the indicated values for the appropriate inspection zone (or the appropriate class of quality according to EN 10228-1, respectively), as well as cracks, open forging laps and discontinuities are to be regarded as defects and shall be removed.

4.8 For the circumferential surfaces of grooves and oil bore holes of crankshafts indications of every type in zone I are not allowed.

4.9 In case doubts exist whether an indication is generated by a crack, additional penetrant testing shall be performed.

Table 3.12 Acceptance criteria for magnetic particle testing according to EN 10228-1

<table>
<thead>
<tr>
<th>Parameter for evaluation</th>
<th>Acceptance limits for inspection zone</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IV</td>
</tr>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Recording level: length of indications [mm]</td>
<td>≥ 5</td>
</tr>
<tr>
<td>max. allowed length L_g of aligned or isolated indications [mm]</td>
<td>20</td>
</tr>
<tr>
<td>max. allowed cumulative length of indications L_k [mm]</td>
<td>75</td>
</tr>
<tr>
<td>max. allowed number of indications on the reference area</td>
<td>15</td>
</tr>
</tbody>
</table>

1 Class of quality not applicable for testing of surfaces with machining allowance exceeding 3 mm.
2 Class of quality not applicable for testing of surfaces with machining allowance exceeding 1 mm.
3 Class of quality not applicable for surfaces of fillets and oil hole bores of crankshafts (cf. G.4.8).
4.10 Repair of defects

Defects are to be removed by suitable measures. In doing so it shall be ensured that the dimensions of the forged component will not exceed the prescribed tolerances. Removal of a defect by grinding shall be performed perpendicular to the defect in such a way that the end of the groove is prepared in a longitudinal direction and smoothly blends to the adjacent surface. The transition radius shall be at least three times the groove depth.

4.11 After the removal of defects by grinding the ground areas are to be subjected again to magnetic particle testing.

4.12 The evaluation of excavated areas concerning their size and position in the specific inspection zones shall be performed by means of manufacturer and/or orderer specifications. If the dimensions fall below the minus tolerances the consent of the Surveyor shall be requested.

5. Penetrant testing (PT)

5.1 The surfaces to be tested shall be free of scale, grease, dirt and protecting paint as well as other contaminations which may affect the detection of indications.

5.2 Penetrant testing is to be performed on forged components made of austenitic or austenitic-ferritic steel grades. It may be performed on forged components made of ferritic steel grades in addition to magnetic particle testing (MT), nevertheless the results of the magnetic particle tests are decisive concerning the acceptance criteria.
5.3 Testing is to be performed in accordance with Chapter 1 – Principles and Test Procedures, Section 3, K, or with other recognized standards such as e.g. EN 571-1 and ISO 3452-2 or EN 10228-2 "Non-destructive testing of steel forgings, Part 2, Penetrant testing".

5.4 The manufacturer shall prepare a test instruction which shall contain at least the following information:
- details of the forged component including the material grade
- standards and specifications to be applied
- description of the test method
- employed testing agent system
- qualification of the inspection personnel
- surface areas to be tested
- required surface condition
- test criteria
- type of testing report

5.5 Unless otherwise agreed the testing according to Chapter 1 – Principles and Test Procedures, Section 3, J, shall be performed on the final machined forged component and shall be performed in the presence of the Surveyor.

6. Ultrasonic testing (UT)

6.1 In the areas to be tested an appropriate surface condition shall be achieved which enables a faultless coupling of the probe. Forging fin, scale, paint, dirt, unevenness and mechanical damages shall be removed/corrected.

6.2 For premachined surfaces the average value of the roughness shall be $R_a \leq 25 \mu m$. It is recommended to agree on the appropriate class of quality for the surface roughness according to Table 3.13.

6.3 The tests are to be performed in accordance with Chapter 1 – Principles and Test Procedures, Section 3, L. Unless otherwise agreed it may also be performed according to EN 583-1, SEP 1921, SEP 1923, EN 10228-3 and/or other equivalent and recognized standards, manufacturer or orderer specifications.

6.4 Unless no other recording levels were agreed on, all indications exceeding a KSR $^1$ with diameter $\geq 2 \text{ mm}$ shall be registered and evaluated and reported concerning their position, size, number and acceptability.

6.5 For indications which shall be registered, the amplitude of the back wall echo in the area of the indication is to be compared with the adjacent areas free of indications.

Attenuations of the back wall echo with $\geq 4 \text{ dB}$ are to be recorded in the testing report in dB.

6.6 Cracks of any type, size and distribution are not allowed.

6.7 Indications exceeding the limiting values contained in Table 3.14 or 3.15, are to be regarded as defects and in the first instance result in rejection of the forged component by the Surveyor. If the tests are performed in accordance with a manufacturer or orderer specification approved by GL then the limiting values indicated there are decisive and the procedure is accordingly.

6.8 The acceptance of the forged component which in the first instance had been rejected is possible on condition that after further evaluation of the indications performed by the orderer and the Surveyor proof has been furnished that due to their size, position and distribution the defects have no considerable effect on utilization of the forged component. In this case the acceptance of the forged component shall be approved by an acceptance test certificate by both the orderer and the Surveyor.

1 KSR = disc shaped reflector (= Kreisscheibenreflektor)

---

### Table 3.13 Recommendations for the surface quality

<table>
<thead>
<tr>
<th>Surface quality</th>
<th>Class of quality and roughness $R_a$ [μm]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>$\leq 25$</td>
</tr>
<tr>
<td>machined</td>
<td>×</td>
</tr>
<tr>
<td>machined and heat treated</td>
<td>×</td>
</tr>
<tr>
<td>forged</td>
<td>×</td>
</tr>
</tbody>
</table>

*Note*

"×" indicates the class of quality which can be achieved with the prescribed roughness.
Table 3.14  Acceptance criteria for ultrasonic testing of forged components

<table>
<thead>
<tr>
<th>Forged component</th>
<th>Zone</th>
<th>Size of the max. allowable KSR (^1) [mm]</th>
<th>Max. allowable length of indications (^3) [mm]</th>
<th>Min. distance between two indications (^3) [mm]</th>
<th>Total of all indication lengths [mm] per &quot;m&quot; component length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propeller shafts</td>
<td>I 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intermediate shafts</td>
<td>II 2</td>
<td>outside: 2 10 10</td>
<td></td>
<td></td>
<td>0,05 \cdot d</td>
</tr>
<tr>
<td></td>
<td></td>
<td>inside: 4 15 10</td>
<td></td>
<td></td>
<td>0,10 \cdot d</td>
</tr>
<tr>
<td>Thrust shafts</td>
<td>III 2</td>
<td>outside: 3 10 10</td>
<td></td>
<td></td>
<td>0,15 \cdot d</td>
</tr>
<tr>
<td></td>
<td></td>
<td>inside: 6 15 10</td>
<td></td>
<td></td>
<td>0,20 \cdot d</td>
</tr>
<tr>
<td>Rudder stocks and pintles</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Piston rods (^4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Connecting rods (^5)</td>
<td>I</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Piston rods</td>
<td>II</td>
<td>2 10 10</td>
<td></td>
<td></td>
<td>0,05 \cdot d</td>
</tr>
<tr>
<td>Cross heads</td>
<td>III</td>
<td>4 10 10</td>
<td></td>
<td></td>
<td>0,15 \cdot d (s) (^5)</td>
</tr>
</tbody>
</table>

1 KSR = disc shaped reflector
2 The classifying in inspection zones is depicted in Fig. 3.15 to 3.20.
3 For accumulations of 2 or more isolated indications to be recorded the minimum distance between 2 adjacent indications shall be at least of length of the major indication.
   This applies to distances in axial as well as in thickness direction.
   Isolated indications with smaller distance are to be regarded as aligned indication.
4 Piston rods with shaft diameter larger than 150 mm.
5 For rectangular cross-section "d" corresponds to the smallest side length "s".

Table 3.15  Acceptance criteria for ultrasonic testing of crank shafts

<table>
<thead>
<tr>
<th>Zone (^2)</th>
<th>Size of the max. allowable KSR (^1) [mm]</th>
<th>Max. allowable length of indications [mm]</th>
<th>Min. distance between two indications (^3) [mm]</th>
<th>Max. number of isolated indications (^3, 4) ([-)</th>
<th>Total of all indication length [mm] (^4) per pin or journal, or per web or flange, respectively</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>2 10 10</td>
<td></td>
<td>0,01 \cdot d (D) \cdot \frac{1}{\text{mm}}</td>
<td>0,20 \cdot d (D)</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>4 15 10</td>
<td></td>
<td>0,02 \cdot d (D) \cdot \frac{1}{\text{mm}}</td>
<td>0,40 \cdot d (D)</td>
<td></td>
</tr>
</tbody>
</table>

1 KSR = disc shaped reflector
2 The classifying in inspection zones is depicted in Fig. 3.21.
3 For accumulations of 2 or more isolated indications to be recorded the minimum distance between 2 adjacent indications shall be at least of length of major indication.
   This applies to distance in axial as well as in thickness direction.
   Isolated indications with smaller distance are to be regarded as aligned indication.
4 Related to be diameter of crank pin "d" or to the diameter of main journal "D", respectively.
### H. List of Forged Components for which Non-destructive Tests are Required

<table>
<thead>
<tr>
<th>Name of the forged component</th>
<th>Test method to be employed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>VT</td>
</tr>
<tr>
<td><strong>Structural parts concerning the hull:</strong></td>
<td></td>
</tr>
<tr>
<td>rudder stocks and pintles</td>
<td>X</td>
</tr>
<tr>
<td><strong>Parts for diesel engines:</strong></td>
<td></td>
</tr>
<tr>
<td>– crank shafts</td>
<td>X</td>
</tr>
<tr>
<td>– connecting rods</td>
<td>X</td>
</tr>
<tr>
<td>– piston rods</td>
<td>X</td>
</tr>
<tr>
<td>– crossheads</td>
<td>X</td>
</tr>
<tr>
<td>– piston crowns</td>
<td>X</td>
</tr>
<tr>
<td>– cylinder covers</td>
<td>X</td>
</tr>
<tr>
<td>– piston pins</td>
<td>X</td>
</tr>
<tr>
<td>– tie rods</td>
<td>X</td>
</tr>
<tr>
<td>– bolts ≥ M50 for:</td>
<td></td>
</tr>
<tr>
<td>– main bearing</td>
<td>X</td>
</tr>
<tr>
<td>– connecting rod bearing</td>
<td>X</td>
</tr>
<tr>
<td>– cross heads</td>
<td>X</td>
</tr>
<tr>
<td>– cylinder covers</td>
<td>X</td>
</tr>
<tr>
<td>– camshaft drive gear wheels and chain wheels</td>
<td>X</td>
</tr>
<tr>
<td><strong>Main shafting and gears:</strong></td>
<td></td>
</tr>
<tr>
<td>– propeller shafts</td>
<td>X</td>
</tr>
<tr>
<td>– intermediate shafts</td>
<td>X</td>
</tr>
<tr>
<td>– thrust shafts</td>
<td>X</td>
</tr>
<tr>
<td>– gear wheels</td>
<td>X</td>
</tr>
<tr>
<td>– gear shafts</td>
<td>X</td>
</tr>
<tr>
<td>– pinions</td>
<td>X</td>
</tr>
<tr>
<td>– wheel rims</td>
<td>X</td>
</tr>
<tr>
<td><strong>Turbo machinery (main drive):</strong></td>
<td></td>
</tr>
<tr>
<td>– rotors</td>
<td>X</td>
</tr>
<tr>
<td>– rotor discs</td>
<td>X</td>
</tr>
<tr>
<td>– shafts</td>
<td>X</td>
</tr>
<tr>
<td>– blades guide vanes and blades</td>
<td>X</td>
</tr>
<tr>
<td>– turbine casing bolt ≥ M50</td>
<td>X</td>
</tr>
<tr>
<td><strong>Other components:</strong></td>
<td></td>
</tr>
<tr>
<td>– shafts for e-engines (main)</td>
<td>X</td>
</tr>
<tr>
<td>– forged components</td>
<td>X</td>
</tr>
<tr>
<td>– made of steels for use at elevated temperatures</td>
<td>X</td>
</tr>
<tr>
<td>– made of steels tough at sub-zero temperatures</td>
<td>X</td>
</tr>
<tr>
<td>– bolts for fixing of propeller blades ≥ M50</td>
<td>X</td>
</tr>
<tr>
<td>– bolts for superheated steam pipelines</td>
<td>X</td>
</tr>
</tbody>
</table>

1 for diameters ≥ 250 mm
2 for diesel engines with cylinder diameter > 400 mm
3 for batchwise testing of small crankshafts ultrasonic testing of the prematerial is sufficient. Small crankshafts are those with gross weights not exceeding 500 kg.
4 for diameter of the gearing or of the shafts > 200 mm
5 for finished weights > 300 kg
6 for austenitic or austenitic-ferritic steels penetrant testing (PT) instead of magnetic particle testing (MT)
7 for main steam temperatures > 350 °C
8 Instead of surface crack testing (MT, PT) eddy current testing may be considered, too.
I. Classifying of Inspection Zones for Magnetic Particle Testing (MT)

![Diagram of Shaft Inspection Zones]

- **L** = Length of the tapered portion

(a) Propeller shaft

(b) Intermediate shaft

(c) Thrust shaft

**Note**

- For principles for classifying in inspection zones I to IV see G.1.6
- Acceptance criteria are contained in G. table 3.12

Fig. 3.10  Inspection zones for magnetic particle testing of shafts
Fig. 3.11 Inspection zones for magnetic particle testing of rudder stocks and accessories
Fig. 3.12  Inspection zones for magnetic particle testing of machinery components
Note

Threads, oil bore holes and their radii are to be regarded as zone I in the regime of $2 \cdot d_B$.

$d_B = Bore\ hole\ diameter$

Fig. 3.13  Inspection zones for magnetic particle testing of machinery components
Fig. 3.14  Inspection zones for magnetic particle testing of crank shafts

Note
1. Areas of $2 \cdot db$ around lubricant bore holes of crank pin or journal are to be regarded as zone I (sketch to the right).

2. Explanations to the upper figures:
   - $\theta = 60^\circ$
   - $a = 1.5 \cdot r$
   - $b = 0.05 \cdot d$ (Peripheral area of the shrinkage fit)
   - as well as
   - $r =$ Radius of the groove
   - $d =$ Pin or journal diameter

3. Identification of the zones:

<table>
<thead>
<tr>
<th>Color</th>
<th>Zone</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Zone I</td>
</tr>
<tr>
<td></td>
<td>Zone II</td>
</tr>
</tbody>
</table>

4. The above mentioned classifying applies accordingly to forged throws.
J. Classifying of Inspection Zones for Ultrasonic Testing (UT)

![Scanning directions diagram]

(a) Propeller shaft

(b) Intermediate shaft

(c) Thrust shaft

Note
1. UT in premachined rotation symmetric condition before machining the taper and threading.
2. For hollow shafts: 360° radial scanning applies to Zone II.
3. Circumferences of the bolt holes in the flanges are to be treated as Zone II.

Fig. 3.15 Inspection zones for ultrasonic testing of shafts
Fig. 3.16 Inspection zones for ultrasonic testing of rudder stocks and accessories

Scanning directions for Type A and Type B

(a) Type A

(b) Type B

Note
1. Welded areas are to be regarded as zone II
2. $d =$ Diameter of shaft
Fig. 3.17 Inspection zones for ultrasonic testing of rudder stocks and accessories

Note
Testing in premachined rotation symmetric condition before machining the taper and threading
**Fig. 3.18  Inspection zones for ultrasonic testing of machinery components**

*Note*

1. UT of pinion shafts with $D \geq 200$ mm, in premachined condition before machining the gear tooth
2. For zone I $360^\circ$ radial and $90^\circ$ axial scanning direction applies
Fig. 3.19  Inspection zones for ultrasonic testing of machinery components
Fig. 3.20  Inspection zones for ultrasonic testing of machinery components
Fig. 3.21   Inspection zones for ultrasonic testing of crank shafts

**Note**

1. Explanations to the upper figures:
   - $a = 0.1 \ d$ or 25 mm, whichever greater
   - $b = 0.05 \ d$ or 25 mm, whichever greater (position of shrinkage fit)
   - $d$ = Pin or journal diameter.

2. Core areas of crank pins and/or journals within a radius of 0.25 $d$ between the webs are to be regarded as zone II.

3. Identification of the zones:
   - : Zone I
   - : Zone II
   - : Zone III

---

**Scanning directions**

**Section A-A**

(a) Solid crankshaft

**Section B-B**

(b) Semi built-up crankshaft
Section 4

Cast Steel

A. General Rules

1. Scope

This Part contains general rules to be applied in the manufacture and testing of steel castings. Also applicable are Chapter 1 – Principles and Test Procedures, Sections 1 – 3.

2. Selection of grades of cast steel

2.1 All cast steel shall be suitable for the intended application and shall satisfy the minimum requirements specified in the following individual Rules. Subject to these conditions, grades of cast steel conforming to the relevant standards or to the material specifications approved by GL may be used.

2.2 The grades of cast steel shall be identified by the standardized designations or the designations given in the specifications.

3. Requirements to be met by foundries

3.1 Foundries wishing to supply castings in accordance with these Rules shall be approved by GL. This is conditional upon their fulfilling the manufacturing and quality control requirements stated in Chapter 1 – Principles and Test Procedures, Section 1, C. and furnishing proof of this to GL prior to the commencement of supplies.

3.2 Irrespective of the requirements stated in 3.1, the manufacturer shall demonstrate by approval tests carried out on the products that these can be manufactured in accordance with the conditions imposed. The scope of these tests will be determined by GL.

4. Method of manufacture

4.1 Cast steel shall be produced in an electric furnace, by a basic oxygen process, in an induction furnace or by other methods approved by GL. On request, the steel-making process shall be made known to GL for approval.

4.2 Where castings are produced by welding together two or more separate components, details of the method shall be submitted for approval. This normally calls for a test of the welding procedure.

5. Condition of supply, heat treatment

5.1 All castings shall undergo heat treatment appropriate to the material. The heat treatments shall be performed in suitable furnaces. The dimensions of the furnace shall enable the entire casting to be raised uniformly to the required heat treatment temperature. Where, in the case of large castings, the size of the furnace does not allow the entire casting to be normalized at once, other arrangements shall be agreed with GL.

5.2 Where, following final heat treatment, a casting is heated locally or undergoes hot or cold straightening, subsequent stress relief heat treatment may be required to remove residual stresses.

5.3 Flame cutting, flame scarfing or flame gouging to remove excess material or feeders shall be carried out by a recognized method prior to final heat treatment. Preheating shall be applied where the chemical composition and/or the thickness of the casting make this necessary. Where required, the heat-affected zones of the casting shall be machined or ground off.

6. General characteristics of castings

6.1 All castings shall have a clean surface compatible with the conditions of manufacture. Minor casting defects such as small sand and slag marks, small cold shuts and small scabs may be trimmed off within the negative tolerance on the wall thickness.

6.2 Defects liable to impair the use and workability of the material to a more than minor degree are not allowed. They may be removed by one of the methods named in 13.

7. Dimensions; dimensional and geometrical tolerances

The dimensions and the dimensional and geometrical tolerances are governed by the values specified in the drawings relating to the order or in the relevant standards, as applicable. Appropriate details shall be made known to the Surveyor.

8. Tightness

All castings which are subjected to internal pressure by the operating medium or for which special proof of impermeability is required shall be leakproof at the specified test pressures after being machined.
9. General requirements applicable to cast materials

9.1 Chemical composition

The chemical composition of grades of cast materials shall conform to limit values specified in the Tables contained in this Section and/or in the relevant standards or specifications, as applicable. The manufacturer shall take suitable measures to ensure that the residual elements remain within the permitted limits.

9.2 Mechanical properties

9.2.1 Tensile test

The tensile characteristics indicated in the Tables contained in this Section or, where applicable, in the relevant standards or specifications shall be verified by tensile test.

9.2.2 Notch bar impact test

The impact energy specified for the various grades of cast steel shall be satisfied by the average value measured on 3 Charpy V-notch or Charpy U-notch test specimens, one of which may give a result below the required average value although it may not be less than 70 % of the required average value.

9.3 Other characteristics

Where special characteristics are specified for particular grades of cast steel, e.g. resistance to intercrystalline corrosion and mechanical characteristics at elevated temperatures, these shall, where necessary, be proved by appropriate tests.

10. Testing

10.1 Testing of chemical composition

The manufacturer shall determine the chemical composition of each heat or, where necessary, of each ladle and shall present corresponding certificates to the Surveyor. Should there be any doubt as to the chemical composition of the products, a product analysis shall be performed.

10.2 Testing of the mechanical properties and the selection of specimens

10.2.1 The mechanical properties shall be ascertained by tensile test to determine tensile strength, yield strength or 0.2 % proof stress, reduction in area and elongation.

