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Rules for Classification and Construction

Part 1 Seagoing Ships

RULES FOR MATERIALS

Volume V

2024 Consolidated Edition

Biro Klasifikasi Indonesia

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Foreword

This Rules is a consolidated edition 2024 of Rules for Materials (Pt.1, Vol.V).

In this edition, there are no new amendment added, only consolidate the 2022 edition, RCN No.1 and RCN No. 2. The summary of previous edition and amendments including the implementation date are indicated in Table below:

	Edition/ Rule Change Notice (RCN)	Effective Date	Link
1	RCN No.4, October 2023	1st July 2024	
2	RCN No.3, April 2023	1st July 2023	
3	RCN No.2, October 2022	1st July 2023	
4	RCN No.1 April 2022	1st January 2023	
5	Consolidated Edition 2022	-	
6	RCN No.1, May 2021	1st July 2021	
7	Consolidated Edition 2021	-	
8	RCN No.1, July 2020	1st January 2021	
9	Edition 2019	1st July 2019	
10	RCN No.1, October 2018	1st January 2019	
11	Edition 2018	1st April 2018	

Note: *Full previous edition and amendments including its amendment notice is available through link above.*

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Section 1 Principles Covering the Manufacture and Testing of Materials

A. Scope

1. The Rules for Materials apply to materials and products which are intended for the construction, repair and equipping of ships, offshore installations and other structures which are classified by Biro Klasifikasi Indonesia (BKI) or whose classification has been applied for.

2. The scope of these Rules includes all those materials and products whose use is referred to in the Rules for Construction. BKI reserves the right to extend the scope of these Rules to materials and products not specifically mentioned in the Rules for Construction.

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

4. This Section contains principles governing metallic materials and the forms in which these are produced, e.g. plate, strip, sections, rod, pipes, forgings and castings, as well as propellers and anchoring and mooring components, which are to be applied in the course of manufacture and testing. These general principles are to be implemented in conjunction with the specific rules prescribed in the following Sections in reference to the particular products.

B. Other Relevant Specifications and Documents

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

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

3. Subject to the conditions mentioned in 2. BKI may sanction the supply of products conforming exclusively to the relevant standard or material specifications.

4. Should differences exist between these Rules and the relevant standards or specifications with regard to their requirements, the tests shall take account of the more stringent requirements.

C. Requirement Applied to Manufacturing Works

1. The materials and products covered by these Rules may only be manufactured in works approved by BKI for this purpose. Manufacturers shall apply in writing to BKI for approval. Applications are required to contain the following information:

— Materials and products for which approval is sought, including the method of manufacture, guide values for the chemical composition, condition in which the materials and products are to be supplied, properties and dimensions.

— A list of the manufacturing plant and testing equipment used together with descriptions of the quality control system and details of the persons responsible for quality control. Where tests are performed by outside bodies, the addresses of these and their testing facilities are also to be stated. Such testing bodies are subject to BKI approval. This condition is deemed satisfied if the testing body is accredited by an authorized institution.

2. In order to be approved, works shall satisfy at least the following conditions, proof of which shall be furnished to BKI during a factory inspection and by submission of relevant documents prior to the commencement of manufacture:

2.1 They shall be equipped with plant enabling the materials to be expertly manufactured and worked in accordance with modern technical practice.

2.2 They shall have the necessary testing equipment and the skilled staff required for its operation in order to perform expertly the tests specified in these Rules and in the relevant documents. Where, in exceptional cases, individual tests have to be carried out by outside bodies, such tasks shall be entrusted by the manufacturer only to those firms or institutes which also meet the aforementioned conditions and have been approved by BKI.

2.3 The works shall, by their own quality control arrangements, ensure that the products are expertly manufactured and processed and that they meet the specified requirements. Testing carried out by BKI shall not exonerate the manufacturer from this liability. Where internal quality control departments are established for the performance of these functions, this shall be independent of the management of the production and processing departments.

2.4 As part of their own internal quality control system, works shall keep a constant record of the manufacture and testing of materials and products.

2.5 Where required in D.5., works shall demonstrate the properties of their products by preliminary testing of the procedure and/or the product suitability.

3. If the assessment by BKI yields that the requirements of 1. and 2. are met, the manufacturer will be approved by BKI. The approval normally valid for not more than 5 years. The manufacturer receives a certificate of approval and will be included in the list of approved material manufacturers, which also contains the scope of approval and the area of validity. The validity may thereafter be extended where it is demonstrated by repeat testing that the conditions under which the first approval was issued continue to be fulfilled.

4. During the validity period the following cases may give rise to a new decision regarding maintenance of the approval:

— damages during operation due the quality of the product

— discrepancies of the product established between manufacture and assembly.

— ascertained deficiencies in the quality system of the manufacturer

— changes regarding approval matters carried out by the manufacturer, which have Not been agreed with BKI

— indications for major discrepancies during testing of the products.

D. General Requirements Relating to the Manufacture and Properties of Materials

1. Manufacture

1.1 All materials shall be manufactured by sufficiently well proven techniques, which ensure that the required properties are achieved. Where new processes are to be employed, preliminary proof of their suitability is to be submitted to BKI. According to the decision of BKI, this shall take the form of special procedure tests and/or the presentation of works documentation of tests performed or of expert assessments by independent testing bodies.

1.2 In the case of steel, the well proven techniques referred to in 1.1 include basic oxygen or electric furnace steel-making and continuous, ingot and mould casting.

2. Chemical composition and required properties

Materials and products shall satisfy the requirements relating to chemical composition and properties specified in these Rules or, where applicable, in the relevant documents. As a rule, the chemical composition is that of the melt (ladle or cast analysis).

3. Condition of supply and heat treatment

3.1 Products are to be supplied in the prescribed heat-treated condition. Where the final heat treatment is to be performed by the steel user, the condition in which the material is supplied shall be clearly stated in the relevant certificates.

3.2 All heat treatments are to be carried out in suitable furnaces, which shall be efficiently maintained. The furnaces shall be provided with devices for controlling and indicating the temperature; these devices are to be checked at regular intervals.

3.3 If it is intended to apply other treatments in place of the prescribed heat treatments such as normalizing or quenching and tempering, the manufacturer shall first prove to BKI that, when these other processes are used, the mechanical properties of the products meet the requirements.

4. Freedom from defects

4.1 All materials and products shall be free from defects which have more than an insignificant adverse effect on their use or appropriate further working.

Insignificant surface defects may be removed mechanically provided that the dimensional tolerances permitted for these products are not exceeded.

4.2 Defects in the material may be repaired by welding only where this is permitted by the specifications relating to the product in question, the Surveyor has given his consent and the welding technique has been approved by BKI.

5. Weldability

Materials intended for the manufacture of welded structures shall be weldable by standard workshop techniques. Where welding is possible only in special conditions, these shall be determined in agreement with BKI and shall be validated by a procedure test.

6. Approval of materials and products

6.1 The manufacturer shall first prove that the properties of the materials and products made by him fulfill the stipulated requirements. As a rule, this calls for a test of suitability performed on selected products, the scope of which shall be decided by BKI in each case. With the consent of BKI, account may be taken for this purpose of the reports of other independent testing bodies.

6.2 In the case of standardized materials mentioned in these Rules which correspond to ISO or EN standards or to national or international standards of equivalent standing, a test of product suitability may, with the consent of BKI, be dispensed with. Materials for the loading and processing equipment of gas tankers, with the exception of austenitic steels, are excluded from this Rules.

E. General Test Conditions

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

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

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

For acceptance tests according to the BKI Rules only materials and products included in the scope of approval shall be submitted.

4. The chemical composition of materials shall normally be demonstrated by the manufacturer by melt analyses, and these shall cover all those elements for which limited values are prescribed in these Rules or in the other relevant documents, or which are added in order to guarantee the required mechanical properties. The certificate of the manufacturer is generally recognized as proof of the chemical composition.

Where doubts exist as to the composition, BKI may also require the performance of product analyses.

Possible deviations between the melt and product analyses shall conform to the relevant standards or specifications.

5. All products are to be checked by the manufacturer for compliance with the specified dimensions. They shall also be inspected by him for possible defects and shall, when this is called for, be presented to the Surveyor.

For this purpose, the products shall normally be in the prescribed "as delivered" or heat-treated condition and shall have a clean surface, prepared for testing, which is free from coatings or other protective media which impair the detection of defects.

Unless otherwise specified in the following sections or specially agreed, the Surveyor shall perform a random test of the dimensions and surface finish as he sees fit.

Products which do not meet the requirements shall be set aside by the manufacturer beforehand.

6. Where in exceptional cases testing cannot be carried out in accordance with the methods stated in these Rules for technical reasons, other equivalent test methods or techniques may, with the consent of BKI, be applied.

7. Where products are manufactured in large runs by series-manufacturing techniques and/or using continuous processes with constant, monitored conditions, BKI may entrust the manufacturer with the performance of some or all of the tests. This is inter alia subject to the condition that the manufacturer has established and maintains a quality assurance system, e.g. in accordance with ISO 9001, and furnishes proof thereof by a certificate bearing the certifier's mark of accreditation. Furthermore it is amongst others to be demonstrated that the requirements for the product have already been satisfied for several years. Approval of testing on the manufacturer's responsibility is to be applied for in writing to BKI Head Office and can only be granted after close examination.

8. If there is reasonable doubt as to the quality of a product, the Surveyor may require additional tests to be performed.

9. BKI gives no guarantee that products which have been subjected to testing to the prescribed extent, either individually or grouped together in test batches, fulfill in all respects the requirements contained in these Rules or in other relevant documents.

Products which prove defective in the course of subsequent application or processing may be rejected despite satisfactory previous testing.

F. Identification and Marking of Products

1. Retraceability

The manufacturer shall introduce a system which enables the product to be identified after every stage of the manufacturing process and be traced back to the heat. This system shall be demonstrated to the Surveyor if he so requests.

2. Marking

2.1 Prior to acceptance testing, products shall be provided by the manufacturer at least at one position with the necessary marking as described in the following sections. The marking shall agree with the details given in the works certificates or delivery documents.

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

2.3 All marks shall be so applied that their legibility cannot be impaired by the transportation or storage of the products. Where the further processing of the products entails the removal of existing marks, the manufacturer concerned shall apply these to a different spot and shall arrange for the transfer of the BKI stamp, unless another solution is adopted

2.4 As a general rule, every product shall be marked. In the case of small parts of the same type and size which are securely packed in crates, drums or similar containers, and also in the case of steel rods and sections weighing up to 25 kg/m and packed together in bundles, marking of the uppermost unit is sufficient or by a securely fastened, strong tag.

2.5 Wherever possible, marks should be enclosed by a painted surface. In the case of forgings and castings, the area to be marked should be bright machined.

3. Use of the BKI stamps

3.1 Specimens and the product from which specimens have been taken are to be marked with the "specimen stamp" , unless otherwise agreed in accordance with 4.

3.2 Products for which individual tests of some kind, e.g. tests of mechanical properties and surface finish, internal pressure test and non-destructive testing, are specified are to be marked in the presence of the Surveyor with the "anchor stamp" , provided that all the requirements have been satisfied. As an exception, shipbuilding steels of grades E and F which are subject to individual testing may also be stamped in accordance with 3.3.

3.3 Plates, sections and rods of steel which are grouped into test batches for testing, are to be marked with the "batch stamp" , provided that all the requirements have been satisfied. This stamp may be applied by approved materials manufacturers and suppliers themselves.

In exceptional cases, e.g. series-produced steel castings, the letters "KI" may be cast or stamped in after agreement with BKI.

3.4 Should it be shown during subsequent tests or during further processing of the tested products that these have defects or in some way no longer meet the requirements, BKI stamps shall be cancelled in a suitable manner.

4. Stamping of specimens by the works

Manufacturers of materials who have an independent quality control department in accordance with C.2.3 may, with the consent of BKI Branch Office, allow members of this department to apply the specimen stamp. The Surveyor shall be notified of the names of the persons authorized for stamping and of the marks identifying their personal stamps.

In case of automated production facilities for specimen selection the stamping may be dispensed with, provided the responsible Branch Office verified the continuous retraceability of specimen marking.

G. Test Documents

For testing purposes, the manufacturer shall submit to the Surveyor documents referring to the materials or products to be tested. These documents shall contain at least the following information:

— name of purchaser together with order number

— newbuilding and project number respectively, where known

— item numbers and quantities

— dimension and indication of product

— material grade, type and specification

— application and drawing number, where necessary

— weight of products.

H. Certificates

The type of required certificate is specified in the Rules.

1. Certificates of the manufacturer

Where, in accordance with the Rules or special agreements, the task of material testing is left to the manufacturer, the latter shall issue a relevant certificate. In case testing yields that the prescribed requirements are met, the result will be certified by the manufacturer.

1.1 Test report of the manufacturer (C-type Certificate)

Where, in accordance with the Rules or special agreements, a certificate of the manufacturer, independent of the material/product at hand, is required, the manufacturer shall issue a relevant test report (see, 2.2 according to EN 10204). The manufacturer shall be approved for the material/product.

Besides the information listed in G., the test report shall also specify the following:

— Manufacturing process

— Condition of supply

— Details of heat treatment, where necessary

— Marking

— Results of non-specific material testing of current production

1.2 Manufacturer’s inspection certificate (B-type Certificate)

Where, in accordance with the Rules or special arrangements, a certificate of the manufacturer for the material at hand and product respectively is required, the manufacturer shall issue a relevant inspection certificate (e.g. 3.1 according to EN 10204). Also in such cases the manufacturer shall be approved for the material/product.

Besides the information listed in G., the test report shall also specify the following:

— Manufacturing process

— Heat number and chemical composition

— Condition of supply

— Details of heat treatment, where necessary

— Test pressures, where necessary

— Results of special tests to be undertaken, where necessary

— Results of mechanical tests of the delivery at hand

2. BKI Certificates

Where, in accordance with the Rules or special arrangements, material testing under survey of BKI is required, a relevant BKI Certificate will be issued.

In case testing yields that the prescribed requirements are met, the result will be certified by the Branch Office Manager.

2.1 Material certificate according to BKI Rules (A-type Certificate)

Materials and products intended for use within the scope of Classification have to be delivered with a material certificate according to BKI Rules, see A.2.

To obtain this material certificate the BKI Rules relevant for the material/product shall be satisfied. The manufacturer shall be approved by BKI for the material/ product. The BKI Rules shall be named as test procedure. Normally, stamps are the ”anchor stamp” as well as the ”batch stamp” .

Besides the information listed in G., the certificate shall also specify the following:

— Manufacturing process

— Heat number and chemical composition

— Condition of supply

— Details of heat treatment, where necessary

— Test pressures, where necessary

— Results of special tests to be undertaken, where necessary

— Results of mechanical tests of the delivery at hand

3. Alternative verification (A-type Certificate)

By agreement, the results may also be attested using the following alternatives:

3.1 Confirmation of the test results on a commonly issued certificate of manufacturer and BKI (e.g. inspection certificate 3.2 according to EN 10204).

3.2 In the case of products produced in large quantities and subjected to testing by heat or batch, by confirmation of the Surveyor who appends his stamp and signature to the manufacturer's certificate in token that the tests carried out on the consignment in accordance with the Rules have satisfied the requirements. In addition, the manufacturer shall add by printing in the certificate an appropriate remark and shall also confirm that the products listed in the documents have been manufactured in accordance with BKI Rules.

4. Issuing of test certificates by a material user or a merchant

If a product is supplied by a material user or a merchant, he shall put the manufacturer's certificates[1)] at the disposal of the purchaser without amendment.

These manufacturer's certificates shall be accompanied by a suitable means of identifying the product, so as to ensure that product and certificates can be clearly matched up.

If the material user or the merchant has modified the condition or dimensions of the product in any way, these particular new properties shall be confirmed in an additional certificate.

The same applies to special requirements in the order which are not shown in the manufacturer's certificates.

1) See standard EN 10204

Section 2 Mechanical and Technological Test

A. Scope

1. This Section contains general rules for the mechanical and technological test methods for metallic materials and for the necessary test specimen shapes which are to be used for materials testing.

2. It is a fundamental requirement that all tests shall be performed in accordance with established national and/or international standards and in conformity with these Rules.

3. Departures from the prescribed test specimen shapes or from the conditions governing sampling and specimen preparation are permitted only in exceptional, technically justified cases where this enables the materials to be subjected to equivalent tests and where BKI has given its consent to the change.

B. Testing Machines and Personnel

1. All tests shall be performed by trained personnel using calibrated testing machines. The testing machines shall be maintained by the owners in a good working condition and shall be calibrated at regular intervals by a testing authority acknowledged by BKI. The calibration records shall be kept available for inspection in the test laboratory.

2. Tensile testing machines are subject to the calibration periods and permitted indication errors shown in Table 2.1. Tensile testing machines shall be calibrated in accordance with ISO 7500-1:2018 or another commonly accepted standard.

3. For pendulum impact testing machines, the total friction with the full swing of the pendulum may not exceed 0,5% of the available energy. On request, compliance with this value shall be demonstrated to the Surveyor before the machine is used. Pendulum impact testing machines shall be recalibrated at yearly intervals. The calibration of pendulum impact testing machines shall be performed in accordance with ISO 148-2:2016 or another commonly accepted standard.

4. Hardness testing equipment shall be calibrated at yearly intervals. It is to be verified that the acceptable tolerances for the equipment parameters and the indicating accuracy are complied with in accordance with the appropriate standards.

5. Compliance with the above requirements may also be evidenced by the testing laboratory's certificate of accreditation provided that the accreditation was granted by an accredited institution and the test methods in question are stated in the certificate of accreditation.

Table 2.1: Indication errors and calibration periods for tensile testing machines

Type of tensile testing machines	Test class (ISO 7500-1:2018)	Permitted Indication Error, max	Calibration Period
Multi-purpose testing	1	1%	1 year
Testing machines for equipment components	3	3%	2 year

C. Sampling and Specimen Preparation

1. Definition

1.1 Sample

"Sample" is the term applied to the product, e.g. the plate or pipe, which is selected from the unit test quantity for the purpose of taking specimens.

1.2 Unit test quantity/test batch

"Unit test quantity" or "test batch" is the term describing that portion of a consignment to which the result of the test refers.

The term may be applied, for example, to a specific number of products of the same shape and dimensions originating from one melt, or to a length of rolled material (plate or strip) or to a single product (a large forging or casting).

1.3 Test Section

The term "test section" describes a section of material (e.g. a strip of plate) which is taken from the sample and which serves for the preparation of one or more test specimens.

1.4 Test Specimen

"Test specimen" is the term applied to a piece taken from the test section which, in the machined or unmachined condition, has prescribed dimensions and is subjected to the test in question.

2. Marking of test sections and test specimens

2.1 Test sections and test specimens shall be representative of the sample, see 3.1

2.2 Test sections and test specimens shall be so marked that, after their removal and preparation, it is still clear from which sample they were taken and how they were positioned and orientated in the sample. Where, during the preparation of test sections and test specimens, it is impossible to avoid erasing the original markings, these shall be previously reapplied in another position.

2.3 As a general rule, test sections and test specimens shall be marked by the Surveyor with the test stamp before they are removed from the sample unless some other arrangement has been made with the manufacturing works in accordance with Section 1, F.4.

3. Removal and dimensions of test sections

3.1 Test sections are to be removed from the sample at specified positions. They shall be large enough to provide material for the test specimens prescribed for the performance of the tests together with the additional test specimens required for possible retests.

3.2 In general, test sections may be removed from the sample only after completion of all the mechanical and/or heat treatments to be applied to the product prior to delivery. In this context, heat treatments which cause no changes in the mechanical properties may be disregarded.

3.3 If, in exceptional cases, the test section cannot remain attached to the sample until the end of the manufacturing process, e.g. where products are machined to their final dimensions before annealing, then the test section shall undergo the same mechanical and/or heat treatments which are applied to the sample itself. Furthermore, the consent of the Surveyor shall be obtained in cases of premature removal of the test sections.

4. Removal and dimensions of test specimens

The longitudinal axes of test specimens are to be orientated in relation to the main direction of deformation in the manner prescribed in the following sections. Notwithstanding this, the manufacturer may, in order to save test material and after agreement with the Surveyor, take transverse instead of longitudinal test specimens, provided that corresponding requirements are specified for transverse test specimens or the requirements applicable to longitudinal specimens can be satisfied by this means.

The tolerances applicable to the specimen shall be in accordance with ISO 6892-1:2019, ISO 6892-2:2018 or another standard accepted by BKI.

5. Preparation of test specimens

5.1 All test specimens shall be machined to the prescribed dimensions. Exceptions to this requirement are those test sections, e.g. those of small-diameter pipes and rods, which may be subjected to tensile testing in their entirety.

5.2 When removing test sections or test specimens, deformations and heating up of the material are to be avoided as far as possible. Where test sections or test specimens are removed by thermal cutting or shearing from the sample, a sufficient allowance shall be provided to be removed by machining.

5.3 Machining defects, e.g. notches, grooves and burrs, which occur during the preparation of test specimens and which may affect the test results are to be removed, and the execution of this operation shall respect the dimensional and geometrical tolerances applicable to the specimen shape concerned.

5.4 Where test sections have to be straightened before test specimens are taken, e.g. in the case of transverse specimens from pipes, the straightening operation shall normally be performed in the cold state and shall not significantly affect the mechanical properties of the material. If this is not possible, the test specimens shall be taken in such a way that straightening is unnecessary. Tensile specimens taken from the pipe wall in the longitudinal direction may not be pressed flat between the gauge marks.

D. Tensile Tests

1. Specimen shapes

The following notation is used to specify the dimensions of test specimens.

1.1 Notation

A = elongation determined in tensile test for gauge length L_o for short proportional test specimens [%]
A_r = elongation required due to conversion for other gauge lengths [%]
d_o = diameter of round specimen [mm]
a = thickness of flat specimen [mm]
b = width of flat specimen [mm]
L_o = initial gauge length [mm]
L_c = test length [mm]
S_o = initial cross-section within test length [mm^2]

S_u = smallest specimen cross section after fracture [mm^2]
r = shoulder radius at end of specimen [mm]
D = outside diameter of pipe [mm]
t = thickness of product [mm]

1.2 Dimensional tolerances

The dimensional tolerances shall be those specified in the relevant standards, e.g. or ISO 6892-1:2019.

1.3 Dimensions

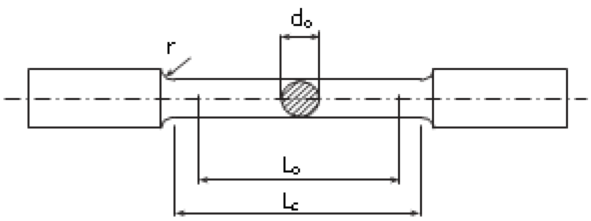
1.3.1 Use shall preferably be made of short proportional test specimens with an initial gauge length of $L_o = 5,65\sqrt{S_o}$ or $L_o = 5d_o$, respectively, as the requirements relating to elongation specified in the following Sections refer to this gauge length. The test length L_c shall be preferably 20 mm larger than L_o.

The gauge length L_o may be rounded to the nearest 5 mm provided that the difference between this gauge length and L_o is less than 10% of L_o.

1.3.2 For forgings and castings, with the exception of grey cast iron, cylindrical specimens conforming to ISO 6892-1:2019 or as shown in Fig. 2.1 are to be used.

Specimen shape A should be preferred. If this is not possible, the alternative dimensions should be determined as specified for shape B with the specimen diameter do selected being between 10 and 20 mm.

1.3.3 For hot-rolled rods and products of similar shape, the specimen shapes prescribed in 1.3.2 are to be used. In the case of bars with a smaller section, suitable lengths may also be tested in their entirety, i.e. without machining the cross-section.

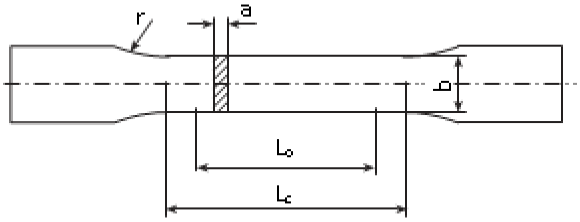


Dimension	Specimen shape A 14 mm round tensile specimen	Specimen shape B alternative specimen
d_o	14 mm	-
L_o	70 mm	$5d_o$
L_c	85 mm	$L_o + d_o$
r	10 mm [1)]	10 mm [1)]

[1)] In the case of nodular graphite cast iron and all materials with a minimum elongation $A \leq 10\%$, r = 20 mm (specimen shape A) or r = 1,5 d_o (specimen shape B).

Figure 2.1: Round tensile specimens

1.3.4 For plates, strips and sections, flat tensile specimens conforming to ISO 6892-1:2019 or as shown in Fig. 2.2 are to be used by preference. In these cases the rolled surface of the metal shall be preserved. Where, in testing heavy plate thicknesses, the tensile loading capacity of the machine is insufficient, the thickness of the specimens may be reduced by machining one side to not less than ½ of the product thickness.



Dimension	Specimen shape C proportional test specimen	Specimen shape D 200 mm specimen
a	t	t
b	25 mm	$\geq$ 25 mm
L_o	$5,65\sqrt{S_o}$	200 mm
L_c	$L_o + 2\sqrt{S_o}$	225 mm
r	25 mm	25 mm

Figure 2.2: Flat tensile specimens

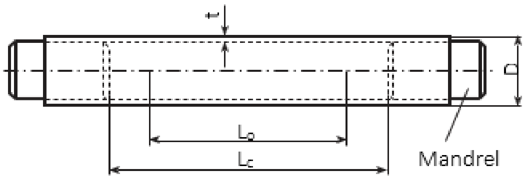
Otherwise round tensile specimens conforming to Fig. 2.1 are to be used, for which the following is to be observed:

In the case of products with a thickness of > 40 mm, round tensile specimens as prescribed in 1.3.2 may also be used. The specimens shall then be taken from the sample in such a way that their axis is located at ¼ of the product thickness measured from one face or as close as possible to this position.

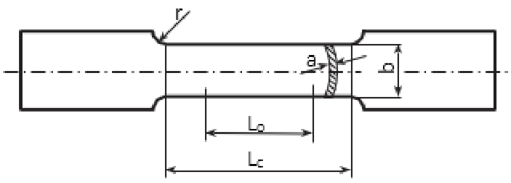
1.3.5 In the case of pipes, the tensile test may be performed on a sufficiently long section of the entire pipe. To enable the specimen to be secured in the test machine, mandrels have to be inserted into the pipe ends, see Fig. 2.3, specimen shape E, or the pipe ends have to be pressed flat. Where the pipe diameter precludes testing a length of the entire pipe, tensile specimens of shape F are to be taken from the pipe wall.

Where the wall thickness of the pipe is sufficient, cylindrical specimens as prescribed in 1.3.2 may also be used. The specimens shall then be taken from the sample in such a way that their axis is located at the mid-point of the wall thickness.

In the case of large pipe diameters, flat or cylindrical specimens perpendicular to the pipe axis may also be taken. To this end the test length may not be pressed flat, but the wider ends may be pressed flat to enable the specimen to be secured in the specimen device of the testing machine.



Shape E



Shape F

Dimension	Specimen shape E (with solid pipe section)	Specimen shape F (Flat specimen from pipe wall)
a	–	t
b	–	$\geq$ 12 mm
L_o	$5,65\sqrt{S_o}$	$5,65\sqrt{S_o}$
L_c	$L_o + D$ [1]	$L_o + 2b$
r	–	10 mm

[1] This value also applies to the minimum distance between the grips of the test machine.

Figure 2.3: Tensile specimens for pipes

1.3.6 For grey cast iron, test specimens as shown in Fig. 2.4 are to be used. These shall be taken from a separately cast cylindrical test bar with a casting diameter of 30 mm.

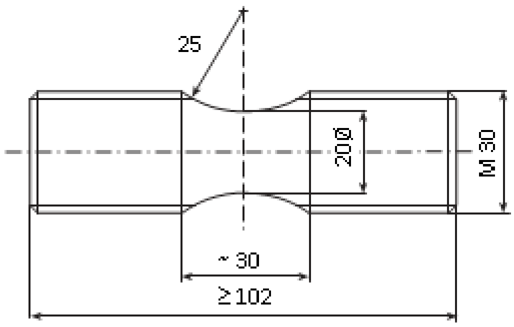


Figure 2.4: tensile specimen for grey cast iron

1.3.7 Tensile specimens which have their axes vertical to the product face (Z-specimens) are to be prepared as described in Section 4, I.3.1.

1.3.8 Aluminium alloys

For aluminium alloys with product thickness including 12,5 mm flat tensile specimens are to be used. The specimens shall be prepared in such a way that both rolled/pressed surfaces shall be preserved. For product thicknesses exceeding 12,5 mm round tensile specimens may be used. For product thicknesses up to and including 40 mm the longitudinal axis of the round tensile specimen shall be located at ½ of the product thickness measured from face. For product thickness measured from on face. For product thicknesses exceeding 40 mm the longitudinal axis of the round tensile specimen shall be located at ¼ of the product thickness measured from one face.

1.3.9 Tensile specimens for wire ropes, single wires and strands are to be performed in accordance with Section 14, E.3. Specimens containing the entire section and the following dimensions are to be tested:

L_o = 200 mm
L_c = L_o + 50 mm

1.4 Tolerances

The manufacturing tolerances for specimens shall meet the requirements of ISO 6892-1:2019, ISO 6892-2:2018 or other recognized standard.