The notched bar impact test shall also be performed where specified for particular grades of cast steel.

10.2.2 The tests shall be performed on a heat-by-heat basis. Castings from each heat that undergo the same heat treatment shall be grouped into test batches of up to 4 500 kg. Residual quantities of up to 1 250 kg shall be allocated to the preceding test batch. Parts with unit weights > 1 000 kg shall be tested individually.

If the finished weight exceeds 10 000 kg, at least two test specimens shall be taken. For this purpose, test samples spaced as widely as possible shall be cast integrally with the casting.

10.2.3 For each casting or for each test batch, as applicable, a sufficient number of samples shall be provided which shall normally be cast integrally with the cast component. The number of samples shall be sufficient to provide material for the test specimens needed for possible retests. The sample may only be removed from the casting after the final heat treatment. The thickness of the sample shall be matched to the relevant wall thickness of the casting, but shall be at least 30 mm. In the case of thick-walled steel castings, the sample thickness need not exceed 100 mm.

10.2.4 Where a number of small castings of approximately the same dimensions are produced from the same heat and are heat treated in the same furnace charge, then, notwithstanding the provisions stated in 10.2.3, specimens may be taken from separately cast samples. For this purpose, at least one sample per furnace charge shall be provided, which shall be heat treated together with the castings to which it relates.

10.2.5 If separately cast samples are used, these shall be cast in moulds made of the same moulding material as that used for the castings themselves.

10.2.6 All samples shall be marked in such a way that they can be clearly related to the castings which they represent. The type of marking shall be agreed with the Surveyor.

10.2.7 Where castings are manufactured by a method subject to the special approval of GL, see 4.1, the number and position of the samples shall be specially agreed so as to take account of the method of manufacture.

10.3 Testing of surface finish and dimensions

10.3.1 All castings shall be inspected by the manufacturer for surface finish and compliance with the dimensional and geometrical tolerances and shall then be presented to the Surveyor for final inspection. Inside surfaces are to be included in the inspection.

10.3.2 The surface of the castings shall be free from material from the mould and shall be properly prepared for inspection. Where necessary, this conditions shall be achieved by pickling, local grinding, shot or sand blasting, cleaning with wire brushes or by chemical means. Chipping and hammering are allowed only if this does not conceal surface defects.
10.3.3 Where there is reasonable suspicion that welds have been carried out on a casting, the Surveyor may require certain areas of the surface to be etched in order to reveal possible welds.

10.4 Non-destructive tests

10.4.1 Where non-destructive tests are required, these shall be performed by the manufacturer of the castings and/or the finishing plant. Tests may also be arranged by GL.

10.4.2 Non-destructive tests shall be performed in accordance with the specifications stated in G. to J. in consideration of the specifications in Chapter 1 – Principles and Test Procedures, Section 3.

10.5 Retests in the event of failure

If tensile test specimens fail to meet the required values under test, if the specified average value is not achieved in a notched bar impact test or if an individual value is less than 70% of the required average value, then, before the unit test quantity or the casting is rejected, the procedures for retests prescribed in Chapter 1 – Principles and Test Procedures, Section 2, H. may be applied. The additional test specimens shall be taken either from the same test sample as the original specimen or from other samples which are representative of the casting or of the unit test quantity.

11. Identification and marking of castings

11.1 The manufacturer shall institute a monitoring system enabling all castings to be traced back to the original heat, and this shall be demonstrated to the Surveyor on request.

11.2 Prior to final inspection, all castings shall be provided by the manufacturer in at least one place with the following marks:
- cast steel grade
- manufacturer's mark
- heat number, casting number, casting date or an abbreviated symbol enabling the manufacturing process to be traced
- specimen number
- date of test
- test pressure, where applicable

11.3 In the case of series-manufactured castings, agreement may be reached with the Surveyor to apply marks other than those specified in 11.2.

12. Certificates

For each consignment the manufacturer shall supply to the Surveyor a certificate or delivery specification containing at least the following details:
- purchaser and order number
- newbuilding and project number, as applicable, if known
- nature of castings and grade of cast steel
- purpose and drawing number, if necessary
- item numbers and numbers of units
- weight of delivery
- method of manufacture
- heat numbers
- chemical composition
- condition of supply
- details of heat treatment
- test pressures, where applicable
- results of the mechanical tests
- results of any special tests applied, e.g. non-destructive tests and test of resistance to inter-crystalline corrosion
- condition of surface

13. Repair of defects

13.1 Methods

Defects may be repaired by machining, grinding, flame scarfing or gouging, or by welding. The method is to be agreed with the Surveyor except where the approval of the Head Office of GL is required for the welding of highly stressed castings, e.g. diesel engine parts and turbine casings.

13.2 Machining and grinding

The repair shall be performed in such a way as to remove the defect completely and provide a gradual transition between the resulting depression and the contour of the casting. The transition shall be 2 to 3 times the depression. The depth of the repair may not have more than an insignificant effect on the strength of the component and the wall thickness shall not be reduced below the minimum tolerance.

13.3 Flame scarfing and gouging

Defects may be removed by flame scarfing and gouging. Cast materials liable to hardening shall be appropriately preheated. The depressions caused by the removal of metal shall afterwards be bright ground. The grinding shall be sufficiently thorough to ensure the removal of any metal with a heat-affected structure.

13.4 Fabrication welding

13.4.1 If major defects have to be welded on steel castings the details of the proposed welding method
are to be submitted to GL by means of WPS for approval. The latter shall be amended with sketches or photographs showing the location of major defects which impair the mechanical strength.

For the purpose of these Rules, the term "major defect" includes any defects, the depth of which exceeds 25% of the wall thickness or 2.5 cm, the area of which exceeds 1.250 cm², and those which due to their amount and distribution exceed an area of 2% of the casting surface.

The characteristics of the weld shall be verified by welding procedure tests. These are to be performed on test pieces according to Chapter 5 – Materials for Propeller Fabrication, Annex B, using filler metals approved by GL. Welding procedure tests and welder’s qualification tests respectively which have been performed by means of above mentioned test pieces remain valid for 3 years and cover thicknesses up to 1.5 "t", with "t" being the thickness of the test piece.

In the case of minor repairs, the decision as to the execution of the repair shall rest with the Surveyor, and the method shall be agreed with him.

It is a basic principle that the welding of major defects may only be started after authorization has been granted and the castings have been presented to the Surveyor in the condition prepared for welding.

13.4.2 Companies wishing to carry out fabrication welds on castings shall have available the necessary workshops, lifting gear, welding appliances, preheating and heat treatment facilities, testing instruments and equipment as well as qualified welders and competent welding supervisors so that the work can be properly executed. As a preliminary measure, compliance with these conditions shall be proved to GL and a description of the welding facilities and procedures shall be submitted.

13.4.3 The following conditions shall be complied with in carrying out welding work:

- Highly stressed parts and alloy steel castings shall be in the prescribed heat-treated condition for welding. This also applies to other castings on which major defects have to be repaired.

- Defects are to be gouged out in such a way as to provide good accessibility for welding. Having been prepared for welding, the sites concerned shall be subjected to non-destructive tests to establish that the defective material has been completely removed. The castings prepared for welding are to be submitted to the Surveyor.

- Steel castings shall be suitably preheated for welding. The level of preheating shall be determined in each case by reference to the chemical composition, the carbon equivalent and the wall thickness, see B.4.1.4. Exceptions to this Rule are austenitic grades of cast steel and, with the consent of the Surveyor, unalloyed grades of cast steel of small wall thickness which because of their composition (C ≤ 0.18 %) are considered to be unsusceptible to cracking.

- All welding work is to be performed by qualified welders, whose work is supervised while in progress, in bays which are protected from draughts and the effects of the weather. Wherever possible, welding shall be performed in the downhand position.

- The filler materials to be used shall produce a weld deposit with mechanical characteristics matching those of the casting. In the case of stainless grades of cast steel, the deposit shall ensure the sufficient chemical stability of the weld. Wherever possible the work shall be performed by manual arc welding using basic-coated electrodes with a controlled, low hydrogen content.

- After welding, the castings shall be properly heat treated as follows:

  - unalloyed steel castings: stress relief heat treatment in temperature range 580 – 620 °C, or renewed normalizing treatment
  - quenched and tempered steel castings: renewed tempering or quenching and tempering
  - ferritic stainless steel and all grades of austenitic steel castings: the heat treatment prescribed in the relevant standard or recognized material specification, as applicable.

- Attention shall be paid to the effect of the heat treatment on the mechanical properties of the weld metal.

- Following welding and heat treatment, the welds and their surrounding areas are to be ground smooth and inspected by the magnetic particle or dye penetrant method. Depending on the nature and size of the original defect, further non-destructive testing by ultrasonic or radiographic inspection may be required. For the evaluation of the indications 10.4.2 is applicable.

13.4.4 After repair and subsequent heat treatment, all castings shall be presented to the Surveyor for reinspection, and the tests for cracks and the ultrasonic tests shall be performed wholly or partly in the Surveyor’s presence at his discretion. In the case of radiographic tests, the radiographs shall be submitted to the Surveyor for expert appraisal.

13.4.5 For large welds on highly stressed or alloy steel castings, the manufacturer shall hand the Surveyor a report containing full details of the repair, including the results of the non-destructive tests. In this report he shall also confirm that the weld has been made in accordance with an approved welding procedure.

---

1 WPS = Welding Procedure Specification
B. Steel Castings for Machine Construction and Shipbuilding

1. Scope
These Rules are applicable to castings made of unalloyed and alloyed grades of cast steel which are intended for the manufacture of components and structural parts in machine construction and shipbuilding, e.g. diesel engine components (excluding crankshafts), gears, couplings, and also stem and stern posts, stern tubes, shaft struts, rudder bearings and anchors.

2. Suitable grades of cast steel
On condition that they meet the requirements specified in 4., the following grades of cast steel may be used:

2.1 General-purpose cast steels conforming to DIN 1681.
2.2 General-purpose cast steels with enhanced weldability and toughness conforming to DIN 17182.
2.3 Quenched and tempered cast steels conforming to DIN 17205.
2.4 High-tensile cast steel with good weldability conforming to "Stahl-Eisen-Werkstoffblatt" SEW 520.
2.5 Other grades of cast steel with minimum impact energy values conforming to other standards or material specifications, provided that they are equivalent to the grades described in 2.1 to 2.4 and their suitability has been confirmed by GL. An initial test of product suitability may be required for this purpose.

3. Condition of supply and heat treatment

3.1 All castings shall be properly heat treated. Acceptable methods of heat treatment are:
   - normalizing
   - normalizing and tempering
   - quenching and tempering

3.2 Where castings are subject to special requirements with regard to their geometrical and dimensional stability or to the absence of internal stresses, e.g. diesel engine bedplates, stem and stern post parts, additional stress-relieving heat treatment is required. For carbon and carbon-manganese steels, the heat treatment shall be performed at a temperature of at least 550 °C followed by cooling in the furnace to below 300 °C. For quenched and tempered steel castings, the heat treatment temperatures shall be specially determined. The stress-relieving heat treatment may be dispensed with in the case of quenched and tempered steel castings where tempering is followed by a cooling rate of up to 15 °C/h.

4. Requirements applicable to the material

4.1 Chemical composition

4.1.1 Carbon and carbon-manganese steel castings including the grades of cast steel described in 2.1 and 2.5 are subject to the limits for the chemical composition of the heat specified in Table 4.1. Where necessary, the manufacturer may add grain refining elements, e.g. aluminium.

4.1.2 For grades of cast steel conforming to 2.2, 2.3 and 2.4, the limits for the chemical composition specified in the standards are applicable.

4.1.3 For cast alloy steels conforming to 2.5, the limits for the chemical composition specified in the recognised standards or material specifications shall apply.

4.1.4 Where the weldability of the casting is subject to special requirements, the carbon equivalent shall be calculated according to the following formula:

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

Table 4.1 Limits for chemical composition [%]

<table>
<thead>
<tr>
<th>Application</th>
<th>C max.</th>
<th>Si max.</th>
<th>Mn max.</th>
<th>S max.</th>
<th>P max.</th>
<th>Residual elements</th>
<th>Sum of the max. permissible residual elements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Cu</td>
<td>Cr</td>
</tr>
<tr>
<td>Castings for general shipbuilding and machinery application</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>Castings for welded structures for shipbuilding</td>
<td>0,23</td>
<td>0,60</td>
<td>1,60 max.</td>
<td>0,015</td>
<td>0,020</td>
<td>0,30</td>
<td>0,30</td>
</tr>
</tbody>
</table>

1 for welded structures for machinery application C ≤ 0,23 or \( C_{eq} \leq 0,49 \)
4.2 Mechanical and technological properties

4.2.1 For grades of cast steel conforming to 2.1 to 2.4, the requirements specified in the respective standards shall apply, see Table 4.2 (grades of cast steel conforming to DIN 1681) and Table 4.3 (grades of cast steel conforming to DIN 17182).

4.2.2 Other grades of cast steel as per 2.5 shall have the characteristic properties of the respective grade according to the standard or the specification. In addition, the minimum requirements specified in Table 4.4 are applicable to castings made of C and CMn cast steels.

4.2.3 The cast steels shown in Table 4.4 may be supplied with any minimum tensile strength within the limits specified in the table. The values graduated in steps of 40 N/mm² do not represent the minimum tensile strengths of particular grades of cast steel but are intended to provide means of determining the required mechanical characteristics by interpolation in relation to specified minimum tensile strengths.

Table 4.2 Mechanical properties of cast steels conforming to DIN 1681

<table>
<thead>
<tr>
<th>Grade of cast steel</th>
<th>Yield strength ReH [N/mm²] min.</th>
<th>Tensile strength Rm [N/mm²] min.</th>
<th>Elongation A [%] min.</th>
<th>Reduction in area Z [%] min.</th>
<th>Impact energy 1 KV [J] 2 min.</th>
</tr>
</thead>
<tbody>
<tr>
<td>GS–38</td>
<td>200</td>
<td>380</td>
<td>25</td>
<td>40</td>
<td>35</td>
</tr>
<tr>
<td>GS–45</td>
<td>230</td>
<td>450</td>
<td>22</td>
<td>31</td>
<td>27</td>
</tr>
<tr>
<td>GS–52</td>
<td>260</td>
<td>520</td>
<td>18</td>
<td>25</td>
<td>27</td>
</tr>
<tr>
<td>GS–60</td>
<td>300</td>
<td>600</td>
<td>15</td>
<td>21</td>
<td>27</td>
</tr>
</tbody>
</table>

1 testing temperature = room temperature
For castings for welded structures in shipbuilding the requirements according to Table 4.3 do apply.
2 Average value of 3 tests
3 t = sample thickness

Table 4.3 Mechanical properties of cast steels in the style of DIN 17182

<table>
<thead>
<tr>
<th>Grade of cast steel</th>
<th>Heat-treated condition 1</th>
<th>Wall thickness [mm]</th>
<th>Yield strength 2 ReH [N/mm²] min.</th>
<th>Tensile strength Rm [N/mm²]</th>
<th>Elongation A [%] min.</th>
<th>Impact energy 1 KV [J] 2 min.</th>
<th>Transition temp. T₀ [27 J] 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>GS–16Mn5 (N)</td>
<td>up to 50</td>
<td>260</td>
<td>430 – 600</td>
<td>25</td>
<td>65</td>
<td>–25 °C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>over 50 to 100</td>
<td>230</td>
<td>430 – 600</td>
<td>25</td>
<td>45</td>
<td>–15 °C</td>
<td></td>
</tr>
<tr>
<td>GS–20Mn5 (N)</td>
<td>up to 50</td>
<td>300</td>
<td>500 – 650</td>
<td>22</td>
<td>55</td>
<td>–20 °C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>over 50 to 100</td>
<td>260</td>
<td>500 – 650</td>
<td>22</td>
<td>40</td>
<td>–10 °C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>over 100 to 160</td>
<td>(260) 4</td>
<td>480 – 630</td>
<td>20</td>
<td>35</td>
<td>0 °C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>over 160</td>
<td>(240) 4</td>
<td>450 – 600</td>
<td>20</td>
<td>27</td>
<td>RT</td>
<td></td>
</tr>
<tr>
<td>GS–20Mn5 (Q+T)</td>
<td>up to 50</td>
<td>360</td>
<td>500 – 650</td>
<td>24</td>
<td>70</td>
<td>–30 °C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>over 50 to 100</td>
<td>300</td>
<td>500 – 650</td>
<td>24</td>
<td>50</td>
<td>–20 °C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>over 100 to 160</td>
<td>(280) 4</td>
<td>500 – 650</td>
<td>22</td>
<td>40</td>
<td>–10 °C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>over 160</td>
<td>(260) 4</td>
<td>480 – 630</td>
<td>22</td>
<td>30</td>
<td>RT</td>
<td></td>
</tr>
</tbody>
</table>

1 (N) = normalized; (Q+T) = quenched and tempered
2 If there is no marked yield strength, the 0.2 % proof stress applies.
3 Average value of 3 tests at room temperature (individual value at least 70 %).
4 The values in brackets are only an approximate indication of the minimum yield strength in the casting.
5 Requirements for welded structures for shipbuilding.
### Table 4.4 Mechanical properties of cast steels conforming to B.2.5

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ordinary quality C- and CMn cast steel</td>
<td>400</td>
<td>200</td>
<td>25</td>
<td>40</td>
<td>25</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td></td>
<td>440</td>
<td>220</td>
<td>22</td>
<td>30</td>
<td>20</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td></td>
<td>480</td>
<td>240</td>
<td>20</td>
<td>27</td>
<td>18</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td></td>
<td>520</td>
<td>260</td>
<td>18</td>
<td>25</td>
<td>15</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td></td>
<td>560</td>
<td>280</td>
<td>15</td>
<td>20</td>
<td>12</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td></td>
<td>600</td>
<td>300</td>
<td>13</td>
<td>20</td>
<td>10</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Special quality C and CMn cast steel</td>
<td>400</td>
<td>200</td>
<td>28</td>
<td>45</td>
<td>32</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td></td>
<td>440</td>
<td>220</td>
<td>26</td>
<td>45</td>
<td>28</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td></td>
<td>480</td>
<td>240</td>
<td>24</td>
<td>40</td>
<td>25</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td></td>
<td>520</td>
<td>260</td>
<td>22</td>
<td>40</td>
<td>20</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td></td>
<td>560</td>
<td>280</td>
<td>20</td>
<td>35</td>
<td>18</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td></td>
<td>600</td>
<td>300</td>
<td>18</td>
<td>35</td>
<td>15</td>
<td>17</td>
<td></td>
</tr>
</tbody>
</table>

1. Where the minimum tensile strength of a steel grade falls between two of the graduated values, the requirements may be determined by interpolation.
2. The tensile strength determined by testing may not exceed the specified minimum tensile strength by more than 150 N/mm$^2$ in case of the ordinary qualities and 120 N/mm$^2$ in the case of the special qualities.
3. Average value of 3 tests (individual value not less than 70%).

### 4.3 Impact energy

All grades of cast steel shall meet the energy impact values prescribed for the grade in question.

### 5. Testing

#### 5.1 Tensile test

The mechanical properties shall be verified by tensile test. The test specimens shall be prepared in accordance with A.10.2.2.

#### 5.2 Notched bar impact test

Notched bar impact testing shall be performed on each test batch or, where applicable, each casting. The test specimens shall be prepared in accordance with A.10.2.2. The type of specimen is governed by the relevant standard or specification.

### 5.3 Non-destructive tests

#### 5.3.1 In case non-destructive tests are prescribed for castings they shall be performed in accordance with G. to J.

#### 5.3.2 Where castings are welded together, the welds shall be subjected to magnetic particle and ultrasonic or radiographic inspection. The extent of the inspection shall be as specified on the approval drawing or will be determined at the time of approval of the welding procedure.

### 5.4 Tightness test

Castings subjected to internal pressure, e.g., stern tubes, shall be subjected to a hydraulic pressure test. The test shall be performed with the casting in machined condition. The test pressure is to be 1.5 times of the service pressure and for stern tubes uniformly 2 bars. The test pressure shall be kept for at least 10 Min.
C. Steel Castings for Crankshafts and Connecting Rods

1. Scope

These Rules are applicable to throws and webs of built crankshafts and connecting rods made of carbon, carbon-manganese and low-alloy grades of cast steel.

2. Approved grades of cast steel

Only grades of cast steel which have been approved by GL as suitable for the intended application may be used. To this end, the engine manufacturer shall submit to GL for approval specifications or drawings containing all the data required for evaluating the castings, e.g. method of manufacture, chemical composition, heat treatment and mechanical properties.

3. Requirements applicable to the material

3.1 With regard to the chemical composition, mechanical properties and required impact energy and hardness values, the data in the approved specifications or drawings are applicable. However, the requirements specified in B.2.5 and, for special quality steel castings, Table 4.4 are to be satisfied as a minimum requirement.