2. Performance of tests

Tests shall be performed in accordance with established standards. This category includes, for example ISO 6892-1:2019.

3. Determination of test results

Using the symbols and units of measurement stated below, the test results shall be determined as follows:

3.1 Yield strength R_{eH}

Generally, the upper yield point R_{eH} [N/mm^2] has to be determined. This corresponds to the maximum stress preceding the initial drop in tensile load as the elongation increases. For determining the yield point at room temperature, the rate at which the stress is increased shall be not be less than 6 N/mm^2 per second and may not exceed 60 N/mm^2 per second for steel. For non-ferrous metals the rate at which the stress is increased shall not be less than 2 N/mm^2 per second and may not exceed 20 N/mm^2 per second. The test result shall be stated accurate to 1 N/mm^2.

3.2 Proof stress R_p

In the case of materials without a marked yield point, the proof stress R_p [N/mm^2] shall be determined. Generally, the 0,2% proof stress R_p0,2 shall be specified. For austenitic steels as well as austenitc-ferritic (=duplex) steels, the 1% proof stress R_p1,0 may be stated instead of, or in addition to, R_p0,2. The rate of loading and the indication of the results shall be as stated in 3.1.

3.3 Tensile strength R_m

In determining the tensile strength R_m [N/mm^2], the strain rate, once the yield point or proof stress has been passed, shall not with ductile materials exceed a maximum of 48% per min. With brittle materials, e.g. grey cast iron, the elastic stress rate may not exceed 10 N/mm^2 per second. The test result shall be stated accurate to 1 N/mm^2.

3.4 Elongation A

If not otherwise stated, this relates to short proportional test specimens with $L_o = 5,65\sqrt{S_o}$ and then is named as A [%]. For test specimens whose gauge length bears a different relationship to the cross section of the test specimen, the required elongation A_r shall comply either with the minimum values specified for the products in question (e.g. for a gauge length L_o = 200 mm), or with the minimum value calculated by applying the following formula:

$$A_r = 2 \cdot A \cdot \left(\frac{\sqrt{S_o}}{L_o}\right)^{\frac{2}{5}}$$

This conversion formula may only be used for ferritic steels with a strength of $\leq$ 700 N/mm^2 which have not been cold formed, see also ISO 2566-1:1984; ISO 2566-2:1984.

The value for the elongation is valid if the distance between the fracture and the nearest gauge mark is not less than $L_o/3$. However, the value is valid, irrespective of the position of the fracture, if the value for the elongation is equal to or greater than the specified value.

The result of the test shall be stated to an accuracy of 0,5%. If the elongation is not determined using short proportional test specimens, then the gauge length [mm] shall be stated in the test certificate, e.g. $A_{200\text{mm}}$= elongation for initial gauge length L_o = 200 mm.

3.5 Reduction in area Z [%]

The reduction in area at fracture Z [%] shall be determined only where this is called for in the following Sections of the Rules.

$$Z = \left(\frac{S_o - S_u}{S_o}\right) \cdot 100 \ [\%]$$

The test result shall be stated to an accuracy of 1%.

E. Notched Bar Impact Tests

1. General

1.1 As specified for the product in question, notched bar impact tests are to be performed either on Charpy V-notch specimens or on Charpy U-notch specimens to ISO 148-1:2016, see Fig. 2.5 and Fig. 2.6.

1.2 Unless otherwise agreed, for products with a thickness of < 10 mm smaller dimension specimens with a specimen width of 7,5 or 5 mm are to be tested. In the case of products with thicknesses of < 6 mm, the notched bar impact test is generally not required. The longitudinal axis of the notch shall be made perpendicular to the surface of the product.

2. Dimensions of test specimens

Test specimens shall be machined to the dimensions shown in Fig. 2.5 or Fig. 2.6 and those stated in Table 2.2. The data given in Table 2.2 shall be regarded as being the permitted tolerances for the specimen dimensions.

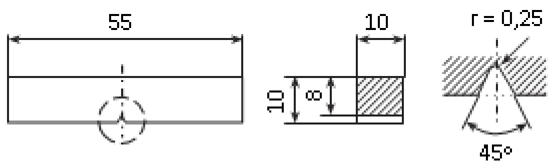


Figure 2.5: Charpy V-nocth specimen

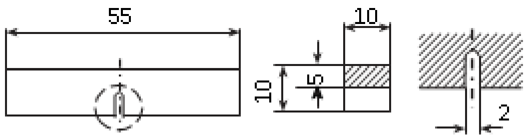


Figure 2.6: Charpy U-notch specimen

Table 2.2: Permitted tolerances of specimen dimensions

Dimensions	V-notch specimen		U-Notch Specimen	
	Normal size	Tolerance	Normal size	Tolerance
Length of specimen Thickness of specimen	55 mm 10 mm	± 0,60 mm ± 0,06 mm	55 mm 10 mm	± 0,60 mm ± 0,11 mm
Width of specimen - Normal specimen - Sub-size specimen - Sub-size specimen	 10 mm 7,5 mm 5 mm	 ± 0,11 mm ± 0,11 mm ± 0,06 mm	 10 mm — —	 ± 0,11 mm — —
Notch angle	45°	± 2	—	—
Thickness at base of notch	8 mm	± 0,06 mm	5 mm	± 0,09 mm
Notch radius	0,25 mm	± 0,025 mm	1 mm	± 0,07 mm
Distance of notch centre from ends of specimen[1)]	27,5 mm	± 0,42 mm	27,5 mm	± 0,42 mm
Angle between plane of symetry of notch and longitudinal axis	90°	± 2°	90°	± 2°
Angle between adjacent longitudinal faces	90°	± 2°	90°	± 2°
[1)] For pendulum impact testing machines which have automatic specimen positioning, a tolerance of ± 0,165 is recommended rather than ± 0,42.				

3. Test machine

Where possible, use shall be made of a pendulum impact testing machine with an impact energy of 450 J or 300 J (in any case not less than 150 J) and an impact velocity of 5 to 5,5 m/s. The test arrangement is shown in Fig.2.7, with characteristic quantities of the test machine being given in Table 2.3.

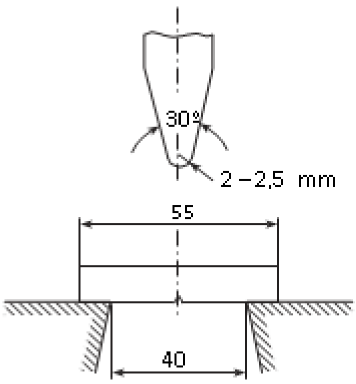


Figure 2.7: Notched bar impact test

4. Performance of test

4.1 Impact tests using U-notch specimens should generally be performed at room temperature (23 ±5)°C. Impact tests on V-notch specimens shall be performed at room temperature or at a lower test temperature, according to specification. With test temperatures below room temperature, the temperatures of the specimens are to be carefully checked. At the moment of fracture they may not vary from the prescribed test temperature by more than ± 2°C. If the specimens are cooled by placing them in a bath, they shall remain there for at least ten minutes.

Table 2.3: Characteristic quantities of test machine

Dimension	Requirement
Clear spacing between supports	$\left(40_{0}^{+0,2}\right)$ mm
Radius of curvature of supports	$\left(1_{0}^{+0,5}\right)$ mm
Undercut of supports	$11^\circ \pm 1^\circ$
Angle of peen wedge	$30^\circ \pm 1^\circ$
Radius of curvature of peen cutter	$\left(2_{0}^{+0,5}\right)$ mm
Maximum thickness of pendulum face	18 mm
Striking velocity of pendulum	5 to 5,5 m/s[1)]
Angle between supports and bearing	$90^\circ \pm 0{,}1^\circ$
[1)] For pendulum impact test machines built before 1983 a value of 4,5 to 7 m/s may be agreed.	

4.2 A test is regarded as being performed under normal conditions when the working capacity of the pendulum impact test machine is (300 $\pm$ 10) J and when a standard specimen is used. The following abbreviations are assigned to the notch impact energy value which is established under these conditions:

— KU for a U-notch specimen

— KV for a V-notch specimen

5. Determination of test results

5.1 Using the symbols shown below, the energy absorbed by the impact shall be normally stated in joules (J), accurately rounded to 1 J.

Where the test is conducted other than at room temperature, this shall also be stated.

5.2 If required, the crystalline proportion of the fracture surface and/or the lateral expansion at the point of fracture shall also be determined.

The crystalline proportion of the fracture surface shall then be estimated and expressed as a percentage of the total area of the fracture. The lateral expansion shall be measured to an accuracy of 0,01 mm on the side opposite the notch (see also ISO 148-1:2016 and ASTM A 370).

F. Technological Tests on Pipes

1. Pipe flattening test

1.1 To perform this test, a section of pipe equal in length to 1,5 times the pipe diameter, but not less than 10 mm and not more than 100 mm, is flattened between two plates to the prescribed distance H see Section 5, A.8.5 or until fracture occurs, see Fig 2.8. In the case of welded pipes, the specimen shall be placed in the press in such a manner that the seam is set at 90° to the direction of the pressure, unless agreed otherwise.

1.2 After the test, the specimens shall be thoroughly examined for defects with normal visual acuity. The test shall be satisfactory if the specimen, having been flattened to the prescribed distance, is free from cracks and did not fracture.

The dimensions of the pipe section, the distance H between the flattening plates as well as the position of the welding joint are to be stated.

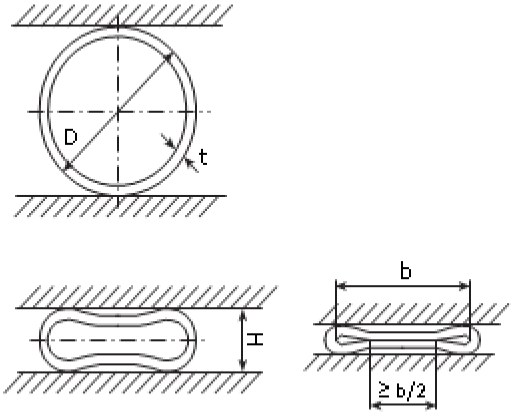
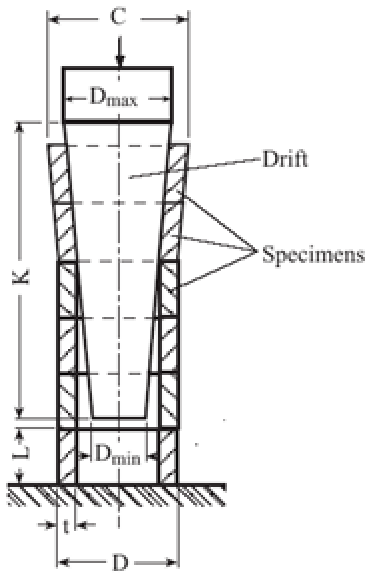


Figure 2.8: Pipe flattening test

Examples of applicable standards: ISO 8492:2013 Pipe Flattening Test

2. Ring expanding test

2.1 To perform this test, sections of pipe measuring 10 to 16 mm in length L are expanded to the prescribed diameter C or until fracture occurs using a drift with a taper of about 1:5. Where necessary, more than one test shall be performed with drifts of increasing diameter. The superimposition of several specimens of the same size and steel grade is permitted, see Fig. 2.9.



$$\frac{D_{max} - D_{min}}{K} = 1 : 5$$

Figure 2.9: Ring expanding test

The intrusion rate of the mandrel may not exceed 30 mm/s.

C = Diameter after the prescribed expansion

The dimensions of the pipe sections, the outer diameter C of the expanded part of the pipe section or the relative expansion [%], as well as the ratio of the taper (if not 1:5) are to be stated.

Examples of standards to be applied: ISO 8495:2013 Ring Expanding Test on Pipes

2.2 After the test, the specimens shall be thoroughly examined for defects with normal visual acuity, and the ductility of the pipes shall be assessed by reference to the expansion achieved and, where applicable, to the appearance of the fracture surface.

The test shall be satisfactory if the specimen reveals no unacceptable defects such as scabs, laps, cracks, grooves or laminations and if the prescribed expansion has been reached.

3. Ring tensile test

3.1 The sections of pipe measuring about 15 mm in length shall have plane and smoothed ends and shall be at right angle to the pipe axis. To perform this test, the pipe sections are stretched in a tensile testing machine until fracture occurs using two pins with a diameter equal to at least three times the wall thickness of the pipe, see Fig. 2.10. In the case of welded pipes, the specimen shall be placed in the tensile testing device in such a way that the welded seam lies at 90° to the direction of the tensile load.

The rate of the pins may not exceed 5 mm/s.

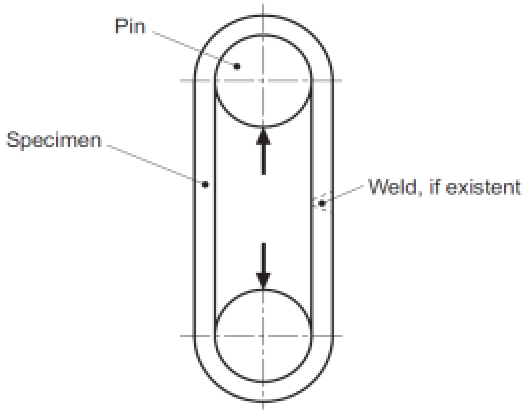


Figure 2.10: Ring tensile test

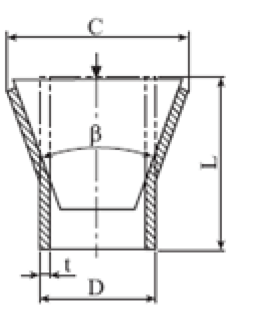
3.2 After the test, the specimens shall be thoroughly examined for defects with normal visual acuity. The test shall be satisfactory if the specimen reveals no unacceptable defects such as scabs, laps, cracks, grooves or laminations and if visible deformation has occurred at the point of fracture. The dimensions of the pipe sections are to be stated.

Example of standards to be applied: ISO 8496:2013 Ring Tensile Test on Pipes

4. Drift expanding test

4.1 To perform this test, a tapered drift is forced into the specimen until the outside diameter has increased to the prescribed value C for the product in question, see Fig. 2.11. The length of the specimen and the taper angle β of the drift shall be as shown in the following Table. The intrusion rate of the taper may not exceed 50 mm/s.

4.2 After the test, the specimens shall be thoroughly examined for defects with normal visual acuity. The test shall be satisfactory if the prescribed expansion has been effected without cracks.



Material	Length of specimen L	Taper angle β
Steel	$\leq$ 2 D $\leq$ 1,5 D; min. 50 mm	30° 45°, 60° over 120°
Copper and Copper alloys	2 D	45°
Aluminium alloys	$\geq$ 2 D , min 50 mm	60 °

Figure 2.11: Drift expanding test

C = Diameter after the prescribed expansion

The dimensions of the pipe section, the outer diameter C of the expanded part of the pipe section or the relative expansion [%], as well as the taper angle are to be stated.

Examples of standards to be applied: ISO 8493:1998 Drift Expanding Test on Pipes.

5. Flanging test

5.1 To perform this test, a sample of pipe with a length L = 1,5 D is worked into a flange in the device shown in Fig. 2.12 until the outer diameter C of the flange attains the value prescribed for the product. The radius r shall match that prescribed for the product.

The intrusion rate of the tool may not exceed 50 mm/min.

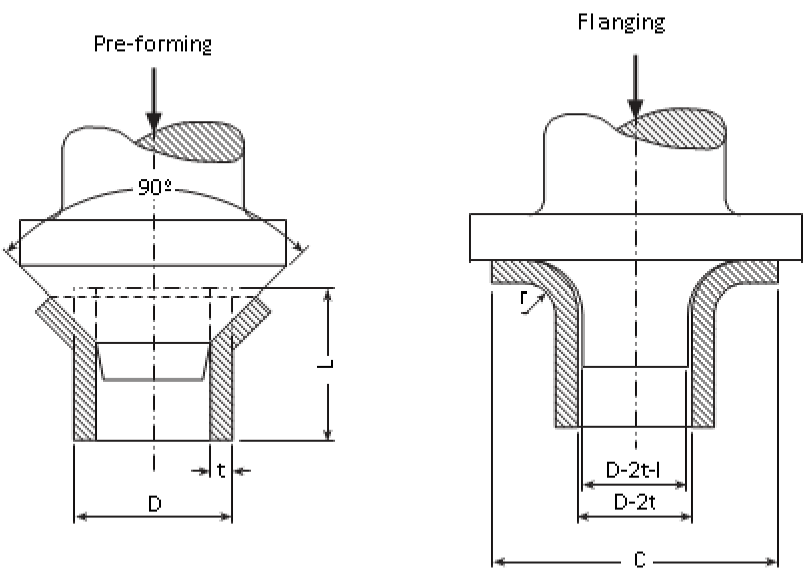


Figure 2.12: Flanging test

5.2 The test shall be satisfactory if the flange has no apparent cracks. Minor defects on the edges can be disregarded. The dimensions of the pipe section, the outer diameter C of the expanded part of the pipe section or the relative expansion [%], as well as the edge radius of the forming tool are to be stated.

Examples of standards to be applied: ISO 8494:2013 Flanging Test on Pipes.

G. Instructions for the Bend Test, Hardness Test and Drop Weight Test

1. Technological bend test

1.1 For this test, specimens with thickness a and width b are to be prepared, the edges of which may be rounded on the tension side to a radius of 1 – 2 mm. For plates and sections the specimen thickness a is equal to the product thickness t. For product thicknesses t exceeding 25 mm the thickness may be reduced by machining the compression side of the bend specimen to not less than 25 mm.

For product widths smaller than or equal to 20 mm the specimen width b shall be equal to the product width. For product widths exceeding 20 mm the specimen width b = 20 – 50 mm.

For forgings, castings and semi-finished products the specimen thickness shall be a = 20 mm and the specimen width b = 25 mm.

1.2 For butt-welded joints the bend specimens at right angle to the weld joint shall have the following dimensions for verification of the final pass and the root pass:

— a = t

— b = 30 – 50 mm

For side bend specimens the following dimensions do apply:

— a = 10 mm

— b = t

For t $\geq$ 40 mm the side bend specimen may be split, with the width of each part being at least 20 mm.

For bend specimens with longitudinal direction to the joint the dimensions shall be in accordance with generally accepted standards.

1.3 To perform this test, the test specimen is bent in a continuous operation as shown in Fig. 2.13 and using a mandrel of specified radius D/2 until the prescribed bending angle α is reached or the initial incipient fracture occurs. For normal strength steels D/2 = 2 · a, for higher strength steels D/2 = 3 · a. The test shall be satisfactory if the prescribed bending angle is achieved without incipient fracture. If, when the specimen is unclamped, it springs back, the bending operation need not be repeated.

Example of standard to be applied: ISO 7438:2020 Metallic materials - Bend Test.

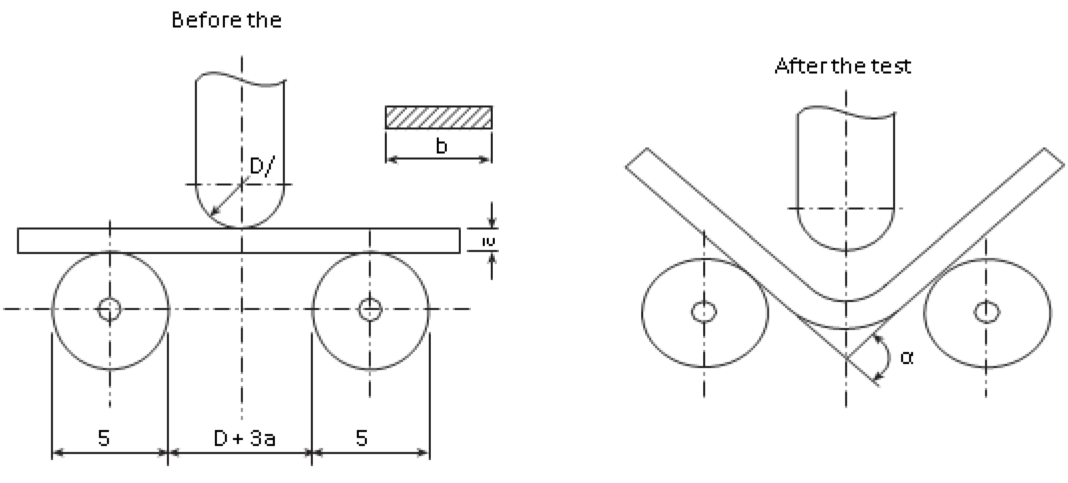


Figure 2.13: Technological bend test

2. Hardness tests

2.1 The tests are to be performed, according to specification, to determine the Brinell, Vickers or Rockwell hardness using standardized methods, see for example:

— ISO 6506-1:2014 Brinell Hardness Test

— ISO 6507-1:2018 Vickers Hardness Test

— ISO 6508-1:2016 Rockwell Hardness Test

2.2 Hardness tests shall not be considered a substitute for the tensile test. Brinell hardness tests may, however, be permitted for the purpose of comparing mechanical properties provided that, of several products of the same shape, grade of material and heat treatment, at least one has been subjected to the tensile test.

3. Pellini drop weight test

3.1 This test shall be performed in accordance with ASTM E-208:2019 on steels with product thicknesses of $\geq$ 16 mm. The specimen shape will be chosen which most closely matches the product thickness accordingly to Table 2.4. The correct specimen thickness shall be achieved by machining one side.

The long sides of the test specimens shall be made with a saw cut or, in the case of specimens obtained by thermal cutting, shall be machined with a machining allowance of at least 25 mm.

Table 2.4: Specimen dimensions for drop weight test

Specimen shape	Dimension [mm]
P1	360 $\times$90 $\times$25
P2	130 $\times$50 $\times$19
P3	130 $\times$50 $\times$16

3.2 At least 2 test specimens shall be prepared from the sample. The position of the longitudinal axis of the specimens in relation to the main direction of deformation of the product is optional, but shall be the same for the set of specimens. Where the testing is performed by heats, specimens shall be taken from the thickest product.

3.3 Where one or both specimens fail to satisfy the aforementioned conditions, a retest may be carried out in accordance with H.4.

3.4 Where drop weight tests are to be performed on products other than those specified in 3.1 or as part of approval tests, the scope of the test shall be specially agreed with BKI.

H. Retests

1. General

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

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

1.3 If the unsatisfactory result of a test is due to obvious defects in the execution of the test or to a narrowly defined fault in the test specimen, the result shall be disregarded and the test in question shall be repeated on a test specimen of the same type which shall be taken from the same test section. This also applies to tensile specimens which, when tested, fracture outside the valid measuring length as defined in D.3.4.

1.4 If the unsatisfactory result of a test is attributable to improper heat treatment of the products, they may be resubjected to heat treatment. Subsequently the entire test shall be repeated, and the original test result shall be disregarded.

1.5 The manufacturer may also follow the procedure described in 1.4 in the case of those products which, according to the specifications, may be supplied without heat treatment but which have failed to meet the requirements in this condition.

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

2. Unsatisfactory tensile test specimens (excluding pipes)

2.1 Individual tests

For each unsatisfactory tensile specimen, two substitute specimens shall be tested, which shall be taken from the same test section as the original specimen, or from the same sample. In every case, both specimens shall satisfy the requirements.

2.2 Testing by heats or batches

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

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

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

Both retests shall satisfy the requirements.

3. Unsatisfactory impact test specimens (excluding pipes)

3.1 Individual tests

If the average value of 3 impact test specimens fails to satisfy the requirements or if a single value is less than 70% of the stipulated average value, 3 substitute specimens shall be taken from the same test section and tested. The average value of the 6 individual tests shall then meet the requirements. However, of the 6 individual values only 2 may be below the required average value, of which only one individual value may be less than 70% of the prescribed average value, failing which the sample in question shall be rejected.

3.2 Testing by heats or batches

If the average value of 3 impact test specimens fails to satisfy the requirements or if a single value is less than 70% of the stipulated average value, then the procedure described in 3.1 shall be applied initially.

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

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

4. Unsatisfactory drop weight test specimens

4.1 Individual tests

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

4.2 Testing by heats

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

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

5. Unsatisfactory results in the testing of pipes

5.1 Testing by batches

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

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

6. Retesting specified in standards

Where a national or international standard specifies a wider scope for the performance of repeat tests; this shall take precedence over the retests described in 5.1.

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Section 3 Non-Destructive Testings

A. General Item

1. This Section contains general rules applicable to the performance of non-destructive tests at semi-finished products and components intended for the installation in ships classed with BKI.

2. Type and scope of the non-destructive testings prescribed for the individual products are stated in the appropriate sections.

B. Standards and Regulations

1. The standards and regulations indicated in the specific sections are integral part of these Rules and have to be observed when performing the non-destructive testing.

2. Testings according to other comparable standards or regulations require prior consent of BKI. For this they shall be submitted to BKI for assessment and approval before starting the testing.

3. The manufacturer or purchaser shall state all details of the testing in a testing instruction or specification and deliver it to the BKI Surveyor before starting the testing.

C. Requirements Applicable to the Inspection Body

1. For performing non-destructive testings the manufacturer shall set up a qualified inspection body independent of the manufacturing departments, which is considered to have been met if the manufacturer has been certified according to ISO 9001, or accredited according to ISO/IEC 17025.

2. The inspection body shall have available the necessary regulations, testing specifications, testing equipment, accessories and, if required, comparators for the surface finish of castings.

3. If the manufacturer has no inspection body available, he shall demonstrate which external inspection body will perform the testings on his behalf if necessary.

This external inspection body shall comply with the requirements specified in Rules for Approval of Manufacturers and Service Suppliers (Pt.1 Vol.XI) Sec. 3.

D. Qualification of Personnel involved in NDT

1. Qualification of personnel

1.1 The Shipbuilder, manufacturer or its subcontractors is responsible for the qualification and preferably 3rd party certification of its supervisors and operators to a recognised certification scheme based on ISO 9712:2012.

1.2 Personnel qualification to an employer-based qualification scheme as e.g. SNT-TC-1A, 2016 or ANSI/ASNT CP-189, 2016 may be accepted if the Shipbuilder, manufacturer or its subcontractors written practice is reviewed and found acceptable by BKI. The Shipbuilder, manufacturer or its subcontractors written practice shall as a minimum, except for the impartiality requirements of a certification body and/or authorised body, comply with ISO 9712:2012.

1.3 The supervisors' and operators' certificates and competence shall comprise all industrial sectors and techniques being applied by the Shipbuilder or its subcontractors. Level 3 personnel shall be certified by an accredited certification body.

(IACS UR W34 3.1)

2. Supervisors

2.1 The Shipbuilder, manufacturer or its subcontractors shall have a supervisor or supervisors, responsible for the appropriate execution of NDT operations and for the professional standard of the operators and their equipment, including the professional administration of the working procedures.

2.2 The Shipbuilder, manufacturer or its subcontractors shall employ, on a full-time basis, at least one supervisor. The supervisor(s) shall, as a minimum, be certified to Level 2 in the method(s) concerned as per the requirements of item 1. with minimum experiences for 5 years in the stated method (for Level 3, experience is not necessary).

2.3 The supervisor shall be directly involved in review and acceptance of NDT Procedures, NDT reports, calibration of NDT equipment and tools.

2.4 The supervisor shall on behalf of the Shipbuilder, manufacturer or its subcontractors re-evaluate the qualification of the operators annually.

3. Operators

3.1 The operator carrying out the NDT and interpreting indications, shall as a minimum, be qualified and certified to Level 2 in the NDT method(s) concerned and as described in item 1.

However, operators only undertaking the gathering of data using any NDT method and not performing data interpretation or data analysis may be qualified and certified as appropriate, at Level 1.

3.2 The operator shall have adequate knowledge of materials, structures or components, NDT equipment and limitations that are sufficient to apply the relevant NDT method for each application appropriately.

E. Test Methods, Equipment and Test Media

1. Test methods

For detecting surface and/or volumetric discontinuities in the components indicated in A.1. the test methods from Table 3.1 or combinations of them shall be employed independence of the material, the geometry of the component, the expected service condition and the possible flaw position.

Table 3.1: Test methods

Testing of	Method	Short name [1)]
External condition	Visual testing	VT
	Magnetic particle testing	MT
	Eddy current testing	ET
	Penetrant testing	PT
Internal condition	Ultrasonic testing	UT
	Radiographic testing	RT
	Leakage testing	LT
	Digital radiography	RT-D
	Phased array ultrasonic testing	PAUT
	Time of flight diffraction	TOFD
[1)] Definition according to ISO 9712.		

2. Equipment and test media

2.1 The equipment and test media used shall conform to the state of art and the relevant standards and shall be in perfect, serviceable condition.

The Surveyor shall be presented by request proof of internal and/or external monitoring of the equipment and the test media.

2.2 If testing facilities, equipment and inspection personnel of external inspection bodies are engaged the workshop in question has to ensure that the conditions according to C. and D. are fulfilled.

F. Requirements, Preparation and Performance of Tests

1. Requirements of tests

1.1 Shipyard or manufacturer is to ensure that personnel carrying out NDT or interpreting the results of NDT are qualified to the appropriate level as detailed in D.