3.2 The cast steel shall undergo vacuum degassing or another suitable treatment after melting, so that the properties mentioned in the specification may be achieved.

4. Method of manufacture and condition of heat treatment

4.1 The method of manufacture shall be approved by GL. The details of the approval test are established by GL from case to case.

4.2 All castings shall be in a heat treated condition appropriate to the grade of steel. The following processes are acceptable:
   - normalizing
   - normalizing and tempering
   - quenching and tempering

Where possible, heat treatment shall be carried out after preliminary machining. If this is not possible, additional stress-relieving heat treatment shall be performed after preliminary machining with the minimum possible cutting allowance.

4.3 Defects shall normally be removed by grinding, gouging and/or machining. Care shall be taken to ensure that the required minimum cross sections are preserved.

The removal of defects by welding requires the consent of GL as a matter of principle and may only be considered if the defects cannot be eliminated by the aforementioned measures.

5. Testing

5.1 Tensile test

The mechanical properties shall be verified by tensile test. For preparing the tensile specimens, test samples shall be cast integrally with the casting at a point stipulated in the specification. Each casting shall be tested individually.

5.2 Notched bar impact test

Notched bar impact specimens shall be taken from every casting and tested. The location of the specimens shall be as described in 5.1. The specimen shape prescribed in the specification (Charpy V-notch or Charpy U-notch specimen) shall be used.

5.3 Non-destructive tests

Crank shafts and connecting rods shall be subjected to non-destructive tests according to the requirements stipulated in G. to J.

By agreement between the foundry and the crankshaft or connecting rod manufacturer, the tests may be performed both at the foundry and at the manufacturer's works.

D. Steel Castings for Steam Boilers, Pressure Vessels and Pipelines

1. Scope

1.1 These Rules are applicable to castings made from unalloyed and alloyed grades of cast steel and used for the manufacture of valve and pump housings, endplates, flanges, nozzles and pipe fittings. Cast steels for use at low temperatures are subject to E.

2. Suitable grades of cast steel

The following grades of cast steel may be used:

2.1 Grades of cast steel for use at room temperature and high temperatures conforming to EN 10213-2 "Technical Specifications relating to Cast Steel for Pressure Vessels", Part 2.

The chemical composition of the commonly used grades of cast steel is given in Table 4.5 and the mechanical properties are stated in Table 4.6.

2.2 Ferritic grades of cast steel GS–38 and GS–45 conforming to DIN 1681 up to a wall temperature of 300 °C.

2.3 Heat resistant ferritic, ferritic-austenitic and austenitic grades of cast steel as well as Nickel and cobalt based alloys conforming to EN 10295.
Table 4.5  Chemical composition (%) of the commonly used grades of cast steel conforming to EN 10213-2

<table>
<thead>
<tr>
<th>Grade of cast steel</th>
<th>C (max.)</th>
<th>Si (max.)</th>
<th>Mn (max.)</th>
<th>P (max.)</th>
<th>S (max.)</th>
<th>Cr</th>
<th>Mo</th>
</tr>
</thead>
<tbody>
<tr>
<td>GP240GH</td>
<td>0,18 – 0,23</td>
<td>0,60</td>
<td>0,50 – 1,20</td>
<td>0,030</td>
<td>0,020¹</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>GP280GH</td>
<td>0,18 – 0,25²</td>
<td>0,60</td>
<td>0,80 – 1,20²</td>
<td>0,030</td>
<td>0,020¹</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>G20Mo5</td>
<td>0,15 – 0,23</td>
<td>0,60</td>
<td>0,50 – 1,00</td>
<td>0,025</td>
<td>0,020¹</td>
<td>—</td>
<td>0,40 – 0,60</td>
</tr>
<tr>
<td>G17CrMo5-5</td>
<td>0,15 – 0,20</td>
<td>0,60</td>
<td>0,50 – 1,00</td>
<td>0,020</td>
<td>0,020¹</td>
<td>1,00 – 1,50</td>
<td>0,45 – 0,65</td>
</tr>
<tr>
<td>G17CrMo9-10</td>
<td>0,13 – 0,20</td>
<td>0,60</td>
<td>0,50 – 0,90</td>
<td>0,020</td>
<td>0,020¹</td>
<td>2,00 – 2,50</td>
<td>0,90 – 1,20</td>
</tr>
</tbody>
</table>

¹ In the case of castings having a standard wall thickness of < 28 mm, 0,030 % is permissible.
² For each 0,01 % reduction in the specified maximum carbon content, a 0,04 % increase of Manganese above the specified maximum content is permissible up to a maximum of 1,40 %.

Table 4.6  Mechanical properties of the commonly used grades of cast steel conforming to  EN 10213-2

<table>
<thead>
<tr>
<th>Grade of cast steel</th>
<th>Heat treatment symbol</th>
<th>Thickness [mm] max.</th>
<th>Tensile test</th>
<th>Notched bar impact test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Rp⁰,₂ [N/mm²] min.</td>
<td>Rm [N/mm²]</td>
</tr>
<tr>
<td>GP240GH</td>
<td>N QT</td>
<td>100</td>
<td>240</td>
<td>420 – 600</td>
</tr>
<tr>
<td>GP280GH</td>
<td>N QT</td>
<td>100</td>
<td>280</td>
<td>480 – 640</td>
</tr>
<tr>
<td>G20Mo5</td>
<td>QT</td>
<td>100</td>
<td>245</td>
<td>440 – 590</td>
</tr>
<tr>
<td>G17CrMo5-5</td>
<td>QT</td>
<td>100</td>
<td>315</td>
<td>490 – 690</td>
</tr>
<tr>
<td>G17CrMo9-10</td>
<td>QT</td>
<td>100</td>
<td>400</td>
<td>590 – 740</td>
</tr>
</tbody>
</table>

¹ N  = denotes normalising  
QT = denotes quenching and tempering  
² Testing temperature = room temperature (individual value not less than 70 %)

2.4 Other grades of cast steel conforming to other standards or material specifications, provided that they are comparable with the grades of cast steel stated in paragraphs 2.1 to 2.3 and proof has been furnished of their suitability for the intended application. An initial test of product suitability may be required for this purpose.

2.4.1 In addition, ferritic grades of cast steel shall satisfy the following minimum requirements:

- The elongation A shall have the characteristic minimum elongation values of the steel grade as specified by GL, but shall be not less than 15 %.
- The impact energy shall be at least 27 J at room temperature in tests performed with Charpy V-notch specimens. Ductile fracture behaviour is a fundamental requirement.
- Where necessary, the yield strength at elevated temperature and the long-time rupture stress properties at elevated temperature shall be verified by the manufacturer, specifying the guide values for the chemical composition.

Proof of weldability shall be furnished by the manufacturer.
3. **Heat treatment and condition of supply**

All steel castings shall be supplied in a heat-treated condition appropriate to the grade of cast steel.

4. **External and internal condition**

The requirements pertaining to the external and internal condition are specified in TRD 103. For this purpose, the cast steel shall be classed into quality levels according to the intended working temperature and pressure, see the Technical Rules for Steam Boilers TRD 103 and "AD-Merkblatt" W5 (AD Data Sheet W5).

5. **Requirements applicable to the material**

5.1 **General requirements**

With regard to the chemical composition, mechanical and technological properties, required impact energy values and hardness of the grades of cast steel, the data contained in the standards mentioned in 2.1 and 2.2 or in the approved specifications shall be applicable.

5.2 **Weldability**

Grades of cast steel conforming to these Rules shall be weldable by established workshop methods. Preheating and/or post-weld heat treatments may be required for this purpose, depending on the chemical composition.

6. **Testing**

The castings shall be presented for testing in finished condition (condition of supply) and shall undergo the following tests.

6.1 **Tensile test**

The mechanical properties shall be verified by tensile test. The tests shall be performed on a heat-by-heat basis, parts undergoing the same heat treatment being grouped into test batches in accordance with A.10.2.2. A tensile specimen shall be taken from each test batch and tested. Castings with unit weights > 1000 kg shall be tested individually.

6.2 **Notched bar impact test**

The castings shall be subjected to the notched bar impact test. The number of sets of specimens (3 Charpy V-notch specimens per set) shall be determined in the same way as the number of tensile specimens.

6.3 **Hardness test**

All quenched and tempered steel castings which are tested on a heat-by-heat basis shall be subjected to a comparative hardness test. The result of the hardness test shall show that quenching and tempering has been carried out homogeneously (the difference in hardness between the hardest and the softest tested component in the test batch shall not exceed 30 HB).

6.4 **Non-destructive tests**

The manufacturer shall ensure by non-destructive tests on his products that the requirements pertaining to the external and internal condition according to 4. are met. Unless otherwise agreed, the scope of testing shall conform to TRD 103 or AD data sheet W5, whichever is appropriate. Valves and fittings are subject to TRD 110. In addition the Rules as stated in Chapter 1 – Principles and Test Procedures, Section 3 shall be observed.

E. **Steel Castings for Use at Low Temperatures**

1. **Scope**

These rules are applicable to steel castings which are to be used for cargo and processing equipment on gas tankers at design temperatures below 0 °C, e.g. flanges, valve parts, weld-on and socket-welding pieces.

2. **Approved grades of cast steel**

The grades of cast steel stated in Table 4.7 may be used within the limits for the minimum design temperatures, provided that they satisfy the requirements of 5.

2.1 Grades of cast steel for use at low temperatures conforming to EN 10213-3 "Technical Specifications relating to Cast Steel for Pressure Vessels" Part 3. The chemical composition of commonly used grades of cast steel is shown in Table 4.8 and the mechanical properties are stated in Table 4.9.

2.2 **Other grades of cast steel**

Other grades of cast steel conforming to other standards or material specifications, provided that they are comparable to the grades of cast steel described in 2.1, that they meet the requirements of 3. to 5. and that proof has been furnished of their suitability for the intended application. An initial test of product suitability may be required for this purpose.

3. **Heat treatment and condition of supply**

All steel castings shall be supplied in a heat-treated condition appropriate to the grade of cast steel, see Table 4.9.
### Table 4.7  Approved grades of cast steels for use at low temperatures

<table>
<thead>
<tr>
<th>Grades of cast steel</th>
<th>Permitted minimum design temperature</th>
<th>Designation or material No.</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weldable cast carbon-manganese steel</td>
<td>$-20 , ^\circ C$ $^1$</td>
<td>G17Mn5</td>
<td>EN 10213-3</td>
</tr>
<tr>
<td></td>
<td>$-40 , ^\circ C$ $^1$</td>
<td>G20Mn5</td>
<td>EN 10213-3</td>
</tr>
<tr>
<td>1.5 % cast nickel steel</td>
<td>$-40 , ^\circ C$ $^1$</td>
<td>GS-10Ni6</td>
<td>SEW 685</td>
</tr>
<tr>
<td>2.25 % cast nickel steel</td>
<td>$-65 , ^\circ C$</td>
<td>G9Ni10</td>
<td>EN 10213-3</td>
</tr>
<tr>
<td>3.5 % cast nickel steel</td>
<td>$-90 , ^\circ C$</td>
<td>G9Ni14</td>
<td>EN 10213-3</td>
</tr>
<tr>
<td>Austenitic grades of cast steel</td>
<td>$-165 , ^\circ C$</td>
<td>1.4308 $^2$</td>
<td>EN 10213-4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.4408</td>
<td>EN 10213-4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.4581 $^3$</td>
<td>EN 10213-4</td>
</tr>
</tbody>
</table>

1 A minimum design temperature down to $-55 \, ^\circ C$ is possible if this is verified by an approval test.
2 In addition EN 10283 does apply.
3 Unsuitable for carriage of ammonia.

### Table 4.8  Chemical composition [%] of the commonly used grades of cast steel conforming to EN 10213-3

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>G17Mn5</td>
<td>0,15 – 0,20</td>
<td>0,60</td>
<td>1,00 – 1,60</td>
<td>0,020</td>
<td>0,020$^1$</td>
<td>—</td>
</tr>
<tr>
<td>G20Mn5</td>
<td>0,17 – 0,23</td>
<td>0,60</td>
<td>1,00 – 1,60</td>
<td>0,020</td>
<td>0,020$^1$ max. 0,80</td>
<td></td>
</tr>
<tr>
<td>G9Ni10</td>
<td>0,06 – 0,12</td>
<td>0,60</td>
<td>0,50 – 0,80</td>
<td>0,020</td>
<td>0,015</td>
<td>2,00 – 3,00</td>
</tr>
<tr>
<td>G9Ni14</td>
<td>0,06 – 0,12</td>
<td>0,60</td>
<td>0,50 – 0,80</td>
<td>0,020</td>
<td>0,015</td>
<td>3,00 – 4,00</td>
</tr>
</tbody>
</table>

1 For castings having a standard wall thickness of $< 28 \, \text{mm}$, 0,030 % S is permissible.

### Table 4.9  Mechanical properties of the commonly used grades of cast steel conforming to EN 10213-3

<table>
<thead>
<tr>
<th>Grade of cast steel</th>
<th>Heat treatment symbol $^1$</th>
<th>Thickness [mm] max.</th>
<th>Tensile test at room temperature</th>
<th>Notched bar impact test $^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>$R_{p0,2}$ [N/mm$^2$] min.</td>
<td>$R_m$ [N/mm$^2$]</td>
</tr>
<tr>
<td>G17Mn5</td>
<td>QT</td>
<td>50</td>
<td>240</td>
<td>450 – 600</td>
</tr>
<tr>
<td>G20Mn5</td>
<td>N</td>
<td>30</td>
<td>300</td>
<td>480 – 620</td>
</tr>
<tr>
<td></td>
<td>QT</td>
<td>100</td>
<td></td>
<td>500 – 650</td>
</tr>
<tr>
<td>G9Ni10</td>
<td>QT</td>
<td>35</td>
<td>280</td>
<td>480 – 630</td>
</tr>
<tr>
<td>G9Ni14</td>
<td>QT</td>
<td>35</td>
<td>360</td>
<td>500 – 650</td>
</tr>
</tbody>
</table>

1 N = denotes normalizing, QT = denotes quenching and tempering
2 Required impact energy value shown in Table 3.11 shall be complied with!
4. External and internal condition

The external and internal condition shall be subject to quality levels in accordance with Table 4.10 depending on the minimum design temperature.

If the evaluation is carried out according to other standards, the requirements shall be equivalent to those specified in Table 4.10.

If castings are required to undergo final inspection in accordance with the AD data sheets, proof of the quality levels and scopes of testing is to be furnished in accordance with these Rules.

### Table 4.10 Assignment of quality levels

<table>
<thead>
<tr>
<th>Minimum design temperature</th>
<th>Quality level according to:</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ –105 °C</td>
<td>SM4, LM4, AM4 1,</td>
</tr>
<tr>
<td></td>
<td>SP4, CP3, LP4, AP4 2,</td>
</tr>
<tr>
<td></td>
<td>UV4 3, RV4 4</td>
</tr>
<tr>
<td>&lt; –105 °C</td>
<td>SM3, LM3, AM3 1,</td>
</tr>
<tr>
<td></td>
<td>SP3, CP3, LP3, AP3 2,</td>
</tr>
<tr>
<td></td>
<td>UV3 3, RV3 4</td>
</tr>
<tr>
<td>Welding edges 5</td>
<td>SM011</td>
</tr>
<tr>
<td></td>
<td>CP01 2</td>
</tr>
</tbody>
</table>

1. EN 1369
2. EN 1371-1
3. EN 12680-2
4. EN 12681 and former DIN 1690-2
5. For surface crack detection linear indications are not allowed.

5. Requirements applicable to the material

5.1 General requirements

The chemical composition and the mechanical properties are subject to the requirements specified in the standards or the approved specifications (see Tables 4.8 and 4.9).

5.2 Weldability

Grades of cast steel conforming to these rules shall be weldable by established workshop methods.

5.3 Impact energy at low temperatures

The required impact energy values specified in Table 4.11 for the relevant grades of cast steel shall be met at the test temperatures stated in the table, using Charpy V-notch specimens.

### Table 4.11 Required impact energy values at low temperatures

<table>
<thead>
<tr>
<th>Grade of cast steel</th>
<th>Test temp. [°C]</th>
<th>Impact energy KV [J] 1 min.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weldable cast carbon manganese steel</td>
<td>5 K below minimum design temp., not exceeding –20 °C</td>
<td>27 (19)</td>
</tr>
<tr>
<td>1,5 % cast nickel steel</td>
<td>–70 °C</td>
<td>34 (24)</td>
</tr>
<tr>
<td>2,25 % cast nickel steel</td>
<td>–95 °C</td>
<td>34 (24)</td>
</tr>
<tr>
<td>3,5 % cast nickel steel</td>
<td>–95 °C</td>
<td>34 (24)</td>
</tr>
<tr>
<td>Austenitic grades of cast steel 2</td>
<td>–196 °C</td>
<td>41 (27) 3</td>
</tr>
</tbody>
</table>

1. Average value for 3 specimens. Figures in parentheses indicate lowest individual value.
2. For design temperatures of – 105 °C and above, verification of the impact energy may be dispensed with.
3. Some austenitic grades of cast steel are subject to higher required impact energy values, see Table 4.13, Part F.

6. Testing

The castings shall be presented for testing in finished condition (condition of supply) and shall undergo the following tests.

6.1 Tensile test

The mechanical properties shall be verified by tensile test. The tests shall be performed on a heat-by-heat basis, parts undergoing the same heat treatment being grouped into test batches in accordance with A.10.2.2. A tensile specimen shall be taken from each test batch and tested. Castings with unit weights > 1 000 kg shall be tested individually.

6.2 Notched bar impact test

The castings shall be subjected to the notched bar impact test in compliance with the prescribed test temperature according to Table 4.11. The number of sets of test specimens (3 Charpy V-notch specimens per set) shall be determined in the same way as the number of tensile specimens.

The test may be dispensed with in the case of austenitic steel castings with design temperatures of ≥ 105°C.

6.3 Hardness test

All quenched and tempered steel castings which are tested on a heat-by-heat basis shall be subjected to a comparative hardness test. The result of the hardness test shall show that quenching and tempering has been carried out homogeneously (the difference in hardness between the hardest and the softest tested component in the test batch shall not exceed 30 HB).
6.4 Non-destructive testing

The manufacturer shall ensure by non-destructive tests on his products that the requirements pertaining to the external and internal condition according to 4. are met. Unless otherwise agreed, the scope of testing shall conform to AD data sheet W5; valves and fittings are subject to AD data sheet AD-W10. In addition the Rules as stated in Chapter 1 – Principles and Test Procedures, Section 3 shall be observed.

F. Stainless Steel Castings

1. Scope

These Rules are applicable to steel castings made from austenitic and austenitic-ferritic grades of steel which are intended for use in cargo and processing equipment for chemical tankers and other equipment for which chemical stability in relation to the cargo or the operating fluid is required. These Rules also apply to sleeves and bushes for propeller shafts and rudder stocks.

The Rules are also applicable in conjunction with E. for austenitic grades of cast steel which are designed for use in cargo and processing systems for gas tankers.

2. Suitable grades of cast steel

The following grades of casting may be used, provided that they satisfy the requirements stated in 6.

2.1 Austenitic and austenitic-ferritic grades of steel conforming to EN 10213-4, "Technical Specifications relating to Cast Steel for use in pressure Vessels" as well as the grades indicated in EN 10283, Corrosion resistant steel castings. The chemical composition of these grades of cast steel is shown in Table 4.12 and the mechanical properties are given in Table 4.13.

2.2 Other stainless steels conforming to other standards or specifications after their suitability has been established by GL. An initial test of product suitability on the manufacturer's premises may be required for this purpose.

3. Selection of grades of cast steel

As regards their chemical resistance, the grades of steel shall be selected in accordance with the operator's list of substances, which provides information on the nature of the substances to be transported or stored.

3.1 Where austenitic grades of cast steel are intended for cargo and process equipment for gas tankers, the requirements applicable to castings as stated in E., "Steel castings for use at low temperatures" shall apply.

4. Heat treatment and condition of supply

All steel castings shall be supplied in a heat-treated condition appropriate to the grade of cast steel, i.e. the grades specified in Table 4.13 shall be solution-annealed and quenched in water.

5. External and internal condition

Requirements to the external and internal condition shall be agreed on by the orderer and the manufacturer. Requirements to welding edges and special rim zones shall be agreed on separately. In case no agreements were made G.3. does apply.

6. Requirements applicable to the material

6.1 Chemical composition

6.1.1 The limits stated in Table 4.12 and/or the specifications approved by GL are applicable.

6.1.2 For steel castings for the cargo and processing equipment of chemical tankers, the composition shall be selected so as to ensure the chemical stability required for the particular application, having regard to the intended heat-treated condition of the material. Furthermore, where steel castings are to be used for welded structures, the composition shall be selected so as to ensure that the material is suitable for the proposed welding process and that it remains chemically stable after welding and any post-weld heat treatments which may be applied. In the case of austenitic and austenitic-ferritic grades of cast steel, 6.2 shall be complied with. The manufacturer shall prove the weldability of the material if requested to do so.

6.1.3 If compliance with a minimum value for the aggregate effective chromium value W is required for a particular application, this is calculated as follows:

\[ W[\%] = [\%]Cr + 3,3 \cdot [\%]Mo \]

Note

This formula is applicable for austenitic cast steel which has a molybdenum content of < 3 \%.

6.2 Resistance to intercrystalline corrosion

Austenitic grades of cast steel shall be resistant to intercrystalline corrosion in the condition in which they are supplied. If it is intended to weld castings without post-weld heat treatment, only grades of cast steel that are corrosion-resistant in this condition as well shall be used, e.g. cast steels stabilized with Nb or containing not more than 0,03 \% C.

6.3 Mechanical properties and impact energy

The requirements specified in Table 4.13 or in the approved specifications are applicable.
<table>
<thead>
<tr>
<th>Designation</th>
<th>Grade of cast steel</th>
<th>Material no.</th>
<th>C max.</th>
<th>Si max.</th>
<th>Mn max.</th>
<th>P max.</th>
<th>S max.</th>
<th>Cr</th>
<th>Mo</th>
<th>Ni</th>
<th>Cu</th>
<th>other elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>GX2CrNi19-11</td>
<td>1</td>
<td>1.4309</td>
<td>0.030</td>
<td>1.50</td>
<td>2.00</td>
<td>0.035</td>
<td>0.025</td>
<td>18.00</td>
<td>20.00</td>
<td>9.00</td>
<td>12.00</td>
<td>N: max. 0,20</td>
</tr>
<tr>
<td>GX5CrNi19-10</td>
<td>1</td>
<td>1.4308</td>
<td>0.07</td>
<td>1.50</td>
<td>1.50</td>
<td>0.040</td>
<td>0.030</td>
<td>18.00</td>
<td>20.00</td>
<td>8.00</td>
<td>11.00</td>
<td></td>
</tr>
<tr>
<td>GX5CrNiNb19-11</td>
<td>1</td>
<td>1.4552</td>
<td>0.07</td>
<td>1.50</td>
<td>1.50</td>
<td>0.040</td>
<td>0.030</td>
<td>18.00</td>
<td>20.00</td>
<td>9.00</td>
<td>12.00</td>
<td>Nb: 8 · C, max. 1,00</td>
</tr>
<tr>
<td>GX2CrNiMo19-11-2</td>
<td>1</td>
<td>1.4409</td>
<td>0.030</td>
<td>1.50</td>
<td>2.00</td>
<td>0.035</td>
<td>0.025</td>
<td>18.00</td>
<td>20.00</td>
<td>2.00</td>
<td>2.50</td>
<td>N: max 0,20</td>
</tr>
<tr>
<td>GX5CrNiMo19-11-2</td>
<td>1</td>
<td>1.4408</td>
<td>0.07</td>
<td>1.50</td>
<td>1.50</td>
<td>0.040</td>
<td>0.030</td>
<td>18.00</td>
<td>20.00</td>
<td>2.00</td>
<td>2.50</td>
<td>9.00  12.00</td>
</tr>
<tr>
<td>GX5CrNiMoNb19-11-2</td>
<td>1</td>
<td>1.4581</td>
<td>0.07</td>
<td>1.50</td>
<td>1.50</td>
<td>0.040</td>
<td>0.030</td>
<td>18.00</td>
<td>20.00</td>
<td>2.00</td>
<td>2.50</td>
<td>9.00  12.00</td>
</tr>
<tr>
<td>GX2NiCrMo28-20-2</td>
<td>1</td>
<td>1.4458</td>
<td>0.030</td>
<td>1.00</td>
<td>2.00</td>
<td>0.035</td>
<td>0.025</td>
<td>19.00</td>
<td>22.00</td>
<td>2.00</td>
<td>2.50</td>
<td>26.00 30.00</td>
</tr>
<tr>
<td>GX2CrNiMoN22-5-3</td>
<td>1</td>
<td>1.4470</td>
<td>0.030</td>
<td>1.00</td>
<td>2.00</td>
<td>0.035</td>
<td>0.025</td>
<td>21.00</td>
<td>23.00</td>
<td>2.50</td>
<td>3.50</td>
<td>4.50  6.50</td>
</tr>
<tr>
<td>GX2CrNiMoCuN25-6-3-3</td>
<td>1</td>
<td>1.4517</td>
<td>0.030</td>
<td>1.00</td>
<td>1.50</td>
<td>0.035</td>
<td>0.025</td>
<td>24.50</td>
<td>26.50</td>
<td>2.50</td>
<td>3.50</td>
<td>5.00  7.00</td>
</tr>
<tr>
<td>GX2CrNiMoN26-7-4</td>
<td>2</td>
<td>1.4469</td>
<td>0.030</td>
<td>1.00</td>
<td>1.00</td>
<td>0.035</td>
<td>0.025</td>
<td>25.00</td>
<td>27.00</td>
<td>3.00</td>
<td>5.00</td>
<td>6.00  8.00</td>
</tr>
</tbody>
</table>

1 According to the intended purpose, e.g. at high or low temperatures, narrower limits may be specified for some elements by agreement between foundry and customer.

2 For this grade of steel a minimum value for the "pitting factor" \( P = Cr + 3,3 \cdot Mo + 16 \cdot N \geq 40 \) may be called for.
Table 4.13 Mechanical properties of suitable grades of cast steel

<table>
<thead>
<tr>
<th>Designation</th>
<th>Material No.</th>
<th>Heat treatment + AT (^1) ({}^\circ\text{C})</th>
<th>Thickness [mm]</th>
<th>Tensile test at room temperature</th>
<th>Notched bar impact test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(R_{p1,0}) [^4] [N/mm(^2)]</td>
<td>(R_m) [N/mm(^2)]</td>
</tr>
<tr>
<td>GX2CrNi19-11</td>
<td>1.4309</td>
<td>1050 – 1150</td>
<td>150</td>
<td>210</td>
<td>440 – 640</td>
</tr>
<tr>
<td>GX5CrNi19-10</td>
<td>1.4308</td>
<td>1050 – 1150</td>
<td>150</td>
<td>200</td>
<td>440 – 640</td>
</tr>
<tr>
<td>GX5CrNiNb19-11</td>
<td>1.4552</td>
<td>1050 – 1150</td>
<td>150</td>
<td>200</td>
<td>440 – 640</td>
</tr>
<tr>
<td>GX2CrNiMo19-11-2</td>
<td>1.4409</td>
<td>1080 – 1150</td>
<td>150</td>
<td>220</td>
<td>440 – 440</td>
</tr>
<tr>
<td>GX5CrNiMo19-11-2</td>
<td>1.4408</td>
<td>1080 – 1150</td>
<td>150</td>
<td>210</td>
<td>440 – 640</td>
</tr>
<tr>
<td>GX5CrNiMoNb19-11-2</td>
<td>1.4581</td>
<td>1080 – 1150</td>
<td>150</td>
<td>210</td>
<td>440 – 640</td>
</tr>
<tr>
<td>GX2NiCrMo28-20-2</td>
<td>1.4458</td>
<td>1100 – 1180</td>
<td>150</td>
<td>190</td>
<td>430 – 630</td>
</tr>
<tr>
<td>GX2CrNiMoN22-5-3</td>
<td>1.4470</td>
<td>1120 – 1150(^2,3)</td>
<td>150</td>
<td>420 (^5)</td>
<td>600 – 800</td>
</tr>
<tr>
<td>GX2CrNiMoCuN25-6-3-3</td>
<td>1.4517</td>
<td>1120 – 1150(^2,3)</td>
<td>150</td>
<td>480 (^5)</td>
<td>650 – 850</td>
</tr>
<tr>
<td>GX2CrNiMoN26-7-4</td>
<td>1.4469</td>
<td>1140 – 1180(^2,3)</td>
<td>150</td>
<td>480 (^5)</td>
<td>650 – 850</td>
</tr>
</tbody>
</table>

1. The heat treatment applicable to all grades of steel is + AT + QW (solution annealing + quenching in water).
2. Following solution annealing at high temperature, the castings may be cooled to between 1 040 °C and 1 010 °C before quenching in water to improve corrosion resistance and prevent cracks in the event of complex shapes.
3. In the case of cast steel intended for pressure vessels, the precipitation-hardened condition is not applicable to austenitic-ferritic steels.
4. \(R_{p0.2}\) may be estimated by reducing the \(R_{p1.0}\) value by 25 N/mm\(^2\).
5. \(R_{p0.2}\)
6. Test temperature = room temperature RT (individual value not less than 70 %)

7. Testing

The castings shall be presented for testing in finished condition (condition of supply) and shall undergo the following tests:

7.1 Tensile test

The mechanical properties shall be verified by tensile test. The tests shall be performed on a heat-by-heat basis, parts undergoing the same heat treatment being grouped into test batches in accordance with A.10.2.2. A tensile specimen shall be taken from each test batch and tested. Castings with unit weights > 1000 kg shall be tested individually.

7.2 Notched bar impact test

The castings shall be subjected to the notched bar impact test. The number of sets of test specimens (3 Charpy V-notch specimens per set) shall be determined in the same way as the number of tensile specimens.

7.3 Test of resistance to intercrystalline corrosion

Austenitic and austenitic-ferritic steel castings shall be tested per heat and heat treatment batch for their resistance to intercrystalline corrosion in accordance with ISO 3651-1 or -2. Austenitic-ferritic grades of cast steel shall be tested in accordance with Iron and Steel Test Specification SEP 1877, Method I, or an equivalent method. The test shall be confirmed by the manufacturer by means of a certificate.

7.4 Non-destructive testing

The manufacturer shall ensure by non-destructive tests on his products that the requirements pertaining to the external and internal condition according to 5. are met. Unless otherwise agreed, the scope of testing shall conform to AD Data Sheet W5. Valves and fittings are subject to TRD 110. In addition the Rules as stated in Chapter 1 – Principles and Test Procedures, Section 3 shall be observed.
G. Non-destructive Testing of Cast Steel Components

1. Scope of validity

1.1 These Rules apply to the non-destructive testing of cast steel components for which in B. to F. and H. appropriate requirements are prescribed, and for which no other regulations or manufacturer specifications are agreed upon.

1.2 A list containing the cast steel components for which non-destructive testing is required and the specific tests to be performed is contained in H. For propellers made of stainless cast steel the specifications in Chapter 5 – Materials for Propeller Fabrication, Section 2 do apply.

1.3 The general requirements for inspection bodies, inspection personnel, testing methods and certification of the results are prescribed in Chapter 1 – Principles and Test Procedures, Section 3 and are mandatory for all tests.

1.4 These Rules apply for the following testing methods defined according to EN 473, see Table 4.14:

1.5 Methods and testing, criteria indicated in G. are to be employed by the foundries, companies performing the further processing and the GL Surveyors.

1.6 For testing, the cast steel components shall be classified in inspection zones with different requirements for the severity levels.

For classifying one or several of the following principles is/are decisive:

- the operating loads to be expected
- the effects of the defects on the reliability of the component
- possible risk of damage if the component fails
- required welding security for the welding edges
- freedom of defects and surface condition after machining

Table 4.14 Test methods

<table>
<thead>
<tr>
<th>Testing of 1</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual testing</td>
<td>VT</td>
</tr>
<tr>
<td>Magnetic particle testing</td>
<td>MT</td>
</tr>
<tr>
<td>Penetrant testing</td>
<td>PT</td>
</tr>
<tr>
<td>Ultrasonic testing</td>
<td>UT</td>
</tr>
<tr>
<td>Radiography testing</td>
<td>RT</td>
</tr>
</tbody>
</table>

1 For testing of stainless austenitic cast steel only the methods VT, PT and RT are applicable.

2. Performing the tests

2.1 After the inspector of the internal or external inspection body in charge of testing has performed the prescribed tests, the cast steel components shall be presented to the GL-Surveyor for visual testing.

2.2 Concerning the tests it shall be differentiated between pre-testing and acceptance testing. With pretests, where decisions concerning the testability and the employability of the cast steel component are made, they are in general the business of the foundry. Acceptance tests shall be performed preferably on the final machined cast steel component after the heat treatment appropriate for the required properties has been performed. The Surveyor shall be informed in time about the intended tests. It is up to the discretion of the Surveyor to attend the tests.

2.3 The tests shall be performed for the zones described in the specification or in the test plan. In case the results indicate that further defects are present in the cast steel component, the test scope shall be extended according to agreement with the Surveyor.

2.4 The cast steel components for which testing is prescribed are listed in H. Concerning the test scope and the severity level requirements for specific hull structural parts and for machinery parts test instructions are prescribed in I. and J. which shall be observed in addition to the manufacturer specifications.

3. Classifying in severity levels

3.1 The classifying in severity levels for the inner and outer condition is performed in accordance with the criterias indicated in the tables for the specific test methods. Table 4.15 sums up the various severity levels.

3.2 The selection of severity levels shall be agreed upon in accordance with EN 1559-1 and EN 1559-2 within the order.

As a rule this is business of the orderer, in doing so the inspection zones shall be specified in accordance with 1.6 and the following requirements shall be observed:

3.2.1 Special rim zones such as welding edges shall be classified in the severity levels SM1, LM1, AM1, SP1, CP1, LP1, AP1, UV1 and RV1 over their entire length and over a width of \(3 \times \text{wall thickness}\), but at least of 50 mm.

For welding edges with thickness larger than 50 mm the severity levels SM2, LM2, AM2, SP2, CP2, LP2, AP2, UV2 and RV2 are sufficient.

For valve casings DIN 1690 part 10 does apply.
Table 4.15 Overview of the severity levels

<table>
<thead>
<tr>
<th>Testing of</th>
<th>Test method</th>
<th>Description of severity levels 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outer condition</td>
<td>VT</td>
<td>V1, V2, V3, V4</td>
</tr>
<tr>
<td></td>
<td>MT</td>
<td>SM1, SM2, SM3, SM4, LM1, LM2, LM3, LM4, AM1, AM2, AM3, AM4</td>
</tr>
<tr>
<td></td>
<td>PT</td>
<td>SP1, SP2, SP3, SP4, CP1, CP2, CP3, LP1, LP2, LP3, LP4, AP1, AP2, AP3, AP4</td>
</tr>
<tr>
<td>Inner condition</td>
<td>UT</td>
<td>UV1, UV2, UV3, UV4</td>
</tr>
<tr>
<td></td>
<td>RT</td>
<td>RV1, RV2, RV3, RV4</td>
</tr>
</tbody>
</table>

1 according to EN 12454, EN 1369, EN 1371-1, EN 12680-2, EN 12681 and DIN 1690-2

3.2.2 For fabrication weldings as a basic principle the same requirements as for the base material do apply.

3.2.3 For zones of steel castings for machinery parts, for valve casings as well as for dynamically loaded hull structural parts where no higher requirements are prescribed at least the severity levels SM3, LM3 and AM3 are to be met.

3.2.4 Apart from the specifications in 3.2.1 to 3.2.3, and if in the purchasing documents no higher classifying is required, for not specified zones at least severity level V2 does apply.

3.2.5 For the inner and outer condition of cast steel components equivalent severity levels as well as different severity levels may be determined.

3.3 Before testing is commenced the position and dimension of the zones to be tested and the severity levels to be met shall be specified in test plans, drawings or specifications taking into account 1.6, 3.1 and 3.2. These documents shall be provided to GL.

4. Special agreements for the surface roughness

For the surface roughness limit values such as e.g. comparators 2 may be agreed upon if requested by the orderer or necessary due to technical reasons. Requirements for the surface condition of surfaces of cast steel components depending on the smallest indication to be registered are listed in Tables 4.16 and 4.17 for the magnetic particle testing and for the penetrant testing. Concerning the surface roughness for non-destructive tests then the following applies:

- Cast steel components where requirements for the surface roughness were specified are to be tested visually in accordance with 5.
- Cast steel components which are subjected to radiographic, magnetic particle or ultrasonic testing shall comply at least with the comparators 3 S1 or 4 S2.
- Cast steel components which are subjected to penetrant testing shall comply at least with the comparators 3 S2.

Table 4.16 Recommended surface condition for magnetic particle testing

<table>
<thead>
<tr>
<th>Dimension of the smallest indication [mm]</th>
<th>Surface comparators 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5</td>
<td>BNIF 2</td>
</tr>
<tr>
<td></td>
<td>SCRATA 2</td>
</tr>
<tr>
<td>1 S1 – 2 S1</td>
<td>A 1</td>
</tr>
<tr>
<td>3 S2 – 4 S2</td>
<td>H 1</td>
</tr>
<tr>
<td>2</td>
<td>BNIF 2</td>
</tr>
<tr>
<td>2 S1 – 3 S1</td>
<td>SCRATA 2</td>
</tr>
<tr>
<td>4 S2 – 5 S2</td>
<td>A 2</td>
</tr>
<tr>
<td>≥ 3</td>
<td>H 2</td>
</tr>
<tr>
<td>not specified (rough surface)</td>
<td>SCRATA 2</td>
</tr>
<tr>
<td>A 3 – A 4</td>
<td>H 3</td>
</tr>
</tbody>
</table>

1 see EN 1370.
2 see Annex A of EN 1369.

Table 4.17 Recommended surface condition for penetrant testing

<table>
<thead>
<tr>
<th>Dimension of the smallest indication [mm]</th>
<th>Surface comparators 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5</td>
<td>BNIF 2</td>
</tr>
<tr>
<td></td>
<td>SCRATA 2</td>
</tr>
<tr>
<td>1 S1 – 2 S1</td>
<td>A 1</td>
</tr>
<tr>
<td>3 S2 – 4 S2</td>
<td>H 1</td>
</tr>
<tr>
<td>2</td>
<td>BNIF 2</td>
</tr>
<tr>
<td>2 S1 – 3 S1</td>
<td>SCRATA 2</td>
</tr>
<tr>
<td>4 S2 – 5 S2</td>
<td>A 2</td>
</tr>
<tr>
<td>≥ 3</td>
<td>H 2</td>
</tr>
<tr>
<td>not specified (rough surface)</td>
<td>SCRATA 2</td>
</tr>
<tr>
<td>A 3 – A 4</td>
<td>H 3</td>
</tr>
</tbody>
</table>

1 see EN 1370.
2 see Annex A of EN 1371-1.
5. Visual testing (VT)

5.1 The manufacturer shall verify for each production stage of the cast steel components the external condition and the compliance of the dimensions. Minor casting defects such as small sand and slag inclusions, small cold shuts and small hot tears are to be cleaned out in case they may affect the testability.

5.2 Discontinuities which may affect the employability and the processability appropriate for the material more than irrelevant, such as larger non-metallic inclusions, cavities, gas holes or cracks, are not allowed and shall be repaired.

5.3 After special agreement with GL or if specified in the order the evaluation of the surface condition may be performed by means of comparators in accordance with Table 4.18 (cf. EN 12454 "Visual examination of surface discontinuities – Steel sand castings").

5.4 The Surveyor certifies the visual inspection on the GL acceptance test certificate. E.g. the following text can be typed in the test certificate:

"The aforementioned cast steel components were visually tested.
The prescribed requirements are fulfilled."

5.5 On demand of the orderer the manufacturer shall issue a test report containing the details of the tests, the prescribed severity levels and the test results.

6. Magnetic particle testing (MT)

6.1 The surfaces of the cast steel component to be tested shall be free of oil, grease, and remnants of the moulding material and the blackening, as well as scale, dust and other contaminations.

The required surface condition may be achieved by shot-blasting, grinding or machining. A specific surface roughness that shall be complied with may be agreed upon (cf. 4.).

6.2 The magnetic particle testing is to be performed in accordance with Chapter 1 – Principles and Test Procedures, Section 3, I. In case black magnetic particles are employed the surface to be tested shall be coated with a permanent white paint, applied as thinly as possible (max. 20 μm). A decrease of the test sensibility shall be observed.

6.3 In order to avoid burn marks on the surface of cast steel components in quenched and tempered condition when magnetization is performed by means of prods with alternating current only fusible supply electrodes made of tin-aluminium alloys shall be employed.

Contact points visible on the surface are to be ground if necessary and to be retested by yoke magnetization.

On already machined surfaces of the cast steel component testing is only allowed with yoke magnetization.

6.4 The indications of magnetic particle testing shall be evaluated concerning their type, size and number in accordance with Tables 4.19, 4.20 and 4.21. The reference area for this shall be a rectangle with 105 mm × 148 mm (size DIN A6) and shall be placed on the specific most unfavourable area for each case (area with the highest number of indications). In addition for the evaluation the reference figures according to EN 1369 are to be consulted.