1.2 Procedures

1) All NDT are to be carried out to a procedure that is representative of the item under inspection.
2) Procedures are to identify the component to be examined, the NDT method, equipment to be used and the full extent of the examinations including any test restrictions.
3) Procedures are to include the requirement for components to be positively identified and for a datum system or marking system to be applied to ensure repeatability of inspections.
4) Procedures are to include the method and requirements for equipment calibrations and functional checks, together with specific technique sheets/scan plans, for the component under test.
5) Procedures are to be approved by personnel qualified to Level III in the appropriate technique in accordance with a recognised standard.
6) Procedures are to be reviewed by the BKI's Surveyor.

2. Preparation of tests

The surfaces that will be tested shall be free of remnants of the moulding material, scale, grease, dirt, protective coatings and other contaminations which may affect the indication sensitivity of the specific test methods.

3. Performance of tests

3.1 As a rule the prescribed tests shall be performed by the inspection personnel of the inspection body of the manufacturer or of the external body charged with the inspection.

The specific components that will be tested shall be subjected to the Surveyor in final machined condition for the visual testing.

3.2 In case ultrasonic (UT) and or surface crack detecting (MT, PT) shall be performed by the BKI Surveyor a special agreement is required.

3.3 The Surveyor shall be informed by the manufacturer of the works performing the further processing about the planned non-destructive testings in time. He will attend the testings in his discretion.

G. Certification of Test Results

1. Inspection reports shall be prepared on all performed tests, and these shall be submitted to the Surveyor together with the further documentation (e.g. NDT plans, film position plans, radiographs).

The inspection reports shall contain all the necessary details according to I. to L. relating to the particular test method used, the position at which the test was performed and the results obtained.

2. The inspection department shall attest the test results by means of inspection certificate according to EN 10204-3.1.

H. Visual Testing (VT)

1. The surfaces of the components that shall be subjected to testing shall be at least in the condition specified in F.1 or in the final machined condition.

2. Of the components that shall be tested the entire surfaces shall be visually tested. In doing so internal surfaces such as bore holes shall be included in the tests.

3. For performing visual testing optical magnifying devices, endoscopes or surface comparators shall be employed if necessary.

Specifications concerning testing criteria are contained in the appropriate specific section of Sections 4 to 17.

4. The manufacturer or the company performing further processing shall arrange that testing can be performed with adequate illumination.

The viewing conditions shall be in accordance with the requirements of ISO 3059.

Light and surface reflections shall be avoided by appropriate means.

I. Magnetic Particle Testing (MT)

1. Magnetization equipment and method

1.1 The surfaces of the components that shall be subjected to testing shall be at least in the condition specified in F.1 or in the final machined condition.

1.2 The stationary or portable equipment for magnetic particle testing shall be in accordance with the state of art for testing and with the standards ISO 9934-1, ISO 9934-2 and ISO 9934-3 or with other standards which are equivalent to these standards.

1.3 The choice of the method of magnetization and of the current for magnetization depends on the geometry of the component and on the type of surface defect to be detected (cracks, inclusions that are lying open towards the surface or inclusions close towards the surface).

1.4 If possible, magnetization shall be effected by passing a current through the work piece and/or by yoke magnetization using alternating or direct current.

1.5 Where a current is passed through the work- piece, alternating, direct, impulse or surge current may be used. A combination of the aforementioned methods for the detection of variously orientated defects is allowed.

2. Test media

2.1 Suspensions consisting of a carrier liquid (test oils or water with inhibitors) and dispersed magnetic particles (black or fluorescent) shall be used as test media.

Only such test media shall be used that conform to the requirements of ISO 9934-2.

2.2 Before magnetic particle testing is commenced the inspector shall verify the test media by means of suitable reference blocks according to ISO 9934-2 and shall prove this to the Surveyor by request.

Note

— *Reference blocks 1 and 2 according to ISO 9934 Part 2*

— *JIS-test block according to JIS Z 2343*

3. Performance of magnetic particle testing

3.1 Manual testing

In order to reveal variously orientated defects the magnetization shall be effected in a crosswise manner in two different directions. The angle of the both directions for magnetization should be in the range from 60° to 90°. The magnetizing field strength (effective tangential field strength) should be at least 2 kA/m but should not exceed 6 kA/m.

3.2 Mechanized testing

When mechanized testing is performed the conditions stated in 3.1 shall be provided by an adequate choice or combination of magnetization currents and methods.

3.3 When burn marks on final machined surfaces have to be avoided then for the magnetization by means of prods with alternating current only fusible supply electrodes made of tin-aluminium alloys shall be employed.

3.4 Testing of machinery components in the final machined condition shall preferably be performed by stationary appliances. The appliances for magnetizing employed for this shall fulfill the requirements of ISO 9934-3 or another equivalent standard. On demand of the Surveyor the parameters of magnetization stated in 3.1 shall be proved by the manufacturer by means of measurement of the effective tangential field strength or by means of "Berthold" test blocks.

4. Applying of test media, magnetization

The suspension containing the magnetic particles shall be applied on the surface to be tested by spraying or wetting. When doing so the magnetization shall last at least that long as the surface to be tested is sprayed with the magnetic particle suspension; subsequently magnetization shall be performed (at least 5 seconds) until no movement of the magnetic particle suspension can be detected. Testing when remanence is present (residual magnetism in the component) is not allowed.

5. Illumination of testing surfaces

In order to obtain an adequate contrast of test surface and indication the following requirements according to ISO 3059 for the light intensity and the UV intensity shall be fulfilled and shall be proved on the test surface with adequate and verified measuring devices, e.g. luxmeter or UV intensity meter.

The UV intensity on the test surface shall be not less than 10 W/m^2, the maximum ambient light intensity shall be 20 Lux.

6. Certification of testing results

The manufacturer or the inspection body charged by him shall issue a certificate concerning the performed magnetic particle test containing at least the following information:

- name and address of the inspection body (for external inspection bodies)
- details concerning the accreditation or the approval of the inspection body
- testing specification to be applied and/or testing instructions
- details of the component such as:
  - order no.
  - material designation
  - heat no.
  - specimen no.
  - machining condition
- surface condition
- testing scope, inspection zones, severity levels
- type of magnetization, e.g. according to ISO 9934 Part 3
- test equipment, test media, test blocks
- proof of the magnetization by means of measurement of the effective tangential field strength
- declaration of the inspection zones and acceptance criteria
- time of testing
- evaluation of test results
- place and date of testing
- name of the inspector, the inspection supervisor and their qualifications.

The aforementioned details may also be certified by means of works instructions of the manufacturer.

They above and the test certificate shall be submitted to the Surveyor together for assessment and acknowledgement.

Specifications for the aforementioned acceptance and assessment criteria are contained in the appropriate specific section of Sections 4 to 17.

J. Penetrant Testing (PT)

1. Testing is to be performed with a testing agent system consisting of penetrant remover, penetrant and developer in accordance with EN 571-1 or other recognized standards. The employed equipment for this shall fulfill the criteria of ISO 3452-4.

2. Test media and their verification

2.1 The testing agent system required for penetrant testing shall fulfill the requirements of ISO 3452-4 or of another recognized standard.

2.2 Before penetrant testing is commenced the suitability of the testing agent system is to be verified by means of test blocks e.g. according to ISO 3452-4 and is to be proven on demand to the Surveyor.

3. Performing penetrant testing

3.1 Before testing is commenced the manufacturer or purchaser shall submit to the Surveyor test instructions fulfilling at least the requirements listed in the following.

3.2 Pre cleaning of test surface

The surface to be tested shall correspond to the requirements specified in F.1 and shall be cleaned completely with a cleaner adequate for the testing agent system before testing is commenced.

Specifications concerning the surface areas for which testing is required are contained in the appropriate specific section of Sections 4 to 17.

3.3 Testing temperature

As a rule the temperature of the surfaces to be tested shall be between +5°C and +50°C. For lower temperatures pre heating of the test area shall be performed on an extensive surface by which the test area achieves the permitted temperature range from +5°C and +50°C.

3.4 Applying the penetrant

The penetrant may be applied by spraying, brushing or electrostatic spraying depending on the shape and size of the surface or of the geometry of the component to be tested. The test surface shall be completely wetted throughout the entire penetration time.

3.5 Penetration time

The penetration time depends on the properties of the penetrant, testing temperature, the material of the component to be tested and the type of discontinuities that are to be detected and should last from 5 to 60 minutes.

3.6 Intermediate cleaning

Following penetration, the surplus penetrant shall be completely removed in an appropriate manner from the test surface in such a way as to leave behind the penetrant lodged in any defects present.

3.7 Developing process

The developer is to be applied evenly and as thinly as possible immediately after intermediate cleaning and drying. The test surface should just be completely covered.

The developing time should be at least of the same as the time allowed for penetration.

The evaluation of the indications shall not start before the developing time has expired.

4. Illumination of the test surfaces

The test surfaces shall be illuminated adequately and reflection of light from already machined surfaces are to be avoided.

Precondition for an adequate evaluation of the indications are the requirements for illumination specified in I.5.

5. Testing criteria, evaluation of indications

Discontinuities exceeding the prescribed acceptance criteria by size and quantity as well as cracks of every type are not permitted.

Specifications for the evaluation of indications are contained in the appropriate specific section of Sections 4 to 17.

6. Cleaning of the test surfaces

After completion of penetrant testing any residuals of the test media shall be removed of the test surfaces. For this a cleaning agent shall be used that corresponds to the prior employed testing agent system and which will not have any effect on the further processing of the component.

7. Certification of test results

The manufacturer or the inspection body charged by him shall issue a certificate concerning the performed penetrant test containing at least the following information:

- name and address of the inspection body (for external inspection bodies)
- details concerning the accreditation or the approval of the inspection body
- testing specification to be applied and/or testing instructions
- details of the component such as:
  - order no.
  - material designation
  - heat no.
  - specimen no.
  - machining condition
- surface condition
- testing scope, testing areas, severity levels
- employed testing agent systems according to EN 571-1, test blocks according to ISO 3452-3
- declaration of the inspection zones and acceptance criteria
- time of testing
- evaluation of test results
- place and date of testing
- name of the inspector, the inspection supervisor and their qualifications.

The aforementioned details may also be certified by means of works instructions of the manufacturer.

They and the test certificate shall be submitted to the Surveyor together for assessment and acknowledgement.

K. Ultrasonic Testing (UT)

1. Methods

1.1 Ultrasonic testing is to be performed with the impulse echo technique in accordance with recognized standards. Such are e.g. ISO 2400, ISO 7963, EN 12668-3, EN 583-1, EN 10228-3, EN 10160 and EN 12680-1.

Other national or international standards may be applied if they provide an equivalent method.

1.2 The methods described here relate to the testing of components and machinery constructions made of ferritic steels. For testing of components made of austenitic or austenitic-ferritic steels special agreements are to be made.

1.3 Alternatively ultrasonic testing may be performed according to the test instructions of the manufacturer or of the purchaser on condition that an equivalent test can be achieved.

2. Test specification

The manufacturer or the purchaser shall prepare a test specification which shall contain at least the following information:

— state of machining for pre and final testing

— test method, type of test equipment, type of probes, testing frequencies

— calibration of equipment

— surface condition depending on the manufacturing stage, surface roughness (if necessary)

— position of incidences, if necessary explained by means of sketches

— heat treatment condition depending on the manufacturing stage

— determination of testing areas in accordance with the requirements specified in Section 6 or Section 7.

— evaluation criteria for the specific testing areas and severity levels, respectively

— indication of other applicable standards and regulations.

3. Test appliances and accessories

Ultrasonic testing appliances and probes shall comply with the state of the art and with recognized standards [1)] and shall fulfill at least the following requirements:

3.1 Requirements for the test equipment

— The ranges of adjustment shall enable the range of at least 20 mm up to 2 m without any intervening gap for longitudinal and transverse waves in steel.

— The amplification shall be adjustable for a range up to at least 80 dB with switching stages of 2 dB, the accuracy shall be 1 dB.

— The linearity of the time sweep and the vertical linearity shall be better than 5 % of the adjustment range or of the screen.

— The test equipment shall be applicable for probes from 1 to 6 MHz nominal frequency for impulse echo technique with straight or SE (twin transducer) probes.

3.2 Requirements for the probes

3.2.1 The selection of the probes concerning the nominal frequency and the transducer size depends on the size of the disc-shaped reflector to be detected, the sound path travel distance and the sound attenuation of the material to be tested.

3.2.2 Depending on the geometry of the component and the type and position of discontinuity to be detected straight beam probes and/or angle probes are to be employed; for testing of regions close to the surface SE straight beam probes shall be employed.

3.2.3 For oblique scanning probes with angle of incidence between 35° and 70° shall be employed. Their nominal frequency shall be between 1 and 6 MHz.

[1)] Recognized standards are e.g. EN 12668-1, EN 12668-2 and EN 12668-3.

4. Calibration blocks

For verification of the inspection system calibration blocks type 1 according to ISO 2400 and calibration blocks type 2 according to ISO 7963 or other adequate calibration blocks with reference reflectors are to be used.

5. Coupling media

For inspection the oils, greases or other adequate coupling media recommended by the manufacturer of the equipment shall be used preferably.

For calibration of the equipment the same coupling medium shall be used.

6. Performing ultrasonic testing

Ultrasonic testing of machinery parts is to be performed in accordance with the method, standards and regulations specified in 1.1 and/or according to specifications of the manufacturer or the purchaser.

6.1 Calibration of the inspection system

6.1.1 Calibration of the distance

The calibration of the distance is to be performed at the calibration block type 1 in accordance with ISO 2400 or at the component.

The inspection range shall be selected in such a way that the backwall echo of the component thickness to be tested will appear at 80% of the screen width.

6.1.2 Calibration of sensitivity

Calibration of sensitivity shall be adjusted in such a way that indications to be registered are not smaller than 2/5 of the screen height at the end of the inspection range.

The signal-to-noise ratio based on the registration level shall be at least 6 dB.

Deviations of these specifications may be agreed on by the purchaser and/or manufacturer and BKI in technically justified exceptional cases.

6.2 Scanning of the test area and testing velocity

6.2.1 Scanning of the test area

In case scanning of test surfaces without any intervening gap is required, e.g. in case of 100% volumetric inspection, the test paths shall overlay each other with at least 15%.

6.2.2 Testing velocity

If ultrasonic testing is performed manually then with regard to optimal localisation of the indications the testing velocity shall not exceed 100 mm/s.

7. Evaluation of indications

7.1 Indications without extension

The evaluation of indications without extension is to be performed according to the DGS method (distance gain size method). In doing so the reference reflector size shall be specified as diameter of the equivalent disc shaped reflector (DSR) [mm].

7.2 Indication with extension

If not otherwise agreed, the determination of the reflector extension shall be performed according to the half-amplitude technique.

Specifications concerning the aforementioned evaluation and acceptance criteria are contained in Section 6, H. and Section 7, G.