<table>
<thead>
<tr>
<th>Category</th>
<th>Severity Levels</th>
<th>V 1</th>
<th>V 2</th>
<th>V 3</th>
<th>V 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inclusions close to the surface</td>
<td></td>
<td>B 1</td>
<td>B 2</td>
<td>B 4</td>
<td>B 5</td>
</tr>
<tr>
<td>Gas porosity</td>
<td></td>
<td>C 1</td>
<td>C 2</td>
<td>C 3</td>
<td>C 4</td>
</tr>
<tr>
<td>Cold shuts</td>
<td></td>
<td>D 1</td>
<td>D 2</td>
<td>D 5</td>
<td>—</td>
</tr>
<tr>
<td>Hot tears</td>
<td></td>
<td>E 3</td>
<td>E 5</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Inserts</td>
<td></td>
<td>F 1</td>
<td>F 3</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Welds</td>
<td></td>
<td>J 1</td>
<td>J 2</td>
<td>J 3</td>
<td>J 5</td>
</tr>
</tbody>
</table>

1 The required severity level can be different for each category.
2 See references to standards in 4.
Table 4.19  Nature of discontinuities and the corresponding indications for magnetic particle testing

<table>
<thead>
<tr>
<th>Nature of discontinuities</th>
<th>Symbol</th>
<th>non-linear SM</th>
<th>non-linear LM</th>
<th>aligned AM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas porosity</td>
<td>A</td>
<td>X</td>
<td>—</td>
<td>X</td>
</tr>
<tr>
<td>Sand and slag inclusions</td>
<td>B</td>
<td>X</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Cracks</td>
<td>D</td>
<td>—</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Chill cracks</td>
<td>E</td>
<td>—</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Inserts</td>
<td>F</td>
<td>—</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Cold shuts</td>
<td>H</td>
<td>—</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

Table 4.20  Severity levels for magnetic particle testing - non-linear indications isolated (SM)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Severity level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SM 1</td>
</tr>
<tr>
<td>Inspection means</td>
<td>eye</td>
</tr>
<tr>
<td>Magnification for observation of magnetic particle indication.</td>
<td>1</td>
</tr>
<tr>
<td>Length $L_1$ of the smallest indication to be considered [mm].</td>
<td>1.5</td>
</tr>
<tr>
<td>Non-linear indications (SM) maximum total surface area allowed [mm$^2$]</td>
<td>10</td>
</tr>
<tr>
<td>Non-linear indications (SM) maximum individual length $L_2$ allowed [mm]</td>
<td>$2^1$</td>
</tr>
</tbody>
</table>

1  At maximum 2 indications of the designated maximum dimension are permitted.

Note
Only values expressed in this table are valid. The reference figures according to EN 1369 Annex B and C are for information only.

6.5  Definition of indications of magnetic particle testing

6.5.1  Non-linear indications (SM)
Indications are to be assessed as non-linear if the length $L$ is smaller than 3 times the width $W$.

The symbol for non-linear indications is SM (S for surface and M for magnetic particle).

6.5.2  Linear indications (LM)
Indications are to be assessed as linear if $L$ is equal or larger than 3 times $W$.

The symbol for linear indications is LM (L for linear and M for magnetic particle).

6.5.3  Aligned indications (AM)
In the following cases the indications are assessed as aligned:

- non-linear: the distance between the indications is less than 2 mm and at least 3 indications are registered.
- linear: the distance between 2 indications is smaller than the length $L$ of the longest discontinuity in a line.

Aligned indications are assessed as one single indication. Its length equals the total length $L$ of this line, see Fig. 4.1.

Fig. 4.1  Example for $L$
Table 4.21  Severity levels for magnetic particle testing - linear (LM) and aligned (AM) indications

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Severity levels</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LM 1 AM 1</td>
</tr>
<tr>
<td>Inspection means</td>
<td>eye</td>
</tr>
<tr>
<td>Magnification for observation of magnetic particle indication</td>
<td>1</td>
</tr>
<tr>
<td>Length $L_1$ of the smallest indication to be considered [mm]</td>
<td>1, 5</td>
</tr>
<tr>
<td>Arrangement of indications $^1$ isolated (I) or cumulative (C)</td>
<td>I</td>
</tr>
<tr>
<td>Maximum length $L_2$ of linear (LM) and aligned (AM) indications allowed depending on the wall thickness $t$ [mm]</td>
<td></td>
</tr>
<tr>
<td>Wall thickness class a $t \leq 16$ mm</td>
<td>2</td>
</tr>
<tr>
<td>Wall thickness class b $16$ mm $&lt; t \leq 50$ mm</td>
<td>3</td>
</tr>
<tr>
<td>Wall thickness class c $t &gt; 50$ mm</td>
<td>5</td>
</tr>
</tbody>
</table>

$^1$ The linear and aligned indications shall be taken into consideration for the calculation of the cumulative length.

Reference figures according to EN 1369 annex C

Note

Only values expressed in this table are valid. The reference figures are according to EN 1369 annex C are for information only.

The symbol for aligned indications is AM (A for aligned and M for magnetic particle).

Note:

The total length $L$ equals the distance between the start of the first indication and the end of the last indication.

Example: $L = \ell_1 + \ell_2 + \ell_3 + \ell_4 + \ell_5$

6.6 Defects which concerning their size and number exceed the requirements for the prescribed severity levels as well as cracks are not allowed and shall be removed. Repaired zones shall be retested.

7. Penetrant testing (PT)

7.1 Testing is to be performed with an inspection system consisting of penetrant remover, penetrant and developer in accordance with Chapter 1 – Principles and Test Procedures, Section 3, J.

7.2 The surface of the cast steel component to be tested shall correspond to the requirements for the surface condition specified in 6.1 and 4.

7.3 The indications shall be evaluated concerning their type, size and number in accordance with Tables 4.22, 4.23 and 4.24. The reference area for this shall be a rectangle with $105$ mm $\times 148$ mm (size DIN A6) and shall be placed on the specific most unfavourable area for each case (area with the highest number of indications). In addition for the evaluation the reference figures according to EN 1371-1 part 2, or another recognized standard, may be consulted.

7.4 Definition of indications of penetrant testing

7.4.1 Linear indication (LP)

Indication where the largest dimension equals at least 3 times the smallest dimension (i.e. $L \geq 3 W$).
Table 4.22 Nature of discontinuities and type of corresponding indications for penetrant testing

<table>
<thead>
<tr>
<th>Nature of discontinuities</th>
<th>Symbol</th>
<th>Type of corresponding indications for penetrant testing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>non-linear</td>
</tr>
<tr>
<td></td>
<td></td>
<td>isolated SP</td>
</tr>
<tr>
<td>Gas porosity</td>
<td>A</td>
<td>X</td>
</tr>
<tr>
<td>Sand and slag inclusions</td>
<td>B</td>
<td>X</td>
</tr>
<tr>
<td>Cracks</td>
<td>D</td>
<td>—</td>
</tr>
<tr>
<td>Chill cracks</td>
<td>E</td>
<td>—</td>
</tr>
<tr>
<td>Inserts</td>
<td>F</td>
<td>X</td>
</tr>
<tr>
<td>Cold Shuts</td>
<td>H</td>
<td>—</td>
</tr>
</tbody>
</table>

Table 4.23 Severity levels for penetrant testing - non-linear indications¹, isolated (SP) or clustered (CP)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Severity Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SP1</td>
</tr>
<tr>
<td>Inspection means</td>
<td>eye</td>
</tr>
<tr>
<td>Magnification for observation of penetrant indication</td>
<td>1</td>
</tr>
<tr>
<td>Diameter of the smallest indication to be considered [mm]</td>
<td>1,5</td>
</tr>
<tr>
<td>Maximum number of non-linear indications allowed</td>
<td>8</td>
</tr>
<tr>
<td>Maximum size of discontinuity indication A, B and F [mm]</td>
<td></td>
</tr>
<tr>
<td>isolated indications SP</td>
<td>3</td>
</tr>
<tr>
<td>clustered indications CP</td>
<td>10</td>
</tr>
</tbody>
</table>

¹ Such that L ≤ 3 W where L is the length and W is the width of the indication.

Note
Only values expressed in this table are valid. The reference figures according to EN 1371-1 Annex B and C are for information only.

7.4.2 Non-linear indication
Indication where the largest dimension is smaller than 3 times the smallest dimension (i.e. L < 3 W).
- isolated (SP)
- cumulative (CP): area with many indications, the distance between the indications can not be measured (seemingly they form only one single indication)

7.4.3 Aligned indications (AP)
- linear: the distance between 2 indications is smaller than the length of the largest defect in the line; or
- non-linear: the distance between 2 indications is less than 2 mm and at least 3 indications are registered.

7.5 Defects which concerning their size and number exceed the requirements for the prescribed severity levels as well as discontinuities in the material (cracks) are not allowed and shall be removed.

Repair zones shall be retested. For this the same inspection system as before shall be employed.

8. Ultrasonic testing (UT)
8.1 Ultrasonic testing is preferably performed for cast steel components with larger wall thickness and for examination of fabrication weldings as well as in addition to radiographic testing for determining the position in thickness and the dimension of defects, and shall be performed in accordance with Chapter 1 – Principles and Test Procedures, Section 3, K.
Table 4.24  Severity Levels for penetrant testing - linear (LP) and aligned (AP) indications

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>LP 1</th>
<th>LP 2</th>
<th>LP 3</th>
<th>LP 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inspection means</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magnification for observation of penetrant indication</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length L₁ of the smallest indication to be considered [mm]</td>
<td>1,5</td>
<td>2</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Arrangement of indications isolated (I) or cumulative (C)</td>
<td>I</td>
<td>I</td>
<td>I</td>
<td>I</td>
</tr>
<tr>
<td>Maximum length of linear (LP) and aligned (AP) indications allowed depending on the wall thickness t [mm]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wall thickness class a ( t \leq 16 \text{ mm} )</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>Wall thickness class b ( 16 \text{ mm} &lt; t \leq 50 \text{ mm} )</td>
<td>3</td>
<td>6</td>
<td>12</td>
<td>18</td>
</tr>
<tr>
<td>Wall thickness class c ( t &gt; 50 \text{ mm} )</td>
<td>5</td>
<td>10</td>
<td>20</td>
<td>30</td>
</tr>
</tbody>
</table>

Note
The penetrant indications may grow over a period of time and this should be taken into account.

1  The length L₁ of an aligned indication is the distance between the starting point of the first discontinuity and the opposite end of the last discontinuity (\( L \geq 3 \text{ W} \)).

Note
Only values expressed in this table are valid. The reference figures according to EN 1371-1 annex D are for information only.

8.2 All cast steel components shall be presented for testing in heat treated condition. As a rule ultrasonic testing may not be considered for austentic and austenitic-ferritic cast steel grades.

8.3 In the areas to be tested an appropriate condition of the surface of the cast steel component shall be achieved which enables a faultless coupling of the probe. For this the surface shall be clear of remnants of the moulding material and the blackening, scale, dust and other contaminations which may affect the coupling.

A specific surface roughness that shall be complied with according to 4. may be agreed upon.

8.4 Ferritic cast steel components shall only then be subjected to ultrasonic testing if disc shaped reflectors of 3 mm, 4 mm and 6 mm diameter can be verified definitely for the specific wall thickness regime, cf. Table 4.25. The echo height of these smallest disc shaped reflectors to be verified shall be at least 6 dB higher than the spurious echo at the end of the thickness regime to be evaluated. The fulfilment of the aforementioned conditions shall be proven to the GL-Surveyor within the testing.

8.5 If possible zones to be tested shall be tested from both sides. In case only one side is accessible near resolving probes, SE probes, shall be used in order to detect inhomogeneities close to the surface. Testing with SE probes is convenient only for thicknesses up to 50 mm.

8.6 If not otherwise agreed on by the purchaser and the manufacturer for all cast steel components in addition the following zones shall be tested with SE-straight beam and/or angle probes up to 50 mm depth:
Table 4.25  Ultrasonic testability requirements according to EN 12680-1

<table>
<thead>
<tr>
<th>Wall thickness [mm]</th>
<th>Smallest flat-bottom hole diameter detectable [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤300</td>
<td>3</td>
</tr>
<tr>
<td>&gt;300 to ≤400</td>
<td>4</td>
</tr>
<tr>
<td>&gt;400 to ≤600</td>
<td>6</td>
</tr>
</tbody>
</table>

Table 4.26  Registration levels for ultrasonic testing of ferritic steel castings in accordance with EN 12680-1

<table>
<thead>
<tr>
<th>Wall thickness [mm]</th>
<th>Inspected area</th>
<th>Reflectors without measurable dimension diameter of the equivalent flat-bottomed hole 1 min. [mm]</th>
<th>Reflectors with measurable dimension diameter of the equivalent flat-bottomed hole 1 min. [mm]</th>
<th>Attenuation of back wall echo min. [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤300</td>
<td>–</td>
<td>4</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td>&gt;300 to ≤400</td>
<td>–</td>
<td>6</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>&gt;400 to ≤600</td>
<td>–</td>
<td>6</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>–</td>
<td>Severity level 1 areas</td>
<td>3</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>–</td>
<td>special rim zone</td>
<td>3</td>
<td>3</td>
<td>–</td>
</tr>
</tbody>
</table>

1 Formula for converting the flat-bottomed hole diameter into the side-drilled hole diameter, see EN 12680-1.

- Grooves, transitions in wall thickness, zones with outer cooling webs
- Fabrication weldings, welding edges and special rim zones
- Fabrication weldings with depths exceeding 50 mm shall be tested in addition with other appropriate angle probes.

8.7 All echo indications and attenuations of the back wall echo shall be registered which are equal to the registration levels indicated in Table 4.26 or exceed them.

8.8 Indications exceeding the acceptance limits contained in Table 4.27 or Fig. 4.3 are not allowed and will result in rejection of the cast steel component by the Surveyor. Nevertheless acceptance of the cast steel component is possible on condition that after further evaluation of the indications performed by the orderer and GL proof has been furnished that in case no repair will be performed the employability of the cast steel component will not be effected considerably, or repair will be performed. In the later case the testing shall be repeated.

8.9 For determining the acceptance criteria according to Table 4.27 the cast wall is to be divided in rim and core zones according to Fig. 4.2.

![Fig. 4.2 Deviation of wall section into zones](image-url)

\[ a = t/3 \text{ (max. 30 mm)} \]

(The classification of the wall refers to the dimensions of the cast steel component ready for assembling.)
<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Unit</th>
<th>Zone (see figure 2)</th>
<th>Severity level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>UV 1</td>
</tr>
<tr>
<td>Casting wall thickness at the examined area</td>
<td>mm</td>
<td></td>
<td>–</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>&gt; 100</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reflectors without measurable dimension</td>
<td></td>
<td>rim core</td>
<td>3</td>
</tr>
<tr>
<td>Largest diameter of equivalent flat-bottomed hole</td>
<td>mm</td>
<td>rim</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>core</td>
<td>2</td>
</tr>
<tr>
<td>Number of discontinuities to be recorded in a frame</td>
<td>mm</td>
<td>rim</td>
<td>3</td>
</tr>
<tr>
<td>100 mm · 100 mm</td>
<td></td>
<td>core</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reflectors with measurable dimension</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Largest diameter of equivalent flat-bottomed hole</td>
<td>mm</td>
<td>rim</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>core</td>
<td>1</td>
</tr>
<tr>
<td>Maximum values of dimension in through-wall</td>
<td>mm</td>
<td>rim</td>
<td>15%</td>
</tr>
<tr>
<td>direction of discontinuities</td>
<td></td>
<td>core</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>15%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>15%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>15%</td>
</tr>
<tr>
<td>Maximum length without measurable width</td>
<td>mm</td>
<td>rim</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td></td>
<td>core</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>100</td>
</tr>
<tr>
<td></td>
<td></td>
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<td>100</td>
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<td></td>
<td></td>
<td>120</td>
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<td></td>
<td></td>
<td>100</td>
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<td></td>
<td></td>
<td></td>
<td>100</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>150</td>
</tr>
<tr>
<td>Largest individual area 3, 4</td>
<td>mm²</td>
<td>rim</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td></td>
<td>core</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td></td>
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<td>100</td>
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<td>100</td>
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<td></td>
<td></td>
<td>150</td>
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<td></td>
<td></td>
<td></td>
<td>150</td>
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<td></td>
<td></td>
<td></td>
<td>2000</td>
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<td>2000</td>
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<td>2000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2000</td>
</tr>
<tr>
<td>Largest total area for a reference area 3</td>
<td>mm²</td>
<td>rim</td>
<td>10000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>core</td>
<td>15000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>15000</td>
</tr>
<tr>
<td></td>
<td></td>
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<td>15000</td>
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<td></td>
<td></td>
<td></td>
<td>15000</td>
</tr>
<tr>
<td>Reference area</td>
<td>mm²</td>
<td></td>
<td>150000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(390 mm · 390 mm)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>100000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(320 mm · 320 mm)</td>
</tr>
</tbody>
</table>

1. For wall thickness not greater than 50 mm, flat-bottomed holes exceeding 8 mm are unacceptable.
2. For wall thickness greater than 50 mm the acceptability of flat-bottomed holes exceeding 8 mm in the rim zone shall be agreed between the manufacturer and the purchaser.
3. Accumulated in core zone and rim zone.
4. Indications less than 25 mm apart shall be considered as one discontinuity.
5. If the indication in the core zone is caused by an individual reflector the thickness of which does not exceed 10% of the wall thickness, (e.g. centreline shrinkage) then, in case of severity levels 2 to 4, values 50% higher than those specified in this table, are acceptable and in case of severity level 5, no limit is specified.
Fig. 4.3 Acceptance criteria for ultrasonic testing for individual planar indications mainly orientated in through-wall direction, detected with angle probes following EN 12680-1

**Key**

- UV 2  Severity level 2
- UV 3  Severity level 3
- UV 4  Severity level 4
- UV 5  Severity level 5

Indications with measurable dimensions are not allowed for severity level 1.
9. Radiographic testing (RT)

9.1 Radiographic testing of cast steel components is to be performed in accordance with Chapter 1 – Principles and Test Procedures, Section 3, L.

9.2 Selection of radiation source depends on the required testing category and the wall thickness to be penetrated, see Table 4.28. If necessary radiographic testing shall be performed in addition to ultrasonic testing if doubts exist concerning the evaluation of indications of ultrasonic testing.

9.3 Indications which concerning their type and dimension exceed the maximum permissible values indicated in Table 4.29 for the required test category are not allowed and will result in rejection of the cast steel component by the Surveyor. Nevertheless acceptance of the cast steel component is possible on condition that after further evaluation of the indications performed by the orderer and GL proof has been furnished that in case no repair will be performed the employability of the cast steel component will not be affected considerably, or repair will be performed. In the later case the testing shall be repeated.

Table 4.28 Radiation source in dependence of the test class and the penetrated thickness following EN 444 and EN 12681

<table>
<thead>
<tr>
<th>Radiation source</th>
<th>Penetrated thickness $\omega$ [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Class A</td>
</tr>
<tr>
<td>TM 170</td>
<td>$\omega \leq 5$</td>
</tr>
<tr>
<td>Yb 169</td>
<td>$1 \leq \omega \leq 15$</td>
</tr>
<tr>
<td>Se 75</td>
<td>$10 \leq \omega \leq 40$</td>
</tr>
<tr>
<td>Ir 192</td>
<td>$20 \leq \omega \leq 100$</td>
</tr>
<tr>
<td>Co 60</td>
<td>$40 \leq \omega \leq 170$</td>
</tr>
<tr>
<td>X-ray equipment with energy from 1 MeV to 4 MeV</td>
<td>$30 \leq \omega \leq 200$</td>
</tr>
<tr>
<td>X-ray equipment with energy from 4 MeV bis 12 MeV</td>
<td>$\omega \geq 50$</td>
</tr>
<tr>
<td>X-ray equipment with energy above 12 MeV</td>
<td>$\omega \geq 80$</td>
</tr>
<tr>
<td>Type</td>
<td>Code letter as ASTM</td>
</tr>
<tr>
<td>----------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Blowholes</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-metallic</td>
<td>B</td>
</tr>
<tr>
<td>inclusions</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Shrinkage</td>
<td>C</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Cracks</td>
<td>D + E</td>
</tr>
<tr>
<td>Chaplets and</td>
<td>F</td>
</tr>
<tr>
<td>iron chills</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 Caption: ASTM-E 446 — Reference radiographs for steel castings up to 2 in. (51 mm) in thickness.
ASTM-E 186 — Reference radiographs for heavy walled (2 to 4 1/2 in. (51 to 114 mm) steel castings.
ASTM-E 280 — Reference radiographs for heavy walled (4 1/2 to 12 in. (114 to 305 mm) steel castings.

2 If for example it is shown by ultrasonic testing that the defects are in the core zone (see Fig. 4.1), the specifications for the next higher (numerical) severity level shall apply, unless otherwise specified in the material standard or in the order.

3 The values to be adhered shall be agreed.

4 Unless the minor nature of the cracks is proved by fracture-mechanical tests.

5 Chaplets may be present, but they shall be welded free from cracks at the surface.
### List of Cast Steel Components for which Non-destructive Tests are Required

#### Table 4.30 Test methods to be employed

<table>
<thead>
<tr>
<th>Name of the component</th>
<th>VT</th>
<th>MT</th>
<th>PT</th>
<th>UT</th>
<th>RT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Structural parts concerning the hull</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stern</td>
<td>×</td>
<td>×</td>
<td>(×)²</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>Propeller shaft-nut</td>
<td>×</td>
<td>×</td>
<td>(×)²</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>Rudder horn</td>
<td>×</td>
<td>×</td>
<td>(×)²</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>Rudder bearing</td>
<td>×</td>
<td>×</td>
<td>(×)²</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Rudder coupling</td>
<td>×</td>
<td>×</td>
<td>(×)²</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>Shaft bracket</td>
<td>×</td>
<td>×</td>
<td>(×)²</td>
<td>×</td>
<td>–</td>
</tr>
<tr>
<td>Rudder shaft</td>
<td>×</td>
<td>×</td>
<td>–</td>
<td>×</td>
<td>–</td>
</tr>
<tr>
<td>Tiller</td>
<td>×</td>
<td>×</td>
<td>(×)²</td>
<td>×</td>
<td>–</td>
</tr>
<tr>
<td><strong>Diesel engine parts</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Piston crowns</td>
<td>×</td>
<td>×</td>
<td>–</td>
<td>×</td>
<td>⁵</td>
</tr>
<tr>
<td>Cylinder covers</td>
<td>×</td>
<td>×</td>
<td>–</td>
<td>×</td>
<td>⁵</td>
</tr>
<tr>
<td>Camshaft drive gear wheels and chain wheels</td>
<td>×</td>
<td>×</td>
<td>–</td>
<td>×</td>
<td>–</td>
</tr>
<tr>
<td>Crank webs and throws</td>
<td>×</td>
<td>×</td>
<td>–</td>
<td>×</td>
<td>–</td>
</tr>
<tr>
<td>Connecting rods</td>
<td>×</td>
<td>×</td>
<td>–</td>
<td>×</td>
<td>–</td>
</tr>
<tr>
<td>Bearing transverse girders</td>
<td>×</td>
<td>×</td>
<td>–</td>
<td>×</td>
<td>–</td>
</tr>
<tr>
<td>Main bearings and bearing covers for main, crossheads and piston rod bearings</td>
<td>×</td>
<td>×</td>
<td>–</td>
<td>×</td>
<td>–</td>
</tr>
<tr>
<td>Starting valve casings</td>
<td>×</td>
<td>×</td>
<td>–</td>
<td>–</td>
<td>×</td>
</tr>
<tr>
<td><strong>Further components of the propulsion plant</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turbine casings</td>
<td>×</td>
<td>×</td>
<td>–</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td>Gear wheels</td>
<td>×</td>
<td>×</td>
<td>–</td>
<td>×</td>
<td>×</td>
</tr>
<tr>
<td><strong>Valve casings</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Valve casings for pipe class I ³ with NW ≥ 100</td>
<td>×</td>
<td>×</td>
<td>–</td>
<td>–</td>
<td>× ⁴</td>
</tr>
</tbody>
</table>

1. Testing in the prescribed areas.
2. PT may be employed instead of MT.
4. Random testing according to testing plan
5. For diesel engines with cylinder diameter > 400 mm.
I. Testing Instructions for Hull Structural Parts

In the figures 4.4 to 4.11 the specifications for the non-destructive testings are prescribed.

Testing scope:
Visual testing: entire surface
Magnetic particle testing: Welding edges (ooooooo)
Radiographic testing: Welding edges (-----)
Ultrasonic testing: Welding edges (-----), if permitted by the geometry

Severity levels:
Visual testing: V1 for welding edges; V3 remaining areas
Magnetic particle testing: SM1; LM1; AM1 for welding edges; SM2; LM2; AM2 remaining areas
Radiographic testing: RV1 up to thickness 50 mm and RV2 for thickness > 50 mm
Ultrasonic testing: UV2 instead of radiographic testing for thickness > 50 mm

1 Thickness = Thickness of the cast component at the area to be tested.

Fig. 4.4 Testing instruction for stern
Testing scope:
Visual testing: entire surface
Magnetic particle testing: areas marked with (o o o o o o o o o o)
Radiographic testing: areas marked with ( ~ ~ ~ ~ ~ ~ ~ ~ ~ ~)

Severity levels:
Visual testing: V2 (o o o o o o o o)
Magnetic particle testing: SM2, LM2, AM2 ( o o o o o o o o o o o)
SM3, LM3, AM3 remaining areas
Ultrasonic testing: UV2

Fig. 4.5 Testing instruction for rudder stock
Testing scope:
Visual testing: entire surface
Magnetic particle testing: Welding edges (-----), (ooooo)
Radiographic testing: Welding edges (-----)
Ultrasonic testing: Areas marked with (~~~~~~~~~)

Severity levels:
Visual testing: V1 for areas marked with (-----); V2 for areas marked with (~~~~~~~~~), remaining areas V3
Magnetic particle testing: SM1, LM1, AM1 for (-----); SM2, LM2, AM2 for areas marked with (ooooo); SM3, LM3, AM3 for the remaining areas
Radiographic testing: RV1 up to thickness 50 mm and RV2 for thickness > 50 mm
Ultrasonic testing: UV2; further instead of radiographic testing for thickness > 50 mm

Fig. 4.6 Testing instruction for stern nut
Testing scope:
Visual testing: entire surface
Magnetic particle testing: Welding edges (— — — — — —), (00000)
Radiographic testing: Welding edges (— — — — — —)
Ultrasonic testing: Areas marked with (~~~~~~~~~~~)

Severity levels:
Visual testing: V1 for areas marked with (— — — — — —) and remaining areas V3
Magnetic particle testing: SM1, LM1, AM1 for (— — — — — —); SM2, LM2, AM2 for areas marked with (00000); SM3, LM3, AM3 for the remaining areas
Radiographic testing: RV1 up to thickness 50 mm and RV2 for thickness > 50 mm
Ultrasonic testing: UV2; further instead of radiographic testing for thickness > 50 mm

Fig. 4.7 Testing instruction for rudder horn
Testing scope:
Visual testing: entire surface
Magnetic particle testing: Welding edges (---), (ooooo)
Radiographic testing: Welding edges (---)
Ultrasonic testing: Areas marked with (~~~~~~~~~)

Severity levels:
Visual testing: V1 for areas marked with (---) and V2 for remaining areas
Magnetic particle testing: SM1, LM1, AM1 for (---); SM2, LM2, AM2 for areas marked with (ooooo); SM3, LM3, AM3 for the remaining areas
Radiographic testing: RV1 up to thickness 50 mm and RV2 for thickness > 50 mm
Ultrasonic testing: UV2; further instead of radiographic testing for thickness > 50 mm

Fig. 4.8 Testing instruction for upper rudder coupling
Testing scope:
Visual testing: entire surface
Magnetic particle testing: Welding edges (-----), (ooooo)
Radiographic testing: Welding edges (-----)
Ultrasonic testing: Areas marked with (~~~~~~~~~)

Severity levels:
Visual testing: V1 for areas marked with (-----); V2 remaining areas
Magnetic particle testing: SM1, LM1, AM1 for (-----); SM2, LM2, AM2 for areas marked with (ooooo); SM3, LM3, AM3 for the remaining areas
Radiographic testing: RV1 up to thickness 50 mm and
RV2 for thickness > 50 mm
Ultrasonic testing: UV2, further instead of radiographic testing for thickness > 50 mm

Fig. 4.9 Testing instruction for lower rudder coupling
Testing scope:
Visual testing: entire surface
Magnetic particle testing: Welding edges (---····--), (ooooo)
Radiographic testing: Welding edges (---····--)
Ultrasonic testing: Areas marked with (~~~~~~~~~~)

Severity levels:
Visual testing: V1 for (---····--); V2 remaining areas
Magnetic particle testing: SM1, LM1, AM1 for (---····--); SM2, LM2, AM2 for areas marked with (ooooo); SM3, LM3, AM3 for the remaining areas
Radiographic testing: RV1 up to thickness 50 mm and
RV2 for thickness > 50 mm
Ultrasonic testing: UV2; further instead of radiographic testing for thickness > 50 mm

Fig. 4.10 Testing instruction for stern frame
Testing scope:
Visual testing: entire surface
Magnetic particle testing:  
Penetrant testing:  
Ultrasonic testing: Areas marked with □

Severity levels:
Visual testing: V1  Key way, bore: conical or cylindrical, remaining areas V2
Magnetic particle testing: SM1, LM1, AM1  Tillerarms:
Penetrant testing: SP1, CP1, LP1, AP1  Contact areas for slide piece and ground, lower and upper plane areas
Magnetic particle testing: SP2, LM2, AM2  remaining areas
Penetrant testing: SP2, CP2, LP2, AP2  remaining areas
Ultrasonic testing: UV2  The indicated areas / zones of slide are to be tested before machining the slide surface.
remaining areas UV3

Cracks are not permitted. The machined areas shall not have open sand marks. Whether indications are left as they are, ground or fabrication welded is decided by GL.

Fig. 4.11 Testing instruction for tiller
J. Testing Instruction for Diesel Engine Parts

In the figures 4.12 and 4.13 the specifications for the non-destructive testings are prescribed.

Testing scope:
Visual testing: entire surface
Magnetic particle testing: entire surface
Ultrasonic testing: Shaft and bearing areas
Penetrant testing: machined bearing surfaces (ooooo)

Severity levels:
Visual testing: V1 for zone I and II; remaining areas V2
Magnetic particle testing: SM1, LM1, AM1 for zone I and II; remaining areas SM2, LM2, AM2
Ultrasonic testing: UV1 for zone I and II; remaining areas UV2
Penetrant testing: SP2, CP2, LP2, AP2 for areas marked with (ooooo)

Fig. 4.12 Testing instruction for connecting rods
Testing scope:
Visual testing: entire surface
Magnetic particle testing: Welding edges (---:---), (o0000)
Ultrasonic testing: marked areas with (~~~~)
Penetrant testing: marked areas with (x*x*x*)

Severity levels:
Visual testing: V1 for (---:---), remaining areas V2
Magnetic particle testing: SM1, LM1, AM1, for the areas marked with (---:---);
SM2, LM2, AM2, for the areas marked with (00000)

Ultrasonic testing: UV1 for the areas marked with (----:----);
UV2 for the areas marked with (~~~~)
Penetrant testing: SP2, CP2, LP2, AP2 for the areas marked with (x*x*x*)

Fig. 4.13 Testing instruction for main bearing support
Section 5

Cast Iron

A. General Rules

1. Scope

General Rules to be applied in the manufacture and testing of nodular and grey cast iron are contained in A.

2. Selection of grades of cast iron

2.1 All castings shall be suitable for their intended purpose and satisfy the minimum requirements specified in the following individual Rules. Subject to these conditions, grades conforming to the relevant standards or to material specifications approved by GL may be used.

2.2 The grades of cast iron shall be identified by the standardized designations or the designations in the specifications.

3. Requirements to be met by foundries

3.1 Foundries wishing to supply castings in accordance with these Rules shall be approved by GL. This is conditional upon their fulfilling the manufacturing and quality control requirements stated in Chapter 1 – Principles and Test Procedures, Section 1, C. and furnishing proof of this to GL prior to the commencement of supplies.

3.2 Irrespective of the requirements stated in 2.1, the manufacturer shall himself prove by qualification tests carried out on the products that these can be manufactured in accordance with the conditions imposed. The scope of these tests will be determined by GL on a case to case basis.

4. General characteristics of castings

4.1 All castings shall have a clean surface compatible with the conditions of manufacture. Minor casting defects such as sand and slag marks, small cold shuts and scabs may be trimmed off within the negative tolerance on the wall thickness. Castings shall be free from defects liable to impair machining operations and their subsequent use to a more than insignificant extent.

In this respect orderer and manufacturer have to agree on specific grade levels according to EN 1369, EN 1371-1, EN 12680-3 and EN 12681.

4.2 Feeders and other excess material shall be removed by suitable methods. Where the method of removal causes a change of structure, e.g. in the case of flame cutting, the cut faces shall afterwards be machined.

4.3 Fabrication and repair welds, be it dissimilar welding by means of fillers with high nickel content or similar welding, i.e. using similar fillers, have to be in any case subject to a welding procedure test at the presence of the Surveyor. GL decides about a cast- or component-specific application of the above mentioned procedure.

4.4 With the consent of the Surveyor, local porous areas on castings not subjected to internal pressure may be corrected applying appropriate procedures, such as inserting filler pieces of similar material. It is a condition that the serviceability of the castings shall not be impaired by this.

5. Dimensions; dimensional and geometrical tolerances

The dimensions and the dimensional and geometrical tolerances are governed by the values specified in the drawings relating to the order or in the relevant standards, as applicable. Appropriate details shall be given in the order documents and shall be made known to the Surveyor.

6. Resistance to leakage

All castings which are subjected to internal pressure by the operating medium or for which special proof of impermeability is required shall be tightness tested at the specified test pressures.

7. General requirements applicable to cast materials

7.1 Chemical composition

Unless otherwise agreed or specified in the standards, the chemical composition shall be selected by the manufacturer. The manufacturer shall determine the composition in such a way that the required characteristics are achieved.

7.2 Mechanical properties

The values shown in the Tables in B. and C. or in the standards, where applicable, shall be met under test.

The impact energy specified for special quality nodular cast iron grades shall be met by the average value measured on 3 specimens.
8. Tests

The following tests are to be carried out:

8.1 Test of chemical composition

Where required, the manufacturer shall determine the composition of each treatment batch (ladle) and give the Surveyor a certificate confirming this composition.

8.2 Testing of mechanical properties and selection of specimens

8.2.1 The mechanical properties shall be ascertained by tensile test. In the case of special quality nodular cast iron for which an impact energy is specified, a notched bar impact test shall also be performed.

8.2.2 For each casting or unit test quantity, as applicable, a sufficient quantity of sample material shall be provided to enable the necessary tests and possible retests to be performed.

8.2.3 For proof of the mechanical properties separately cast samples, integrally cast samples or samples taken from the casting unit may be used.

8.2.4 Type, quantity and location of the respective samples are to be agreed between orderer and manufacturer until acceptance of the order, unless otherwise specified.

8.2.5 For casting units with cast weights of maximum 2000 kg and a determining wall thickness of up to 200 mm integrally cast samples are to be used. If the weight of the casting unit exceeds 2000 kg and the determining wall thickness is larger than 200 mm integrally cast samples or samples taken from the casting unit are to be used. The latter is to be agreed between the manufacturer and the orderer as well as GL under consideration of 8.2.4.

8.2.6 Where separately cast samples are used, these shall be cast in moulds made of the same mould material as that used for the casting itself. The samples may not be removed from the moulds until their temperature has dropped to below 500 °C. In the case of chill casting, centrifugal casting and continuous casting, special agreements shall be reached with GL regarding the selection of samples.

8.2.7 All samples are to be marked in such a way that they can be clearly related to the castings which they are intended to represent.

8.2.8 Where castings are supplied in a heat-treated condition, the samples shall be heat treated together with the castings concerned.

8.2.9 Where castings are manufactured in series, the manufacturer may, with the agreement of GL, use other, equivalent methods of testing. In this case, the manufacturer shall have proved the characteristics of the products by a preliminary type test and shall ensure by continuous quality control that the characteristics remain constant.

9. Test of surface finish and dimensions

The manufacturer shall inspect each casting with regard to its surface finish and compliance with the dimensional and geometrical tolerances and shall then present the castings to the Surveyor for final inspection. For this purpose, the surface of the castings shall be free from moulding material and shall be properly prepared for inspection.

10. Non-destructive tests

Generally, a non-destructive test shall be performed only where this is specified in the order according to 4.1. Apart from this, the Surveyor may call for suitable non-destructive tests if there are justified doubts that the castings are free from defects.

11. Hydraulic pressure test

Where specified, castings shall be submitted to a hydraulic pressure test. The test is to be performed in the presence of the Surveyor, wherever possible on the rough-machined castings. Where no other test pressure is specified, the test pressure shall be equal to 1.5 times the operating pressure.

12. Retests in the event of failure

If specimens fail to meet the required values in the tensile or notched bar impact test, or if, in the notched bar impact tests, one value is below the level permitted by the specification, then, before the unit test quantity or the casting is rejected, the procedures for retests prescribed in Chapter 1 – Principles and Test Procedures, Section 2, H. may be applied. The additional test specimens shall be taken either from the same test sample as the original specimen or from other samples which are representative of the casting or of the unit test quantity.

13. Identification and marking

13.1 The manufacturer shall institute a monitoring system enabling all castings to be traced back to the original heat, and this shall be demonstrated to the Surveyor on request.

13.2 Prior to final inspection, all castings shall be provided by the manufacturer in at least one place with the following marks:

13.3 Grade of cast iron, material symbol and/or material number of the cast material:

- heat number or mark enabling the manufacturing process of the casting to be traced back
- manufacturer's name or mark
- test pressure, where applicable
13.4 In the case of series-manufactured castings, agreement may be reached with the Surveyor to apply marks other than those specified above.

14. Certificates

For each consignment, the manufacturer shall supply to the Surveyor a certificate containing at least the following details:

- orderer and order number
- newbuilding or project number, where known
- item number and quantity
- type of casting units and grade of cast iron
- application and drawing number, if necessary
- weight of products
- manufacturing process
- heat number or identifying mark
- chemical composition of the heat
- condition of supply
- details of heat treatment, if necessary
- marking
- test pressures, if necessary
- results of mechanical tests

B. Nodular Cast Iron

1. Scope

These Rules are applicable to nodular cast iron for the manufacture of machinery and pipeline components, e.g. fittings, flanges, housings, hubs, bed-plates and similar parts designed for use and testing at normal ambient temperatures.

The requirements for the use of castings at higher operating temperatures or at low temperatures generally below 0 °C are subject to the special agreement of GL.

2. Suitable grades of cast iron

The following grades of cast iron may be used:

2.1 Nodular cast iron conforming to DIN EN 1563 with the characteristics stated in the standard.

2.2 Nodular cast iron grades conforming to other standards, provided that they are equivalent to the grades specified in 2.1 and satisfy the requirements stated in 4.2 to 4.4.

3. Condition of supply and heat treatment

3.1 Apart from the exceptions provided for in 3.2, the castings may be supplied in as cast or heat-treated condition. The method of treatment shall be specified at the time of the approval test.

3.2 Cast iron of grades EN-GJS-350-22-LT/-22-U-LT to EN-GJS-400-18-LT/-18U-LT or the special qualities according to Table 5.1 with nominal strengths of 350 and 400 N/mm² shall undergo ferritizing treatment.

3.3 Where castings are subject to special requirements in respect of their dimensional or geometrical stability, any heat treatments needed shall be carried out before the castings are machined.

Heat treatments to eliminate casting stresses or for straightening may only be carried out at temperatures up to 550 °C because of the danger that the characteristics might be changed.

4. Requirements applicable to the material

4.1 Nodular cast iron conforming to DIN EN 1563

The requirements specified in the standard and given in Table 5.2 for separately cast samples and in Table 5.3 for integrally cast samples are applicable.

In case of requirements regarding impact energy, the minimum values specified in Tables 5.4 and 5.5 are to be proven.

In addition the requirements in 4.3 and 4.4 apply regarding graphite- or metallic matrix structure respectively.

4.2 Other grades of cast iron

4.2.1 The castings shall achieve the mechanical properties specified in Table 5.1 in testing, depending on their minimum tensile strength. The Brinell hardness data are only guide values.

4.2.2 Special quality castings shall meet the required energy impact values specified in Table 5.1.

4.3 Graphite structure

The manufacturing process shall ensure that 90 % of the graphite is precipitated in nodular form according to Form VI of EN ISO 945. The remaining graphite shall have a structure at least of form V according to the above mentioned standard.