8. Certification of test results

The manufacturer or the inspection body charged by him shall compile a report concerning the test which shall contain at least the following information:

- name and address of the inspection body (for external inspection bodies)
- details concerning the accreditation or the approval of the inspection body
- testing specification to be applied and/or testing instructions
- details of the component such as:
- material
- dimensions
- component no.
- heat no.
- drawing no.
- condition of supply
- time of testing, testing scope, inspection zones, severity levels
- the manufacturer and type of the employed testing equipment
- manufacturer, type, nominal frequency and angle of incidence of the employed probes
- type of calibration of distance and sensitivity
- specifications concerning the suitability for ultrasonic testing, surface preparation, correction, values (transfer correction and sound attenuation) coupling media
- description of the position of reflectors to be recorded by means of sketches, the size of DSR, its extension in length, width and depth as well as the back-wall echo attenuation
- place and date of testing
- name of the inspector, the inspection supervisor and their qualifications.

L. Radiographic Testing (RT)

1. Method

1.1 If necessary radiographic testing is to be performed in addition to ultrasonic testing in case doubts exist concerning the evaluation of indications of ultrasonic testing.

Radiographic testing can be performed depending on the type of the component to be inspected, its material grade and wall thickness, either with x-rays or gamma rays.

1.2 As a rule radiographic testing is to be performed in accordance with recognized standards such as EN 444, ISO 17636-1 for the radiographic examination of welded joints or EN 12681 for the testing of cast components.

2. Scope of validity

The following specifications apply for radiographic testing of components indicated in Section 7.

3. Performing radiographic testing

As a rule radiographic testing is to be performed in accordance with EN 12681, test category A. Thereby the image quality category A according to EN 462-3 shall be fulfilled.

Testing in accordance with other national or international standards may be agreed on with BKI on condition that the conditions of the standards indicated in 1.2 will be fulfilled.

4. Testing specification

4.1 The purchaser or the manufacturer shall prepare a testing specification which shall contain the test method and all relevant details. Especially the following information shall be specified:

- radiation source, focal spot size or dimensions of the employed gamma-ray source
- radiation energy
- film system class and screens
- test category
- thickness range to be penetrated
- type and position of the image quality indicator
- distances between the film and the focal point
- image quality, density
- test arrangement explained by means of sketches or drawings.

4.2 For cast components where a large amount of radiographing is required the manufacturer shall prepare a film position plan.

The specification as well as the film position plan shall be submitted to BKI for evaluation.

5. Selection of radiation source

The selection of the radiation source depends on the thickness w of the tested component to be penetrated, the required test category and the selected radiographic arrangement according to EN 12681.

6. Selection of film system and intensifying screens

6.1 The selection of the film class depends on the test category and the thickness to be penetrated. The selection of the intensifying screens depends on the maximum permissible tube voltage of the X-rays or the type of isotopes, see Table 3.2.

In case intensifying screens are used close contact between film and screen has to be ensured.

6.2 For the selection of the film class EN 444 is to be observed. A comparison of comparable international standards for film system classes is contained in Table 3.3.

Table 3.2: Film system classes and metal screens in accordance with EN 444 and EN 12681

Radiation source	Penetrated thickness (w)	Film system class [1]		Type and thickness of metal screens	
		class A	class B	class A	class B
X-ray potentials $\leq$ 100 kV		C5	C3	None, or front and rear lead screens up to max. 0,03 mm	
X-ray potentials > 100 kV to 150 kV				Front and rear lead screens up to max. 0,15 mm	
X-ray potentials > 150 kV to 250 kV			C4	Front and rear lead screens from 0,02 to 0,15 mm	
Yb 169	w < 5 mm	C5	C3	None, or front and rear lead screens up to max. 0,03 mm	
Tm 170	w $\geq$ 5 mm		C4	Front and rear lead screens from 0,02 to 0,15 mm	
X-ray potentials $\geq$ 250 kV to 500 kV	w $\leq$ 50 mm	C5	C4	Front and rear lead screens from 0,02 to 0,2 mm	
	w > 50 mm		C5	Front lead screens from 0,1 to 0,2 mm[2]	
Se - 75	w > 5 mm	C5	C4	Front and rear screens from 0,1 to 0,2 mm	
Ir 192		C5	C4	Front lead screens from 0,02 to 0,2 mm	Front lead screens from 0,1 to 0,2 mm[2]
				Rear lead screens of steel from 0,02 to 0,2 mm	
Co 60	w $\leq$ 100 mm	C5	C4	Front and rear screens of steel or copper from 0,25 to 0,7 mm[3]	
	w > 100 mm		C5		
X-ray equipment with energy from 1 MeV to 4 MeV	w $\leq$ 100 mm	C5	C3	Front and rear screens of steel or copper from 0,25 to 0,7 mm[3]	
	w > 100 mm		C5		
X-ray equipment with energy from 4 MeV to 12 MeV	w $\leq$ 100 mm	C4	C4	Front screens of steel, copper or tantalum up to max. 1 mm[4]	
	100 mm <w $\leq$ 300 mm	C5	C4		
	w > 300 mm		C5	Rear screens of steel or copper up to max. 1 mm and tantalum up to max. 0,5 mm[4]	
X-ray equipment with energy above 12 MeV	w $\leq$ 100 mm	C4		Front screens of tantalum up to max. 1 mm[5] No rear screens	
	100 mm <w $\leq$ 300 mm	C5	C4		
	w > 300 mm		C5	Front screens of tantalum up to max. 1 mm[5] Rear screens of tantalum up to max. 0,5 mm	

1) Film system classes of higher quality may be used too.
2) Film packaged by the manufacturer with front screens up to max 0,03 mm may be used if in addition a 0,1 mm lead screen is placed between the component to be tested and the film.
3) For class A 0,1 to 0,5 m lead screens may be used too.
4) For class A 0,5 to 1 mm lead screens may be used if agreed on by the contracting partners.
5) For class A 0,5 to 1 mm lead screens may be used if agreed on by the contracting partners.

7. Film density

7.1 The parameters for the exposure shall be selected in such a way that in the entire region to be evaluated the density S of the radiographs according to EN 444 is larger than S $\geq$ 2,0 for test category A and larger than S $\geq$ 2,3 for test category B.

Reduction of the minimum required density to 1,5 for test category A or to 2,0 for test category B is only permitted on condition that an appropriate agreement between the purchaser and the manufacturer is made and that the multiple film technique is employed. This agreement is to be submitted to BKI.

7.2 The upper limit for density depends on the brightness of the film illuminator which is employed for the evaluation.

7.3 In order to depict different wall thickness regimes of cast components without loss of quality within the density limits specified in 7.1 on one screen, the procedures for multiple film technique as indicated in EN 12681 shall be employed.

7.4 For evaluation of radiographs the density shall be verified with a densitometer.

Table 3.3: Comparison of international comparable recognized film system classes (examples)

Manufacturer / film type	ASTM 1)	DIN 4)	EN 4)	ISO 2)	RCC-M 5)	BS 3)
AGFA 6)						
Structurix D2	special	G1	C1	GI	1	A
Structurix D3	1	G1	C2	GI	1	A
Structurix D3 s.c	1	G1	C2	GI	2	A
Structurix D4	1	G2	C3	GI	3	A
Structurix D5	1	G2	C4	GII	3 – 4	A
Structurix D7	2	G3	C5	GIII	4	B
Structurix D8	2	G4	C6	GIII	5	B
Fuji 6)						
IX 25	1	G2	C3	GI	3	A
IX 50	Special	G1	C1	GI	1	A
IX 80	1	G2	C3	GI	3	A
IX 100	1	G2	C4	GII	3 - 4	A
IX 150	2	G4	C6	GIII	4 - 5	B
Kodak 6)						
DR	special	G1	C1	GI		
M	1	G1	C2	GI		
MX125	1	G2	C3	GI		
T200	1	G2	C4	GII		
AA400	2	G3	C5	GIII		
CX	3	G4	C6	GIII		
B	W-B			GIII		

1) ASTM E 94.
2) ISO 5579.
3) BS 2600: type A: high contrast - very fine grain
type B: high contrast - fine grain
4) Classification according to EN 584-1 in comparison to the replaced standard DIN 54117 T1.
5) French standard.
6) Equivalent film types from other manufacturers may also be considered, provided that appropriate proof has been furnished.

8. Verification of image quality

8.1 The image quality is to be verified by means of image quality indicators such as e.g. wire indicators in accordance with EN 462-1.

In case image quality indicators cannot be positioned conforming to standards, i.e. away from the film, the image quality value shall be verified at least once by means of comparative radiographs prepared under the corresponding conditions.

8.2 In general, for steel castings of test category A, the image quality class A and for test category B the image quality class B according to EN 462-3 shall be achieved.

9. Evaluation of radiographs, evaluation criteria

The inspection department shall submit to the Surveyor for evaluation all radiographs and evaluation reports prepared by the inspector. It is up to the Surveyor to evaluate all radiographs or only a specific number of them.

The radiographs evaluated by him are to be stamped by him.
The testing and acceptance criteria applicable for the evaluation of the radiographs are contained in Section 7, G.

10. Certification of the test results

The manufacturer shall compile a report concerning the evaluation of the radiographs which shall contain at least the following information:

- name and address of the inspection body (for external inspection bodies)
- details concerning the accreditation or the approval of the inspection body
- details of the component such as:
  - material
  - heat no.
  - pattern no.
  - drawing no.
- condition of supply
- number and name of the testing specification
- testing standards to be applied and regulations
- method of radiographing and test categories
- film position plans, method of marking
- type of radiation source: tube/isotope, size of focal spot or of the radiation source, respectively
- tube voltage and anode current or activity of the radiation source
- exposure time and distance between radiation source and film supervisor and their qualifications
- selected film systems, screens and filters
- type and position of image quality indicator
- film density
- place and date of testing
- name of the inspector, the inspection supervisor and their qualifications.

M. Advanced Non-Destructive Testing (ANDT)

1. General

1.1 This sub section gives minimum requirements on the methods and quality levels that are to be adopted for advanced non-destructive testing (ANDT) of materials. The advanced methods intended for use under this sub section are listed in 2.1.

1.2 The ANDT is to be performed by the manufacturer or its subcontractors in accordance with these requirements. The BKI's Surveyor may require witnessing testing.

1.3 It is the manufacturer's responsibility to ensure that testing specifications and procedures are adhered to during the construction, and the report is to be made available to BKI on the findings made by the ANDT.

1.4 The extent and method of testing, and the number of checkpoints are normally agreed between the manufacturer and BKI.

2. Applicability

2.1 Materials

This sub section applies to the following materials and manufactured products:

— Material for gas tankers in accordance with Rules for Ships Carrying Liquefied Gases in Bulk (Pt.1, Vol.IX) Sec. 6

— Normal and higher strength hull structural steels in accordance with Section 4

— High strength steels for welded structures in accordance with Section 4

— Hull steel forgings in accordance with Section 6

— Hull and machinery steel castings in accordance with Section 7

— Extremely Thick Steel Plates in Container Ships in accordance with Rules for Container Ships (Pt.1, Vol.XVIII) Sec. 27

— Cast Copper Alloy propellers in accordance with Section 16

— Aluminium alloys for hull construction in accordance with Section 10

— Cast Steel Propellers in accordance with Section 17

— YP47 Steels and Brittle Crack Arrest Steels in accordance with Section 4, L

2.2 Testing methods

2.2.1 The methods for detection of imperfections are Phased Array Ultrasonic Testing (PAUT) (only automated/semi-automated), Time of Flight Diffraction (TOFD), Digital Radiography (RT-D).

2.2.2 Applicable methods for testing of the different types of materials are given in Table 3.4.

Table 3.4: Applicable methods for testing of materials

Materials	Materials Thickness	Applicable Methods
Cast copper alloy	All	PAUT, RT-D*
Steel forgings	All	PAUT, RT-D*
Steel castings	All	PAUT, RT-D*
Base materials/Rolled steels, Wrought Aluminum Alloys	t < 6mm	RT-D
	6 mm $\leq$ t $\leq$ 40 mm	PAUT, TOFD, RT-D
	t > 40 mm	PAUT, TOFD, RT-D*
* Only applicable with limitations, need special qualification subject to acceptance by BKI		

3. Technique and procedure qualification

3.1 General

The manufacturer shall submit to BKI the following documentation for review:

— The technical documentation of the ANDT.

— The operating methodology and procedure of the ANDT according to F.1

— Result of software simulation, when applicable.

3.2 Software simulation

Software simulation may be required by BKI, when applicable for PAUT or TOFD techniques. The simulation may include initial test set-up, scan plan, volume coverage, result image of artificial flaw etc. In some circumstances, artificial defect modelling/simulation may be needed or required by the project.

3.3 Procedure qualification test

The procedure qualification for ANDT system shall include the following steps:

— Review of available performance data for the inspection system (detection abilities and defect sizing accuracy).

— Identification and evaluation of significant parameters and their variability.

— Planning and execution of a repeatability and reliability test programme [1] which including onsite demonstration.

— Documentation of results from the repeatability and reliability test programs.

Note 1

The data from the repeatability and reliability test program is to be analysed with respect to comparative qualification block test report and onsite demonstration. The qualification block shall be in accordance with ASME V Article 14 MANDATORY APPENDIX II UT PERFORMANCE DEMONSTRATION CRITERIA or agreed by BKI, and at least the intermediate level qualification blocks shall be used. The high level qualification blocks shall be used when sizing error distributions and an accurate PoD need to be evaluated. The demonstration process onsite shall be witnessed by BKI's Surveyor.

3.4 Procedure approval

The testing procedure is to be evaluated based upon the qualification results, if satisfactory the procedure can be considered approved.

3.5 Onsite review

Data analyses shall be performed in accordance with 3.3. Probability of Detection (PoD) and sizing accuracy shall be established when applicable.

When the result of inspection review does not conform to the approved procedure, the inspection shall be suspended immediately. Additional procedure review qualification and demonstration shall be undertaken to account for any nonconformity.

When a significant nonconformity is found, BKI has the right to reject the results of such activities.

4. Surface condition

4.1 Area to be examined shall conform to F.2.

4.2 Where there is a requirement to carry out PAUT or TOFD through paint, the suitability and sensitivity of the test shall be confirmed through an appropriate transfer correction method defined in the procedure. In all cases, if transfer losses exceed 12 dB, the reason shall be considered and further preparation of the scanning surfaces shall be carried out, if applicable. If testing is done through paint, then the procedure shall be qualified on a painted surface.

4.3 The requirement for acceptable test surface finish is to ensure accurate and reliable detection of defects.

5. General plan of testing: NDT method selection

5.1 The extent of testing shall be planned by the manufacturer according to the ship design and ship or equipment type. Particular attention shall be paid to highly stressed areas. The extent of testing shall be in accordance with the requirements applicable to material examined.

6. Testing requirements

6.1 General

6.1.1 The methods considered within the application of this sub section are defined in 2.2.1.

6.1.2 PAUT techniques shall conform as a minimum to 6.2. Depending on the complexity of the item under test and the access to surfaces, there may be a requirement for additional scans and/or complementary NDT techniques to ensure that full coverage of the item is achieved.