4.4 Structure of metallic matrix

The metallic matrix shall have the structure indicated in Table 5.1. The proportion of pearlite in the ferritic grades may not exceed 10 %. The graphite- and metallic matrix structures are to be demonstrated by micrographs.
### Table 5.1 Mechanical properties and structure of nodular cast iron

<table>
<thead>
<tr>
<th>Minimum tensile strength $R_m$ $^1$ [N/mm²]</th>
<th>$R_{p0.2}$ $^2$ [N/mm²] min.</th>
<th>$A$ $^3$ [%] min.</th>
<th>Hardness HB $^4$ 10 min.</th>
<th>Impact energy</th>
<th>Test temp. [°C]</th>
<th>$K_V$ $^3$ [J] min.</th>
<th>Structure of metallic matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ordinary qualities</strong></td>
<td></td>
<td></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>
<td>—</td>
<td>Ferrite</td>
</tr>
<tr>
<td>400</td>
<td>250</td>
<td>15</td>
<td>140 – 200</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>Ferrite</td>
</tr>
<tr>
<td>450</td>
<td>310</td>
<td>10</td>
<td>160 – 210</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>Ferrite</td>
</tr>
<tr>
<td>500</td>
<td>320</td>
<td>7</td>
<td>170 – 240</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>Ferrite/pearlite</td>
</tr>
<tr>
<td>600</td>
<td>370</td>
<td>3</td>
<td>190 – 270</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>Ferrite/pearlite</td>
</tr>
<tr>
<td>700</td>
<td>420</td>
<td>2</td>
<td>230 – 300</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>Perlite</td>
</tr>
<tr>
<td>800</td>
<td>480</td>
<td>2</td>
<td>250 – 350</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>Perlite/sorbite</td>
</tr>
<tr>
<td><strong>Special qualities</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>350</td>
<td>220</td>
<td>22 $^4$</td>
<td>110 – 170</td>
<td>17 (14)</td>
<td>—</td>
<td>—</td>
<td>Ferrite</td>
</tr>
<tr>
<td>400</td>
<td>250</td>
<td>18 $^4$</td>
<td>140 – 200</td>
<td>14 (11)</td>
<td>—</td>
<td>—</td>
<td>Ferrite</td>
</tr>
</tbody>
</table>

$^1$ Where the minimum tensile strength of the casting falls between the graduated values indicated, the requirements may be determined by interpolation.

$^2$ The values are intended only as a guide and are not test requirements.

$^3$ The average value measured on 3 Charpy V-notch specimens. One result may be below the average value but not less than the minimum shown in brackets.

$^4$ In the case of integrally cast samples, the elongation may be 2 percentage points less.

### Table 5.2 Mechanical properties determined from samples of separately cast test specimens

<table>
<thead>
<tr>
<th>Material designation</th>
<th>Material code</th>
<th>Tensile strength $R_m$ [N/mm²] min.</th>
<th>0,2-proof stress $R_{p0.2}$ [N/mm²] min.</th>
<th>Elongation $A$ [%] min.</th>
<th>Main structure of metallic matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td>EN-GJS-350-22-LT $^1$</td>
<td>EN-JS1015</td>
<td>350</td>
<td>220</td>
<td>22</td>
<td>Ferrite</td>
</tr>
<tr>
<td>EN-GJS-350-22-RT $^2$</td>
<td>EN-JS1014</td>
<td>350</td>
<td>220</td>
<td>22</td>
<td>Ferrite</td>
</tr>
<tr>
<td>EN-GJS-350-22</td>
<td>EN-JS1010</td>
<td>350</td>
<td>220</td>
<td>22</td>
<td>Ferrite</td>
</tr>
<tr>
<td>EN-GJS-400-18-LT $^1$</td>
<td>EN-JS1025</td>
<td>400</td>
<td>240</td>
<td>18</td>
<td>Ferrite</td>
</tr>
<tr>
<td>EN-GJS-400-18-RT $^2$</td>
<td>EN-JS1024</td>
<td>400</td>
<td>250</td>
<td>18</td>
<td>Ferrite</td>
</tr>
<tr>
<td>EN-GJS-400-18</td>
<td>EN-JS1020</td>
<td>400</td>
<td>250</td>
<td>18</td>
<td>Ferrite</td>
</tr>
<tr>
<td>EN-GJS-400-15</td>
<td>EN-JS1030</td>
<td>400</td>
<td>250</td>
<td>15</td>
<td>Ferrite</td>
</tr>
<tr>
<td>EN-GJS-450-10</td>
<td>EN-JS1040</td>
<td>450</td>
<td>310</td>
<td>10</td>
<td>Ferrite</td>
</tr>
<tr>
<td>ENGJS-500-7</td>
<td>EN-JS1050</td>
<td>500</td>
<td>320</td>
<td>7</td>
<td>Ferrite/Perlite</td>
</tr>
<tr>
<td>EN-GJS-600-3</td>
<td>EN-JS1060</td>
<td>600</td>
<td>370</td>
<td>3</td>
<td>Perlite/Ferrite</td>
</tr>
<tr>
<td>EN-GJS-700-2</td>
<td>EN-JS1070</td>
<td>700</td>
<td>420</td>
<td>2</td>
<td>Perlite</td>
</tr>
<tr>
<td>EN-GJS-800-2</td>
<td>EN-JS1080</td>
<td>800</td>
<td>480</td>
<td>2</td>
<td>Perlite</td>
</tr>
</tbody>
</table>

$^1$ LT for low temperatures

$^2$ RT for room temperature

**Note**
The values for these materials apply to units cast in sand moulds with comparable temperature conductivity.
Table 5.3 Mechanical properties determined from samples of integrally cast test specimens

<table>
<thead>
<tr>
<th>Material designation</th>
<th>Determining wall thickness ( t ) [mm]</th>
<th>Tensile strength ( R_m ) [N/mm(^2)] min.</th>
<th>0.2 % Proof stress ( R_{p0.2} ) [N/mm(^2)] min.</th>
<th>Elongation ( A ) [%] min.</th>
</tr>
</thead>
<tbody>
<tr>
<td>EN-GJS-350-22U-LT (^1)</td>
<td>( t \leq 30 )</td>
<td>350</td>
<td>220</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>( 30 &lt; t \leq 60 )</td>
<td>330</td>
<td>210</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>( 60 &lt; t \leq 200 )</td>
<td>320</td>
<td>200</td>
<td>15</td>
</tr>
<tr>
<td>EN-GJS-350-22U-RT (^2)</td>
<td>( t \leq 30 )</td>
<td>350</td>
<td>220</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>( 30 &lt; t \leq 60 )</td>
<td>330</td>
<td>210</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>( 60 &lt; t \leq 200 )</td>
<td>320</td>
<td>200</td>
<td>15</td>
</tr>
<tr>
<td>EN-GJS-350-22U</td>
<td>( t \leq 30 )</td>
<td>350</td>
<td>220</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>( 30 &lt; t \leq 60 )</td>
<td>330</td>
<td>210</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>( 60 &lt; t \leq 200 )</td>
<td>320</td>
<td>200</td>
<td>15</td>
</tr>
<tr>
<td>EN-GJS-400-18U-LT (^1)</td>
<td>( t \leq 30 )</td>
<td>400</td>
<td>240</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>( 30 &lt; t \leq 60 )</td>
<td>390</td>
<td>230</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>( 60 &lt; t \leq 200 )</td>
<td>370</td>
<td>220</td>
<td>12</td>
</tr>
<tr>
<td>EN-GJS-400-18U-RT (^2)</td>
<td>( t \leq 30 )</td>
<td>400</td>
<td>250</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>( 30 &lt; t \leq 60 )</td>
<td>390</td>
<td>250</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>( 60 &lt; t \leq 200 )</td>
<td>370</td>
<td>240</td>
<td>12</td>
</tr>
<tr>
<td>EN-GJS-400-18U</td>
<td>( t \leq 30 )</td>
<td>400</td>
<td>250</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>( 30 &lt; t \leq 60 )</td>
<td>390</td>
<td>250</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>( 60 &lt; t \leq 200 )</td>
<td>370</td>
<td>240</td>
<td>12</td>
</tr>
<tr>
<td>EN-GJS-400-15U</td>
<td>( t \leq 30 )</td>
<td>400</td>
<td>250</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>( 30 &lt; t \leq 60 )</td>
<td>390</td>
<td>250</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>( 60 &lt; t \leq 200 )</td>
<td>370</td>
<td>240</td>
<td>11</td>
</tr>
<tr>
<td>EN-GJS-450-10U</td>
<td>( t \leq 30 )</td>
<td>450</td>
<td>310</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>( 30 &lt; t \leq 60 )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>( 60 &lt; t \leq 200 )</td>
<td></td>
<td></td>
<td>to be agreed</td>
</tr>
<tr>
<td>EN-GJS-500-7U</td>
<td>( t \leq 30 )</td>
<td>500</td>
<td>320</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>( 30 &lt; t \leq 60 )</td>
<td>450</td>
<td>300</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>( 60 &lt; t \leq 200 )</td>
<td>420</td>
<td>290</td>
<td>5</td>
</tr>
<tr>
<td>EN-GJS-600-3U</td>
<td>( t \leq 30 )</td>
<td>600</td>
<td>370</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>( 30 &lt; t \leq 60 )</td>
<td>600</td>
<td>360</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>( 60 &lt; t \leq 200 )</td>
<td>550</td>
<td>340</td>
<td>1</td>
</tr>
<tr>
<td>EN-GJS-700-2U</td>
<td>( t \leq 30 )</td>
<td>700</td>
<td>420</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>( 30 &lt; t \leq 60 )</td>
<td>700</td>
<td>400</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>( 60 &lt; t \leq 200 )</td>
<td>660</td>
<td>380</td>
<td>1</td>
</tr>
<tr>
<td>EN-GJS-800-2U</td>
<td>( t \leq 30 )</td>
<td>800</td>
<td>480</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>( 30 &lt; t \leq 60 )</td>
<td></td>
<td></td>
<td>to be agreed</td>
</tr>
<tr>
<td></td>
<td>( 60 &lt; t \leq 200 )</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^1\) LT for low temperatures

\(^2\) RT for room temperature
### Table 5.4  Minimum values for impact energy determined from samples with V-notch from separately cast test specimens

<table>
<thead>
<tr>
<th>Material designation</th>
<th>Minimum values for impact energy [J]</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>at RT (23 ± 5 °C)</td>
<td>at (−20 ± 2) °C</td>
<td>at (−40 ± 2) °C</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Average value from 3 tests</td>
<td>Individual value</td>
<td>Average value from 3 tests</td>
<td>Individual value</td>
<td>Average value from 3 tests</td>
</tr>
<tr>
<td>EN-GJS-350-22-LT 1</td>
<td>EN-JS1015</td>
<td>12</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EN-GJS-350-22RT 2</td>
<td>EN-JS1014</td>
<td>17</td>
<td>14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EN-GJS-400-18-LT 1</td>
<td>EN-JS1025</td>
<td>12</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EN-GJS-400-18-RT 2</td>
<td>EN-JS1024</td>
<td>14</td>
<td>11</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 LT for low temperatures 
2 RT for room temperature

**Note**
The values for these materials apply to units cast in sand moulds with comparable temperature conductivity.

### Table 5.5  Minimum values for impact energy determined from samples with V-notch from integrally cast test specimens

<table>
<thead>
<tr>
<th>Material designation</th>
<th>Determining wall thickness [mm]</th>
<th>Minimum values for impact energy [J]</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>rt [mm]</td>
<td>at RT (23 ± 5 °C)</td>
<td>at (−20 ± 2) °C</td>
<td>at (−40 ± 2) °C</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Average value from 3 tests</td>
<td>Individual value</td>
<td>Average value from 3 tests</td>
<td>Individual value</td>
<td>Average value from 3 tests</td>
<td>Individual value</td>
</tr>
<tr>
<td>EN-GJS-350-22U-LT 1</td>
<td>EN-JS1019</td>
<td>t ≤ 60</td>
<td>12</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>60 &lt; t ≤ 200</td>
<td>10</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EN-GJS-350-22U-RT 2</td>
<td>EN-JS1029</td>
<td>t ≤ 60</td>
<td>17</td>
<td>14</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>60 &lt; t ≤ 200</td>
<td>15</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EN-GJS-400-18U-LT 1</td>
<td>EN-JS1049</td>
<td>30 &lt; t ≤ 60</td>
<td>12</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>60 &lt; t ≤ 200</td>
<td>10</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EN-GJS-400-18U-RT 2</td>
<td>EN-JS1059</td>
<td>30 &lt; t ≤ 60</td>
<td>14</td>
<td>11</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>60 &lt; t ≤ 200</td>
<td>12</td>
<td>9</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 LT for low temperatures 
2 RT for room temperature

**Note**
The values for these materials apply as a rule to casting units with thicknesses between 30 and 200 mm.
5. Testing
The following tests shall be performed:

5.1 Test of chemical composition
The manufacturer shall determine and make known to the Surveyor the chemical composition of each heat treatment batch. The analysis report shall cover at least the following elements:
C, Si, Mn, P, S and Mg together with Ni and Cu, where these are added to achieve the required characteristics.

5.2 Testing of mechanical properties and selection of specimens
5.2.1 The mechanical properties such as tensile strength, 0,2 % proof stress and elongation shall be determined by tensile test. In the case of ferritic grades, the yield point revealed by the curve plotted by the testing machine may be stated instead of the 0,2 % proof stress.

5.2.2 For the tensile test, one test specimen each shall be taken from a separately cast U- or a Y-shaped sample piece according to Fig. 5.1 and 5.2 respectively or from an integrally cast sample piece according to Fig. 5.3. The shape of the sample piece shall normally correspond to the standard U or Y2 type with a thickness of 25 mm. In special cases, samples having different dimensions may be agreed. The provision of samples is governed by the following requirements:

- For heavy casting units with gross weights of minimum 1000 kg one sample plus one sample per treatment batch shall be provided.
- For casting units with gross weights of less than 1000 kg one sample per treatment batch shall be provided. In case of testing by batch one sample per 1000 kg gross weight of the test batch shall be provided and one additional sample for each further 2000 kg gross weight of the test batch. Precondition is that all casting units are from a series of the same type and have been cast from the same treatment batch and heat treated, where applicable.
- Where heat treatments are carried out, integrally cast samples may be removed from the casting only after heat treatment. Separately cast samples shall be heat treated together with the casting.

5.3 Notched bar impact test
Where an impact energy is specified for a grade of cast iron, this shall be verified by the notched bar impact test performed on Charpy V-notch specimens at the prescribed test temperature. The requirements regarding impact energy are specified in Table 5.1, 5.4 and 5.5 for the respective grades of cast iron. To carry out the test, one set of specimens shall be taken from each of the samples called for in 5.2.2.

5.4 Test of surface finish and dimensions
The manufacturer shall inspect each casting with regard to its surface finish and compliance with the dimensional and geometrical tolerances and shall then present the casting to the Surveyor for final inspection.
C. Grey Cast Iron

1. Scope

These Rules are applicable to grey cast iron for the manufacture of machinery and pipeline components, e.g. fittings, flanges, housings, hubs, wheel bodies, bed-plates, cylinders, and similar parts.

2. Suitable grades of cast iron

The following grades of cast iron may be used:

2.1 Grey cast iron conforming to DIN EN 1561, with the exception of grades EN-GJL-100 and EN-GJL-150.

2.2 Grades of cast iron conforming to other standards, provided that they are equivalent to the grades specified in 2.1 and meet the requirements of 4.

3. Condition of supply and heat treatment

Castings may be supplied in the as cast or heat-treated condition at the manufacturer's option unless a heat treatment is specified because of special requirements in respect of machinability or geometrical and dimensional stability.

4. Requirements applicable to the material

4.1 Mechanical characteristics

Castings shall normally be supplied with one of the following minimum tensile strengths $R_{\text{m}}$:

- $200 \text{ N/mm}^2$
- $250 \text{ N/mm}^2$
- $300 \text{ N/mm}^2$
- $350 \text{ N/mm}^2$

Castings with minimum tensile strength values of $< 200 \text{ N/mm}^2$ are not allowed. The requirements are applicable to specimens with a diameter of 20 mm in accordance with 5.2.4. The requirements regarding minimum tensile strength for separately and integrally cast specimens are specified in Table 5.6. The requirements for specimens taken from the casting (e.g. core specimens) shall be specially agreed between manufacturer and orderer as well as GL.

4.2 Graphite and matrix structure

The method of manufacture shall ensure that the graphite is present in uniformly distributed flakes and
Table 5.6 Tensile strength of grey cast iron

<table>
<thead>
<tr>
<th>Material designation</th>
<th>Determining wall thickness [mm]</th>
<th>Tensile strength values to comply with</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>over</td>
<td>up to</td>
</tr>
<tr>
<td>EN-GJL-200 EN-JL1030</td>
<td>2,5²</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>80</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td>150</td>
<td>300</td>
</tr>
<tr>
<td>EN-GJL-250 EN-JL1040</td>
<td>5²</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>80</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td>150</td>
<td>300</td>
</tr>
<tr>
<td>EN-GJL-300 EN-JL1050</td>
<td>10²</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>80</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td>150</td>
<td>300</td>
</tr>
<tr>
<td>EN-GJL-350 EN-JL1060</td>
<td>10²</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>80</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td>150</td>
<td>300</td>
</tr>
</tbody>
</table>

¹ These values are guidances.
² This value is included as lower limit of the range of determining wall thickness.
³ The values refer to test specimens with 30 mm diameter of rough casting. This corresponds to a determining wall thickness of 15 mm.

that a saturation level $S_c$ of 1,0 is not exceeded. The level of saturation shall be determined by applying the following formula:

$$S_c = \frac{\% C}{4,3 - 0,33 (\% Si + \% P)}$$

The fracture of tested tensile specimens shall have a uniform grey crystalline appearance.

5. Testing and scope of tests

The following tests are to be performed:

5.1 Test of chemical composition

The manufacturer shall constantly monitor the chemical composition and the saturation level of each treatment unit (ladle) and shall pass this information on to the Surveyor on request. Determination of at least the following elements is required: C, Mn, Si, P and S.

5.2 Testing of mechanical properties and selection of specimens

5.2.1 The tensile strength is to be determined by a tensile test. For this purpose, separately cast specimens with 30 mm diameter of rough casting and 200 mm minimum length according to Fig. 5.4 may be used as well as integrally cast specimens of type 2 according to DIN EN 1561, see also Fig. 5.5.
5.2.2 The test sample type shall be so selected that about the same conditions for cooling down apply as for the casting unit.

5.2.3 For casting units which determining wall thickness exceeds 20 mm and which gross weight is larger than 200 kg, integrally cast test specimens shall be used.

5.2.4 A test specimen of 20 mm diameter is to be taken from each sample for testing. Thereby the fracture surfaces of the test specimens shall be assessed. For test specimen shape, refer to Chapter 1 – Principles and Test Procedures, Section 2, D.1.3.6.

5.2.5 The following number of samples is to be provided:

- For heavy casting units with gross weights of minimum 1000 kg one sample plus one sample per treatment batch shall be provided.
- For casting units with gross weights of less than 1000 kg one sample per treatment batch shall be provided. In case of testing by batch one sample per 1000 kg gross weight of the test batch shall be provided and one additional sample for each further 2000 kg gross weight of the test batch. Precondition is that all casting units are from a series of the same type and have been cast from the same treatment batch and heat treated, where applicable.

5.3 If casting units are supplied in heat treated condition, the samples shall be heat treated together with the respective casting units.

5.4 Test of surface finish and dimensions

The manufacturer shall inspect each casting with regard to its surface finish and compliance with the dimensional and geometrical tolerances and shall then present the casting to the Surveyor for final inspection.
Section 6

Fittings and Pressed Parts, Bolts and Nuts

A. Pressed Parts

1. Scope

1.1 These Rules are applicable 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. They are also applicable to the method of heat treatment which may be required after forming has been carried out.

1.2 These Rules 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 GL Rules Part 3 – Welding.

2. Requirements to be met by manufacturers

Manufacturers wishing to supply products in accordance with these Rules shall be approved by GL. This is conditional upon their fulfilling the manufacturing and quality control requirements specified in Chapter 1 – Principles and Test Procedures, Section 1, C. and furnishing proof of this to GL prior to the commencement of supplies. Tests of product suitability shall additionally be performed on selected products.

3. Requirements applicable to the starting plates

3.1 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 fulfil the requirements to be met by the base material concerned after forming and, where applicable, heat treatment.

3.2 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 the plates and the method of heat treatment of the test specimens shall be indicated in the test certificate.

4. Dimensions, dimensional and geometrical tolerances

These are governed by the relevant standards and/or the information in the order documents. The manufacturer shall keep relevant documents ready for the testing.

5. Principles governing hot forming and heat treatment

5.1 The manufacturer of the 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.

5.2 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 recording instruments which are to be recalibrated at regular intervals.

5.3 As far as possible, all parts shall be heated or annealed in their entirety. With the consent of the Surveyor, this Rule may be waived where only local forming is performed. In these cases the heat treatment shall, however, embrace the whole area of deformation.

5.4 The temperatures, holding times and heating and cooling rates shall be determined by reference to the data contained in the standards or manufacturer's specifications in accordance with the material and the component concerned. The manufacturer is required to guarantee compliance with the conditions.

5.5 Where the testing of finished parts is allowed to be carried out on separate test sections, provision 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.

6. Heat treatment after hot forming

6.1 Ferritic steels

6.1.1 Hot forming shall normally be followed by renewed heat treatment as prescribed for the base material concerned.

This Rule may be waived in the case of normalized and air-quenched and tempered steels with the exception of the steels tough at sub-zero temperatures, provided that the hot forming operation is begun and ended within the temperature range specified for this purpose in the standard or the manufacturer's material specification. In this case, the renewed heat treatment can be dispensed with for normalized steels while tempering can suffice for air quenched and tempered steels.
6.1.2 For the steels tough at sub-zero temperatures, preliminary proof shall be furnished that the intended heat treatment imparted to the finished part the necessary impact energy at the specified test temperature. If this is the case, then, subject to the conditions mentioned in 6.1.1, subsequent heat treatment may be dispensed with for normalized steels, while subsequent tempering may suffice for air quenched and tempered (normalized and tempered) steels, and in the case of 5 % and 9 % nickel steels calling for triple heat treatments (12 Ni 19 and X 8 Ni 9), the second normalizing and tempering operation may be sufficient.

6.1.3 For water-quenched and tempered steels, the nature of the heat treatment to be applied after hot forming shall be specially determined.

6.1.4 The exceptional provisions set out in 6.1.1 and 6.1.2 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.

6.2 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 Rule may be waived where the forming operation is begun in the temperature range from 1150 to 1000 °C and is 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 C ≤ 0,08, followed by rapid cooling to ambient temperature.

6.3 Clad plates

Where parts are made of clad plates, the nature of the heat treatment is governed by the base material, see 6.1. 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 GL.

7. Heat treatment after cold forming

7.1 Ferritic steels

All plates shall be in the prescribed condition of supply before cold forming is carried out, see the individual Rules in Section 1. Due to the changes in material properties which may result from cold forming and ageing, the following procedure applies:

7.1.1 Pressed parts for pressure vessels operated at ambient temperatures or feedstock temperatures down to − 10 °C shall, if the degree of deformation exceeds 5 % (wall thickness s > 0,05 ⋅ Dm for cylindrical shell rings and sphere segments), be subjected to heat treatment (normalizing or quenching and tempering) in accordance with the relevant standards or material specifications.

7.1.2 Pressed parts for pressure vessels operated at charging media temperatures below − 10 °C shall, 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,

be subjected to heat treatment (normalizing or quenching and tempering) in accordance with the relevant standards or material specifications.

7.1.3 Pressed parts for gas tanks with design temperatures below 0 °C shall be treated in accordance with 7.1.2.

7.1.4 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.

7.1.5 The stipulations of 7.1.1, 7.1.2 and 7.1.4 may be relaxed if proof is furnished that the properties of the materials make them able to withstand the stresses prevailing while the pressure vessel is in service.

7.1.6 Cold-formed dished heads made of steel grades 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 does not exceed 120 °C according to GL Construction Rules and the nominal wall thickness is ≤ 8 mm.

7.1.7 If the acceptable degrees of deformation are exceeded in cold forming, heat treatment shall as a rule be performed before welding.

7.1.8 In the case of clad pressure vessels or pressure vessel components, heat treatment shall be performed in accordance with the base material, unless special conditions have to be agreed with regard to the cladding.

7.2 Austenitic steels

7.2.1 Acceptable heat treatments are solution annealing with quenching or, for stabilized steels (exception: Mo-alloyed stabilized steels with more than 0,03 % C) and steels with carbon contents of C ≤ 0,03 %, stabilization annealing.

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1 For further details on heat treatment of austenitic steels, see AD-Merkblatt (AD Data Sheet) HP/7.3.
Note
See AD Data Sheet HP 7/3.

7.2.2 Heat treatment of solution annealed and quenched or stabilization annealed material after cold forming may be dispensed with if:

7.2.2.1 in the case of austenitic steels with required minimum elongation values $A_{\%}$ of $\geq 30$ % 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 $\geq 30$ % is shown in the acceptance test certificate;

7.2.2.2 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 %;

7.2.2.3 in the case of dished, ellipsoidal and hemispherical heads, the following elongations $A$ are shown in the acceptance test certificates for the starting materials:
- $\geq 40$ % for nominal wall thicknesses $\leq 15$ mm at design temperatures down to $-196$ °C,
- $\geq 45$ % for nominal wall thicknesses $> 15$ mm at design temperatures down to $-196$ °C,
- $\geq 50$ % at design temperatures below $-196$ °C;

7.2.2.4 in the case of pressure vessel components, except heads, which are operated at design temperatures below $-196$ °C, the degree of deformation does not exceed 10 %.

7.3 Clad plates

Cold-formed finished parts made of clad plates are subject to the conditions stated in 7.1 for the base material concerned.

8. Testing

8.1 Test of mechanical and technological properties

8.1.1 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. A 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 6.1, shall be taken from surplus material at the edges of the pressed parts or from cutouts.

8.1.2 Where stress relief heat treatment is sufficient after forming, the test section may be removed from the test piece beforehand and subjected to the same annealing treatment.

8.1.3 Where Table 6.1 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.

8.1.4 Where individual testing of the pressed parts is prescribed, testing of the starting material by GL may be dispensed with.

8.1.5 Instead of individual testing of the pressed parts, GL may agree to testing by rolled plate (1 set of specimens per starting plate) provided that the manufacturer of the pressed parts demonstrates to GL 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.

8.2 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 the dimensions.

For this purpose, the manufacturer shall give the Surveyor the measuring records.

9. Marking

Each part shall be marked by the manufacturer with the manufacturer's mark, the material designation, the heat number and the specimen number.

10. Certificates

10.1 In the case of pressed parts which are heat treated after forming, the manufacturer shall certify the proper execution of the heat treatment stating the temperatures, the holding times and the type of cooling applied.

10.2 In the case of pressed parts which may be supplied in the hot pressed condition, the manufacturer shall certify that the forming operation was begun and ended within the specified temperature limits and shall indicate the standard or material specification applicable. In addition, the method of cooling and the condition in which the starting material was supplied shall also be stated.
### Table 6.1 Scope of tests on pressed parts made from plate

<table>
<thead>
<tr>
<th>Grades of steel</th>
<th>Base material according to Section 1</th>
<th>Test performed on</th>
<th>Extent of tests on pressed parts</th>
</tr>
</thead>
<tbody>
<tr>
<td>All unalloyed steels with a minimum tensile strength ≤ 410 N/mm²</td>
<td>C, E</td>
<td>starting plate</td>
<td>not required</td>
</tr>
<tr>
<td>Unalloyed and fine-grained structural steels with a minimum tensile strength 410 &lt; R_m ≤ 510 N/mm², and R_eH ≤ 355 N/mm², also 0.3 %-Mo alloy steels</td>
<td>C, E</td>
<td>starting plate pressed part</td>
<td>testing by batches</td>
</tr>
<tr>
<td>Fine-grained structural steels, R_eH &gt; 355 N/mm²</td>
<td>E</td>
<td>pressed part</td>
<td>1 set of specimens from each pressed part</td>
</tr>
<tr>
<td>High-temperature CrMo alloy steels</td>
<td>E</td>
<td>pressed part</td>
<td>1 set of specimens from each pressed part</td>
</tr>
<tr>
<td>Steels tough at sub-zero temperatures</td>
<td>F</td>
<td>pressed part</td>
<td>1 set of specimens from each pressed part</td>
</tr>
<tr>
<td>Austenitic stainless steels:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thickness [mm]</td>
<td>≤ 20</td>
<td>G</td>
<td>starting plate</td>
</tr>
<tr>
<td></td>
<td>&gt; 20</td>
<td>starting plate pressed part</td>
<td>testing by batches</td>
</tr>
<tr>
<td>Clad plates</td>
<td>H</td>
<td>The extent of the test depends on the base material</td>
<td></td>
</tr>
</tbody>
</table>

1 Pressed parts which are designed for the manufacture of tanks carrying pressure-liquefied ammonia are subject to F.8.2.2.

2 Testing by rolled plate may be agreed if the conditions specified in 8.1.5 are satisfied.

### B. Pipe Fittings

#### 1. Scope

These Rules are applicable 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.

#### 2. Starting materials

Suitable plates or pipes are to be selected as starting materials in accordance with Section 1 or 2. Unless otherwise stipulated by GL, the starting materials shall be ordered with inspection certificates conforming to EN 10204-3.1 from manufacturers approved by GL.

#### 3. Manufacture

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 welded together.

3.2 Proof shall be furnished to GL, 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 GL for consideration. The nature and scope of the procedure approval inspection shall be determined by GL from case to case.

#### 4. Heat treatment

4.1 All fittings shall be in the heat-treated or hot-worked state specified for the material according to GL Rules or other relevant standards or material specifications.

4.2 In the case of ferritic steels for which normalizing is prescribed and which undergo hot forming, subsequent heat treatment may be dispensed with if a corresponding structure can be achieved by the hot forming operation. In the same circumstances, tempering may be sufficient for steels for which quenching and tempering is prescribed.
4.3 Cold formed parts are generally required to undergo renewed heat treatment following the forming operation. If such treatment is not to be applied, the manufacturer shall prove that the finished part retains the required characteristics.

4.4 Where fittings are welded together from hot or cold formed components, the nature of the heat treatment shall be determined at the time of the procedure approval test.

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 radii of \( r_m \geq 1.3 \cdot d_a \), subsequent heat treatment is not required if the outside diameter \( d_a \) is \( \leq 133 \text{ mm} \). The same applies to all elbows manufactured with bending radii of \( r_m \geq 2.5 \cdot d_a \).

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 the neutral zone.

5. Requirements applicable to properties

In the finished state, the fittings shall possess all the required characteristics specified for the starting material used (pipe or plate).

6. Testing

6.1 Inspection and dimensional check

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.

6.2 Testing of materials

6.2.1 For performing the mechanical tests, the fittings shall be divided into test batches in accordance with Table 6.2.

A test batch in accordance with Table 6.2 consists of fittings made of the same materials and having the same dimensions, and, in the case of alloy steel fittings with a \( d_a > 100 \text{ mm} \), originating from the same heat. If final heat treatment is necessary, testing shall also be performed by 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.

6.2.2 The scope of the mechanical tests is as shown in Table 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 of the fittings; the specimens shall be prepared from the hardest and softest fittings determined in the hardness tests. The required values shall be the definitive values for the starting materials.

6.2.3 In the case of steels tough at sub-zero temperatures, the notched bar impact test shall be performed at the appropriate test temperature.

6.2.4 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.

6.2.5 Alloy steel fittings shall be subjected to appropriate testing by the manufacturer to verify the use of the correct material.

6.2.6 Welded alloy steel fittings with nominal bores > 75 mm shall be subjected by the manufacturer to random radiographic inspection of the welds. Unless stipulated in the specification or the order, the number of fittings to be tested shall be agreed with the Surveyor. These shall be selected in such a way that every size of fitting is included.

7. Marking

The fittings shall be marked as follows:

- manufacturer's symbol
- material designation
- where applicable, quality level in the case of boiler tubes
- heat number or code, if the starting material had a corresponding marking

<table>
<thead>
<tr>
<th>Size ( d_a ) [mm]</th>
<th>No. of fittings per test batch</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 100</td>
<td>( \leq 200 )</td>
</tr>
<tr>
<td>( \geq 100 ) &lt; 225</td>
<td>( \leq 100 )</td>
</tr>
<tr>
<td>( \geq 225 ) &lt; 350</td>
<td>( \leq 50 )</td>
</tr>
<tr>
<td>( \geq 350 )</td>
<td>( \leq 25 )</td>
</tr>
</tbody>
</table>

Table 6.2 Test batches for fittings

1 Test batches apply to 90-degree elbows. The number of elbows per test batch is halved in the case of 180-degree elbows and doubled in the case of 45-degree elbows.
### Table 6.3 Classification into test groups and scope of tests

<table>
<thead>
<tr>
<th>Test groups</th>
<th>Size $d_a$ [mm]</th>
<th>Material</th>
<th>Scope of tests per test batch</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>$&lt; 100$</td>
<td>unalloyed</td>
<td>10% $^3$ min. on 3 fittings</td>
</tr>
<tr>
<td>II</td>
<td>$&lt; 100$</td>
<td>alloyed</td>
<td>$^1$ 4</td>
</tr>
<tr>
<td>III</td>
<td>$\geq 100$</td>
<td>unalloyed</td>
<td>2 specimens, only if less than 10 fittings</td>
</tr>
<tr>
<td>IV</td>
<td>$\geq 100$</td>
<td></td>
<td>10% $^3$ min. on 3 fittings</td>
</tr>
<tr>
<td>V</td>
<td>$&gt; 225$</td>
<td>or</td>
<td>100% $^5$</td>
</tr>
</tbody>
</table>

---

1. With austenitic steels, the hardness test is dispensed with if the 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 taken where the wall thickness is $\geq 6$ mm and the 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 Cr Mo 9-10 conforming to EN 10028-2, the scope of hardness testing specified for test group IV is applicable.

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C. **Bolts and Nuts**

1. **Scope**

   1.1 These Rules are applicable to the manufacture, the mechanical properties and the testing of bolts and nuts for
   - boilers, vessels, equipment and pipelines
   - diesel engines, gears, shafting and propellers
   - other components of the machinery plant for which proof of quality is required as specified in the Construction Rules

   1.2 The choice of bolts and nuts, together with the form of the requisite material test certificate is set out in the individual Chapters of the Construction Rules and shall be stated in the purchase order.

2. **Materials**

   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 GL. The steels used in the manufacture of bolts shall have a guaranteed impact energy. Under these conditions, the following materials may be considered:

   2.1.1 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.

   2.1.2 Steels conforming to EN 10269 in conjunction with DIN 267-13.

   2.1.3 Steels conforming to DIN 267-13.

   2.1.4 Stainless steels conforming to ISO 3506-1 and -2.

   2.2 Bolts and nuts conforming to other standards or the manufacturer's material specifications may be used, provided that GL has confirmed their suitability for the intended application. Unless otherwise specified, the materials shall satisfy the requirements of 4.2.2, 4.2.3 and 4.2.4.

   2.3 Free cutting steels with a high sulphur, phosphorous or lead content may not be used.
3. Manufacture

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 the exception of those made of quenched and tempered steels, provided that the latter are to be used at normal ambient temperatures and the hot forming process results in a uniform structure.

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

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

4. Requirements applicable to the material

4.1 Chemical composition
The chemical composition shall satisfy the stipulations according to Section 3.B., Table 3.2 and the relevant standards or specifications respectively.

4.2 Mechanical properties

4.2.1 Bolts and nuts conforming to the standards specified in 2.1.1 to 2.1.4 shall meet the mechanical properties set out in these standards.

4.2.2 Steels tough at sub-zero temperatures for bolts and nuts which are to be used in the construction of gas tanks shall achieve an impact energy of at least 41 Joules at the prescribed test temperature using longitudinal Charpy V-notch specimens. The test temperature is to be determined in accordance with Section 3, F.

4.2.3 Steels for bolts and nuts with threads exceeding M39 as well as according to 2.2 shall have the characteristic values of the material and shall satisfy the following conditions in testing at room temperature with longitudinal specimens.

- Elongation $A \geq 14\%$,
- impact energy using Charpy V-notch specimens $\geq 52$ Joules for quenched and tempered steels and $\geq 40$ Joules for unalloyed steels.

4.2.4 Steels for bolts and nuts intended for engine foundation and with threads exceeding M39 as well as according to 2.2 shall have the characteristic values of the material and shall meet the requirements in testing at room temperature with longitudinal specimens according to Section 3, Table 3.5 and Table 3.6.

4.2.5 Steels or semi-finished products for foundation bolts of propulsion plants may be rolled as well as forged, but shall meet the requirements of 4.2.4.

For threads exceeding M39 forged semi-finished products are to be used.

4.2.6 The impact energy values shall be average values obtained with three test specimens. Of these only one specimen may have a value which is below the average value but not less than 70% of the average value.

5. Testing of bolts

5.1 The manufacturer shall demonstrate the chemical composition of each heat according to C.7.

5.2 Tensile testing shall be performed on bolts and, for thread diameters $\geq 16$ mm, the notched bar impact test shall also be carried out.

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 6.4.

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.

<table>
<thead>
<tr>
<th>Table 6.4 Batch sizes for the testing of mechanical properties</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Quantity</strong></td>
</tr>
<tr>
<td>$\leq 200$</td>
</tr>
<tr>
<td>$&gt; 200$ to $\leq 400$</td>
</tr>
<tr>
<td>$&gt; 400$ to $\leq 800$</td>
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<tr>
<td>$&gt; 800$ to $\leq 1200$</td>
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<tr>
<td>$&gt; 1200$ to $\leq 1600$</td>
</tr>
<tr>
<td>$&gt; 1600$ to $\leq 3500$</td>
</tr>
<tr>
<td>$&gt; 3500$</td>
</tr>
</tbody>
</table>

5.3 For the tensile test, specimens may be machined from the sample material, or turned specimens of the type shown in Fig. 6.1 may be used.

![Fig. 6.1 Turned specimen](image-url)
5.4 Where no heat treatment is performed follow-
ing machining and the starting material is in the final
heat treated condition, testing of the starting material
with regard to demonstrating mechanical properties
shall suffice. In this case steel bars from the same heat
and with the same diameter and heat treatment are to
be grouped into test batches of 5000 kg maximum.
The performance of the tensile and notched bar impact
tests require one set of test specimens to be taken from
each test batch.

5.5 Where machining is followed by heat treat-
ment, testing shall be performed in the same way as on
the corresponding formed bolts as per 5.2.

5.6 The surface finish, dimensions and compli-
ance with tolerances shall be verified by the Surveyor
on at least 20 bolts and on at least 10 bolts in the case
of batch sizes of ≤ 200. The manufacturer shall supply
the gauges and callipers necessary for this purpose.

5.7 The uniformity of the delivery is to be dem-
onstrated 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 ≤ 200. The results of the test are to be
submitted to the Surveyor.

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 approxi-
mates most closely to the level of the operating tem-
perature, rounded off to the nearest 50 °C. The test
may be dispensed with in the case of bolts to recog-
nized standards, the high-temperature mechanical
properties of which are regarded as proven.

6. Testing of nuts

6.1 Chemical composition
The chemical composition shall satisfy the stipulations
according to Section 3, B., Table 3.2 and the relevant
standards or specifications respectively.

6.2 Nuts with nominal thread diameters of up to
and including 39 mm are to be subjected to the expa-
sion test using a mandrel with a 1:100 taper, see Fig.
6.2. 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 ≥ 0,8 · nominal
thread diameter d (at least 4 % for nuts with a depth of
≥ 0,5 to < 0,8 d). The numbers of test specimens
shown in Table 6.4 are applicable, but for quantities of
≤ 200 at least 2 nuts shall be tested.

6.3 Nuts with nominal thread diameters > 39 mm
are to be subjected to testing of the starting material as
specified in 5.2 rather than the expansion test.

Test mandrel for 6% expansion (1.06 d)
or 4% expansion (1.04 d) of the nut

\[ d = \text{nominal thread diameter} \]
\[ m = \text{nominal depth of nut} \]

Test arrangement

Fig. 6.2 Expansion testing of nuts
6.4 The uniformity of the 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 ≤ 200. The results of the test are to be submitted by the Surveyor.

6.5 The surface finish, dimensions and compliance with tolerances shall be verified by the Surveyor in the same way as described in 5.6.

7. Proof of chemical composition

7.1 For each delivery, the manufacturer shall provide the surveyor with a certificate giving the results of the chemical analysis, heat numbers, dimensions and the as-delivered condition of the starting material processed by him. The name of the steel producer shall also be indicated in the certificate.

7.2 Alloy steel bolts and nuts shall be subjected by the manufacturer to appropriate tests for use of the correct material.

8. Non-destructive tests

The manufacturer shall apply a suitable method of crack detection to the following bolts:

- turbine casing bolts
- bolts in main steam lines with temperatures > 350 °C
- propeller blade fixing bolts

and, for diesel engines with cylinder diameters > 400 mm, the following bolts:

- main bearing bolts
- connecting rod bolts
- cross-head bearing bolts
- cylinder cover bolts

9. Retests

9.1 Where one of the test specimens required for carrying out testing of mechanical properties does not satisfy the specified conditions, two additional test specimens or test sets of each are to be taken which shall satisfy the requirements. If these test samples also fail to meet the requirements, the test batch shall be regarded as unacceptable. The manufacturer may, however, heat treat the batch again and present it for retesting. If, however, these test specimens still fail to meet the requirements, the test batch shall be rejected for once and for all.

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 of ≤ 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.

10. Marking

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

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 GL stamp, and alloy steel bars are to be additionally marked with the heat number. Where the diameter of the steel bars is 25 mm or less, it is sufficient to apply the corresponding markings to the label attached to the bundle of bars.