6.1.3 TOFD techniques shall conform as a minimum to Rules for Welding (Pt.1, Vol.VI) Sec.10. Depending on the complexity of the item under test and the access to surfaces, there may be a requirement for additional scans and/or complementary NDT techniques to ensure that full coverage of the item is achieved.

6.1.4 RT-D techniques shall conform as a minimum to Rules for Welding (Pt.1, Vol.VI) Sec.10. For the purpose of this sub section, RT-D comprises of two main RT methods; RT-S and RT-CR. Other methods may be included (e.g. radioscopy systems), however, then must conform to this sub section as applicable, and any specific requirements shall demonstrate equivalence to these requirements.

.1 In all RT-D methods, in addition to specific requirements, detector output quality control methods shall be described within the procedure.

.2 The procedure shall define the level of magnification, post-processing tools, image/data security and storage, for final evaluation and reporting.

6.2 Phased array ultrasonic testing

PAUT shall be carried out according to procedures based on ISO 18563-1:2015, ISO 18563-2:2017 and ISO 18563-3:2015 or recognized standards and the specific requirements of BKI.

6.2.1 Information required prior to testing

A procedure shall be written and include the following information as in minimum shown in Table 3.5 When an essential variable in Table 3.5 is to change from the specified value, or range of values, the written procedure shall require requalification. When a nonessential variable is to change from the specified value, or range of values, requalification of the written procedure is not required. All changes of essential or nonessential variables from the value, or range of values, specified by the written procedure shall require revision of, or an addendum to, the written procedure.

Table 3.5: Requirements of a PAUT Procedure

Requirement	Essential Variable	Nonessential Variable
Material types to be examined, including thickness dimensions and material product form (castings, forgings, pipe, plate, etc.)	X	-
The surfaces from which the examination shall be performed	X	-
Technique(s) (straight beam, angle beam, contact, and/or immersion)	X	-
Angle(s) and mode(s) of wave propagation in the material	X	-
Search unit type, frequency, element size and number, pitch and gap dimensions, and shape	X	-
Focal range (identify plane, depth, or sound path)	X	-
Virtual aperture size (i.e., number of elements, effective height[1)], and element width)	X	-
Focal laws for E-scan and S-scan (i.e., range of element numbers used, angular range used, element or angle increment change)	X	-
Special search units, wedges, shoes, or saddles, when used	X	-
Ultrasonic instrument(s)	X	-
Calibration [calibration block(s) and technique(s)]	X	-
Directions and extent of scanning	X	-
Scanning (manual vs. automatic)	X	-
Method for sizing indications and discriminating geometric from flaw indications	X	-
Computer enhanced data acquisition, when used	X	-
Scan overlap (decrease only)	X	-
Personnel performance requirements, when required	X	-
Testing levels, acceptance levels and/or recording levels	X	-
Personnel qualification requirements	-	X
Surface condition (examination surface, calibration block)	-	X
Couplant (brand name or type)	-	X
Post-examination cleaning technique	-	X
Automatic alarm and/or recording equipment, when applicable	-	X
Records, including minimum calibration data to be recorded (e.g., instrument settings)	-	X
Environmental and safety issues	-	X

Note:
1) Effective height is the distance from the outside edge of the first to last element used in the focal law.

6.2.2 Testing

.1 Material examinations

Material examinations shall conform to 2.1 as a minimum.

.2 Volume to be inspected

The purpose of the testing shall be defined by the testing procedure. Based on this, the volume to be inspected shall be determined.

A scan plan shall be provided.

.3 Reference blocks

Depending on the testing level, a reference block shall be used to determine the adequacy of the testing (e.g. coverage, sensitivity setting).

.4 Indication assessment

Depending on the testing level, a reference block shall be used to determine the adequacy of the testing (e.g. coverage, sensitivity setting).

7. Acceptance levels

7.1 General

7.1.1 This sub section details the acceptance levels followed for the assessment of the NDT results. Methods include but are not limited to: Phased array ultrasonic testing (PAUT), Time of flight diffraction (TOFD), Digital radiography (RT-D).

7.1.2 It may be necessary to combine testing methods to facilitate the assessment of indications against the acceptance criteria.

7.1.3 Acceptance criteria shall be in accordance with 2.1.

7.2 Phased array ultrasonic testing

Quality levels and acceptance levels for PAUT of material testing shall be in accordance to recognized standard agreed with BKI. The acceptance levels for material examinations shall conform as a minimum to the appropriate requirements in relevant Sections.

7.3 Time of flight diffraction

The relationship between acceptance levels, testing levels and quality levels is specified in Rules for Welding (Pt.1, Vol.VI) Sec.10.

7.4 Digital radiography

The relationship between acceptance levels, testing levels and quality levels is specified in Rules for Welding (Pt.1, Vol.VI) Sec.10.

8. Reporting

8.1 The test report shall include at least the following information:

a) A reference to standards of compliance;

b) Information relating to the object under test:

   1. Identification of the object under test,
   2. Dimensions including wall thickness,
   3. Material type and product form,
   4. Geometrical configuration,
   5. Surface condition and temperature,
   6. Stage of manufacture;

c) Information relating to equipment (see Table 3.6)

d) Information relating to test technology (see Table 3.7)

e) Information relating to test results (see Table 3.8)

Table 3.6: Information relating to equipment

Method	Information
All	Manufacturer and type of instrument, including with identification numbers if required
PAUT	1) Manufacturer, type, frequency of phased array probes including number and size of elements, material and angle(s) of wedges with identification numbers if required, 2) Details of reference block(s) with identification numbers if required, 3) Type of couplant used.
TOFD	1) Manufacturer, type, frequency, element size and beam angle(s) of probes with identification numbers if required, 2) Details of reference block(s) with identification numbers if required, 3) Type of couplant used.
RT-D	1) system of marking used, 2) Radiation source, type and size of focal spot and identification of equipment used, 3) Detector, screens and filters and detector basic spatial resolution.

Table 3.7: Information relating to test technology

Method	Information
All	1) Testing level and reference to a written test procedure, 2) Purpose and extent of test, 3) Details of datum and coordinate systems, 4) Method and values used for range and sensitivity settings, 5) Details of signal processing and scan increment setting, 6) Access limitations and deviations from standards, if any.
PAUT	1) Increment (E-scans) or angular increment (S-scans), 2) Element pitch and gap dimensions, 3) Focus (calibration should be the same as scanning), 4) Virtual aperture size, i.e. number of elements and element width, 5) Element numbers used for focal laws, 6) Documentation on permitted wedge angular range from manufacturer, 7) Documented calibration, TCG and angle gain compensation, 8) Scan plan.
TOFD	1) Details of TOFD setups, 2) Details of offset scans, if required.
RT-D	1) Detector position plan, 2) Tube voltage used and current or source type and activity, 3) Time of exposure and source-to-detector distance, 4) Type and position of image quality indicators, 5) Achieved and required SNRN for RT-S or achieved and required grey values and/or SNR_N for RT-CR, 6) For RT-S: type and parameters such as gain, frame time, frame number, pixel size, calibration procedure, 7) For RT-CR: scanner type and parameters such as pixel size, scan speed, gain, laser intensity, laser spot size, 8) Image-processing parameters used, e.g. of the digital filters.

Table 3.8: Information relating to test results

Method	Information
All	1) Acceptance criteria applied, 2) Tabulated data recording the classification, location and size of relevant indications and results of evaluation, 3) Results of examination including data on software used, 4) Date of test, 5) Reference to the raw data file(s), 6) Date(s) of scan or exposure and test report, 7) Names, signatures and certification of personnel.
PAUT	1) Phased array images of at least those locations where relevant indications have been detected on hard copy, all images or data available in soft format, 2) Reference points and details of the coordinate system.
TOFD	TOFD images of at least those locations where relevant TOFD indications have been detected.

8.2 Results of NDT are to be recorded and evaluated by the manufacturer on a continual basis. These records are to be available to the Surveyor.

8.3 The manufacturer is to be responsible for the review, interpretation, evaluation and acceptance of the results of NDT. Reports stating compliance or otherwise with the criteria established in the inspection procedure are to be issued.

8.4 In addition to the above general reporting requirements, all specified NDT methods will have particular requirements and details that shall be listed in the report. Refer to the applicable method standards for specific requirements.

8.5 The manufacturer is to keep the inspection records for the appropriate period deemed by BKI.

9. Unacceptable indications and repairs

All indications (discontinuities) exceeding the applicable acceptance criteria shall be classed as defects, and shall be eliminated and repaired as per requirements in relevant Sections.

Section 4 Steel Plates, Strips, Section, 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 6, 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 fulfill the requirements set out in Section 1, C. and shall demonstrate this to BKI 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 BKI. On request, BKI 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 BKI.

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 normalizing, normalising rolled (controlled rolled), quenching and tempering or thermo-mechanically rolled condition (see 4.3), provided that the processes have been checked and approved by BKI on the manufacturer's premises.

4.3 Definitions

The processes mentioned in 4.2 are defined as follows:

4.3.1 As-Rolled, AR

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

4.3.2 Normalising, N

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

4.3.3 Normalising rolling, NR

A rolling procedure in which the final deformation is carried out in the normalizing temperature range, allowed to cool in air, resulting in a material condition generally equivalent to that obtained by normalising.

4.3.4 Quenching and Tempering, QT

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

4.3.5 Thermo-mechanical rolling, TM (Thermo-Mechanical Controlled Processing, TMCP)

This is a procedure which involves the strict control of both the steel temperature and the rolling reduction. Generally a high proportion of the rolling reduction is carried out close to the Ar3 temperature and may involve the rolling in the dual phase temperature region. Unlike controlled rolled (normalised rolling) the properties conferred by TM (TMCP) cannot be reproduced by subsequent normalising or other heat treatment.

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

4.3.6 Accelerated Cooling, AcC

Accelerated cooling is a process, which aims to improve mechanical properties by controlled cooling with rates higher than air cooling immediately after the final TM-rolling operation. Direct quenching is excluded from accelerated cooling. The material properties conferred by TM and AcC cannot be reproduced by subsequent normalising or other heat treatment.

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 thickness 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 BKI, hot-rolled plates, wide flats and sections shall be subject to the delivery conditions stipulated in EN 10163:2007.

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 either with the minus tolerances shown in Table 4.1 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 made from high-strength steels in accordance with D., 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.

Table 4.1: Permitted minus tolerances for the thickness of plates and wide flats

Nominal Thickness [mm]	Permitted minus tolerances [1)] [mm] for class		
	A	B	C
$3 \leq t < 5$	– 0,3	– 0,3	0
$5 \leq t < 8$	– 0,4	– 0,3	0
$8 \leq t < 15$	– 0,5	– 0,3	0
$15 \leq t < 25$	– 0,6	– 0,3	0
$25 \leq t < 40$	– 0,7	– 0,3	0
$40 \leq t < 80$	– 0,9	– 0,3	0
$80 \leq t < 150$	– 1,1	– 0,3	0
$150 \leq t < 250$	– 1,2	– 0,3	0
$t \geq 250$	– 1,3	– 0,3	0

[1)] See also ISO 7452:2013.

6.2 The thickness is to be measured at points located at least 25 mm from the edge of the product, if not stipulated otherwise in the individual rules, e.g. for shipbuilding steels in accordance with B. and flat products made from high-strength steels in accordance with D. 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 10029:2011 apply.

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

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

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.

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 ≥ 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. 4.1):

- 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.

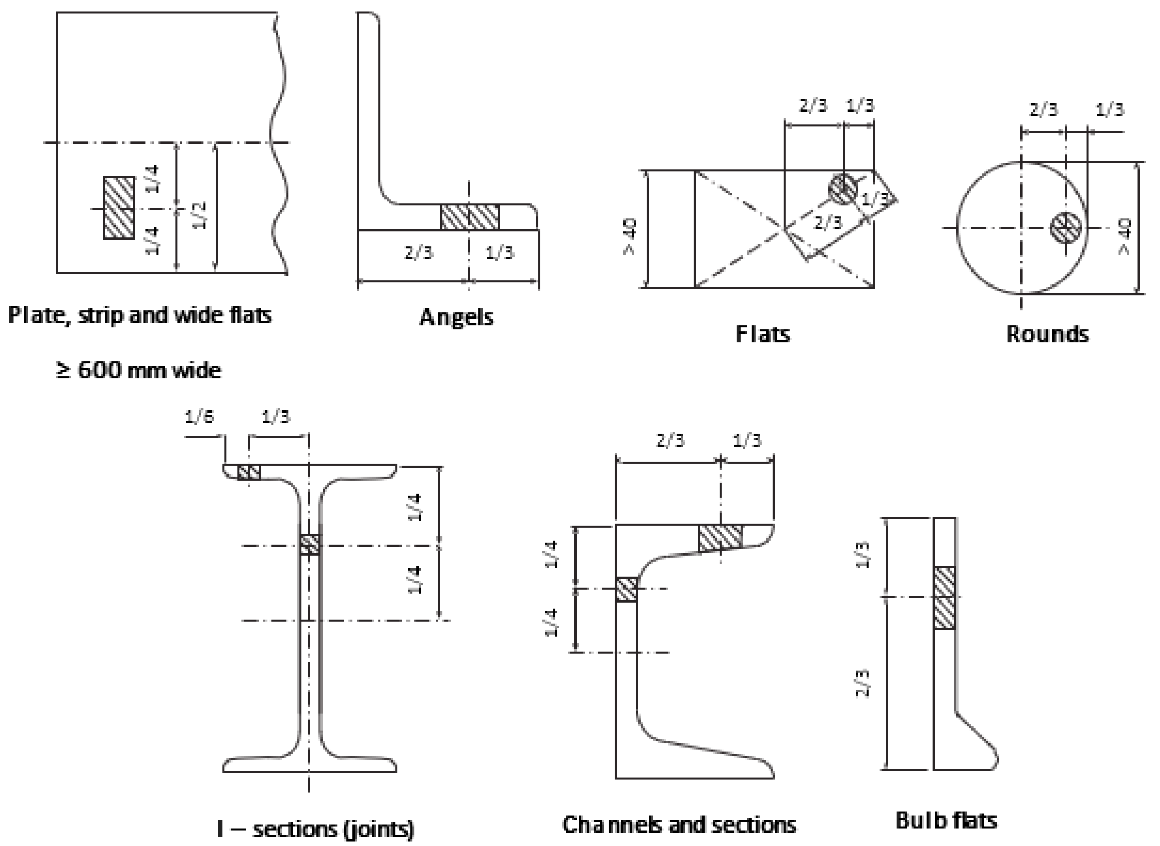


Figure 4.1: Examples showing location of test sections

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 $\leq$ 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

8.6.1 The tests shall be performed in accordance with EN 10160:1999 or another standard accepted by BKI (e.g. ASTM A 578:2017) . 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 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 $\leq$ 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 $\leq$ 25 kg or less per meter 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 BKI Rules for Materials, and the requirements were satisfied. The name ”Biro Klasifikasi Indonesia” (BKI) 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 BKI for testing.”

10.3 Where the steels are not produced and rolled by the same manufacturer, a certificate issued by manufacturer 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 and higher strength hot-rolled steel 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 100 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/mm^2) 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 BKI. Such steels are to be given a special designation.

1.5 These requirements also apply to normal and higher strength Corrosion Resistant steels when such steel is used as the alternative means of corrosion protection for cargo oil tanks as specified in the performance standard MSC.289 (87) of Regulation 3-11, Part A-1, Chapter II-1 of the SOLAS Convention (Corrosion protection of cargo oil tanks of crude oil tankers). Corrosion Resistant steels as defined within this Rules, are steels whose corrosion resistance performance in the bottom or top of the internal cargo oil tank is tested and approved to satisfy the requirements in MSC.289 (87) in addition to other relevant requirements for hull structural steels, structural strength and construction. It is not intended that such steels be used for corrosion resistant applications in other areas of a vessel that are outside of those specified in the performance standard MSC.289 (87) of Regulation 3-11, Part A-1, Chapter II-1 of the SOLAS Convention. These requirements apply to plates, wide flats, sections and bars in all grades up to a maximum thickness of 50 mm.

2. Approval

2.1 All materials are to be manufactured at works which have been approved by BKI for the grade of steel and the shape of the product which is being supplied. The approval of manufacturer is to follow a scheme given in Guidance for The Approval and Type Approval of Materials and Equipment for Marine Use (Pt.1, Vol.W).

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 BKI.

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

For further use, each affected piece is to be tested to the Surveyor's satisfaction.

The frequency of testing for subsequent products offered may be increased to gain confidence in the quality at the discretion of BKI.

2.4 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.

2.5 Where CR and TM with/without AcC are applied, the programmed rolling schedules are to be verified by BKI at the time of the steel works approval.

Note :

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

3. 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 BKI.

3.2 The deoxidation practice used for each grade is to comply with the appropriate requirements of Tables 4.2 and Tables 4.3.

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

3.4 For CR and TM steels with/without AcC, the programmed rolling schedules are to be adhered to during the rolling operation and are to be made available when required by the attending Surveyor. The actual rolling records are to be reviewed by the manufacturer and occasionally by the Surveyor.

When deviation from the programmed rolling schedules or normalizing or quenching and tempering procedures occurs, the manufacturer shall take further measures required in the above 2.3 to the Surveyor's satisfaction.

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 4.2 and 4.3.

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

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 4.4.

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 BKI.

Table 4.2: Chemical composition and deoxidation practice for normal strength steels

<table>
<tr><th>Grade [1]</th><th>KI–A</th><th>KI–B</th><th>KI–D</th><th>KI–E</th></tr>
<tr><td rowspan="2">Deoxidation Practice</td><td>For t ≤ 50 mm :
any method except [1]
rimmed steel</td><td>For t ≤ 50 mm :
any method except
rimmed steel</td><td>For t ≤ 25 mm :
killed</td><td rowspan="2">Killed and fine grain treated</td></tr>
<tr><td>For t > 50 mm :
killed</td><td>For t > 50 mm :
killed</td><td>For t > 25 mm :
killed and fine
grain treated</td></tr>
<tr><td>Chemical composition (%) (ladle analysis) [4] [7] [8]</td><td colspan="4">Carbon plus 1/6 of the manganese content is not to exceed 0,40 %</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 x 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 (acid soluble)$_{min}$</td><td>––</td><td>––</td><td>0,015 [5] [6]</td><td>0,015 [6]</td></tr>
</table>

t = material thickness

1) Grade KI–A sections up to a thickness of 12,5 mm may be accepted in rimmed steel subject to the special approval of BKI.

2) Max. 0,23% for sections.

3) When Grade KI-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 KI–D steel over 25 mm thick.

6) For Grade KI-D steel over 25 mm thick and for Grade KI-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%. BKI 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 4.3: Chemical composition and deoxidation practice for higher strength steels

Grade [1]	**KI–A32, KI–D32, KI–E32** **KI–A36, KI–D36, KI–E36** **KI–A40, KI–D40, KI–E40**	**KI–F32** **KI–F36** **KI–F40**
Deoxidation practice	killed and fine grain treated	
Chemical composition (%) [5] [7] (ladle analysis)		
C_{max}	0,18	0,16
Mn	0,90 – 1,60 [2]	0,90 – 1,60
Si_{max}	0,50	0,50
P_{max}	0,035	0,025
S_{max}	0,035	0,025
Al (acid soluble)$_{min}$	0,015 [3] [4]	0,015 [3] [4]
Nb	0,02 – 0,05 [4] } total $0,12$ max	0,02 – 0,05 [4] } total $0,12$ max
V	0,05 – 0,10 [4]	0,05 – 0,10 [4]
Ti_{max}	0,02	0,02
C_{max}	0,35	0,35
Cr_{max}	0,20	0,20
Ni_{max}	0,40	0,80
Mo_{max}	0,08	0,08
N_{max}	–	0,009 (0,012 where Al is present)
Carbon equivalent value [6]		

[1] The letter "H" may be added to the steel grade designation, e.g. KI–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 4.4: Carbon equivalent values for TM rolled, higher strength shipbuilding steels up to a product thickness of 100 mm

Steel grade	**Carbon equivalent value [%], max.** [1]	
	Thickness of product t [mm]	
	$t \leq 50$	**$50 < t \leq 100$**
KI–A 32, KI–D 32, KI–E 32, KI–F 32	0,36	0,38
KI–A 36, KI–D 36, KI–E 36, KI–F 36	0,38	0,40
KI–A 40, KI–D 40, KI–E 40, KI–F 40	0,40	0,42

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

5. Condition of supply

The condition in which all products are supplied shall correspond to the data given in Tables 4.5 and 4.6.

Table 4.5: Condition of supply for normal strength steels [1)]

Grade	Thickness of product t [mm]	Condition of supply
KI–A	≤ 50	Any
	$50 < t \leq 100$	Normalised, normalising rolled or TM-rolled [2)]
KI–B	≤ 50	Any
	$50 < t \leq 100$	Normalised, normalising rolled or TM rolled [2)]
KI–D	≤ 35	Any
	$35 < t \leq 100$	Normalised, normalising rolled or TM rolled [3)]
KI–E	≤ 100	Normalised or TM rolled [3)]

Notes

1) These conditions of supply and the impact test requirements are summarised in Table 4.9

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

3) Subject to the special approval of BKI, sections in Grade KI-D steel may be supplied in the as-rolled condition provided satisfactory results are consistently obtained from notch impact tests. Accordingly sections in Grade KI–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 4.6: Condition of supply for higher strength steels [1)]

Grades	Grain refining elements used	Thickness range t [mm]	Condition of supply
KI–A 32 KI–A 36	Nb or V	$\leq 12{,}5$	Any
		$12{,}5 < t \leq 100$	Normalised, normalising rolled or TM rolled [3)]
	Al alone or with Ti	≤ 20	Any
		$20 < t \leq 35$	Any, but as rolled subject to special approval of BKI [2)]
		$35 < t \leq 100$	Normalised, normalising rolled or TM rolled [3)]
KI–A 40	Any	$\leq 12{,}5$	Any
		$12{,}5 < t \leq 50$	Normalised, normalising rolled or TM rolled
		$50 < t \leq 100$	Normalised, TM rolled or quenched and tempered
KI–D 32 KI–D 36	Nb and/or V	$\leq 12{,}5$	Any
		$12{,}5 < t \leq 100$	Normalised, normalising rolled or TM rolled [3)]
	Al alone or with Ti	≤ 20	Any
		$20 < t \leq 25$	Any, but as rolled subject to special approval of BKI [2)]
		$25 < t \leq 100$	Normalised, normalising rolled or TM rolled [3)]
KI–D 40	Any	≤ 50	Normalised, normalising rolled or TM rolled
		$50 < t \leq 100$	Normalised, TM rolled or quenched and tempered
KI–E 32 KI–E 36	Any	≤ 50	Normalised or TM rolled [3)]
		$50 < t \leq 100$	Normalised or TM rolled
KI–E 40	Any	≤ 100	Normalised, TM rolled or quenched and tempered
KI–F 32 KI–F 36 KI–F 40	Any	≤ 50	Normalised,TM rolled or quenched and tempered [4)]
		$50 < t \leq 100$	Normalised,TM rolled or quenched and tempered

1) These conditions of supply and the impact test requirements are summarised in Table 4.10.

2) The frequency of impact tests is to be in accordance with 13.2.2.

3) Subject to the special approval of BKI, sections in Grade KI–A 32, KI–A 36, KI–D 32 and KI–D 36 steels may be supplied in as rolled condition provided satisfactory results are consistently obtained from notch impact tests. Accordingly, sections in grade KI–E 32 and KI–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.

4) Subject to special approval of BKI, sections in Grade KI–F 32 and KI–F 36 steels with thickness ≤ 50 may be supplied in normalising rolled condition. The frequency of notch impact tests is to be in accordance with 13.3.3.

6. Mechanical properties

6.1 For tensile testing either the upper yield strength R_{eH} or, where this is not stipulated, the 0,2 percent proof stress $R_{p0,2}$ 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_e.

6.2 The results obtained from tensile tests shall comply with the appropriate requirements of Table 4.7 and Table 4.8.

Table 4.7: Mechanical properties for normal strength steels

Grade	Yield strength R_{eH} [N/mm^2] min.	Tensile strength R_m [N/mm^2]	Elongation [1] A (at $L_o = 5,65 \cdot \sqrt{S_0}$) [%] min.	Notched bar impact energy [5]						
				Test temp [°C]	KV [J] min.					
					$t \leq 50$ [mm]		$50 < t \leq 7$ [mm]		$70 < t \leq 100$ [mm]	
					long.	transv.	long.	transv.	long.	transv.
KI-A	235	400 - 520[2]	22	+ 20	–	–	34[4]	24[4]	41[4]	27[4]
KI-B				0	27[3]	20[3]	34	24	41	27
KI-D				– 20	27	20	34	24	41	27
KI-E				– 40	27	20	34	24	41	27

t = thickness of product [mm]

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

t [mm]	≤ 5	> 5 ≤ 10	> 10 ≤ 15	> 15 ≤ 20	> 20 ≤ 25	> 25 ≤ 30	> 30 ≤ 40	> 40 ≤ 50
Elongation A_{200} mm [%]	14	16	17	18	19	20	21	22

2) For Grade KI–A sections the upper limit for the specified tensile strength range may be exceeded up to 570 N/mm^2, irrespective of product thickness.

3) Notch impact tests are generally not required for Grade KI–B steels with thickness of 25 mm or less.

4) For Grade KI–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 BKI has waived the need.

5) See B.6.3 and B.6.4

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 BKI 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 BKI or sub-size specimens with reduced requirements may be taken as follows:

Specimen dimensions 10 mm x 7,5 mm:

— 5/6 of the tabulated value

Specimen dimensions 10 mm x 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 Table 4.7 or Table 4.8. 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.

Table 4.8: Mechanical properties for higher strength steels

Grade	Yield strength R_{eH} [N/mm^2] min.	Tensile strength R_m [N/mm^2]	Elongation [1] A (at $L_0 = 5,65 \cdot \sqrt{S_0}$) [%] min.	Notched bar impact energy [3]						
				Test temp. [°C]	KV [J] min.					
					t ≤ 50		50 < t ≤ 70		70 < t ≤ 100	
					long.	trans.	long.	trans.	long.	trans.
KI-A32	315	440–570 [2]	22	0	31 [4]	22 [4]	38	26	46	31
KI-D32				– 20	31	22	38	26	46	31
KI-E32				– 40	31	22	38	26	46	31
KI-F32				– 60	31	22	38	26	46	31
KI-A36	355	490–630 [2]	21	0	34 [4]	24 [4]	41	27	50	34
KI-D36				– 20	34	24	41	27	50	34
KI-E36				– 40	34	24	41	27	50	34
KI-F36				– 60	34	24	41	27	50	34
KI-A40	390	510–660 [2]	20	0	39	26	46	31	55	37
KI-D40				– 20	39	26	46	31	55	37
KI-E40				– 40	39	26	46	31	55	37
KI-F40				– 60	39	26	46	31	55	37

t = thickness of product [mm]

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

Thickness of product t [mm]	Grade	≤ 5	> 5 ≤ 10	> 10 ≤ 15	> 15 ≤ 20	> 20 ≤ 25	> 25 ≤ 30	> 30 ≤ 40	> 40 ≤ 50
Elongation A_{200}mm[%]	KI-A32, -D32, -E32, -F32	14	16	17	18	19	20	21	22
	KI-A36, -D36, -E36, -F36	13	15	16	17	18	19	20	21
	KI-A40, -D40, -E40, -F40	12	14	15	16	17	18	19	20

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

3) See B.6.3 and B.6.4.

4) For Grade A32 and A36 steels a relaxation in the number of impact tests for acceptance purposes may be permitted by special agreement.

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 10163:2007, 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:

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

2) Each single ground area does not exceed 0,25 m^2.

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

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

5) Ground areas lying opposite each other on both surfaces shall not decrease the product thickness by values exceeding the limits as stated under 1).

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

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.

7.3.6 The surface quality and condition requirement herein are not applied to products in forms of bars and tubulars

7.3.7 Any single welded area shall not exceed 0,125 m^2 and the sum of all areas shall not exceed 2% of the surface side in question.

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

7.3.9 If weld repair depth exceeds 3 mm, UT may be requested by BKI. If required, UT shall be carried out in accordance with an approved procedure.

8. Dimensions, dimensional and geometrical tolerances

The provisions of A.6 are applicable. With regard to flat products (plates and wide flats) for shipbuilding use, the permitted lower deviation from the nominal thickness for all product thicknesses is uniformly 0,3 mm. However, the average thickness, calculated as arithmetic mean from the measurements made in accordance with 10.5.3, shall not be less than the nominal thickness.

Alternatively Class C given in Table 4.1 may be considered as the permitted lower deviation from the nominal thickness. In this case the provisions of 10.5.3 are not applicable.

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 dispatch of products. The test specimens and test methods shall comply with the information given in Section 2. Unless otherwise agreed with BKI, 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 mm and over 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 I.

10.4 Testing of surface finish and dimensions

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

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

10.4.3 For plates and wide flats, at least two lines along the longitudinal edge of the product are to be selected for the thickness measurements and at least three points on each selected line are to be selected for thickness measurement as shown in Fig. 4.2. If more than three points are taken on each line the number of points shall be equal on each line.

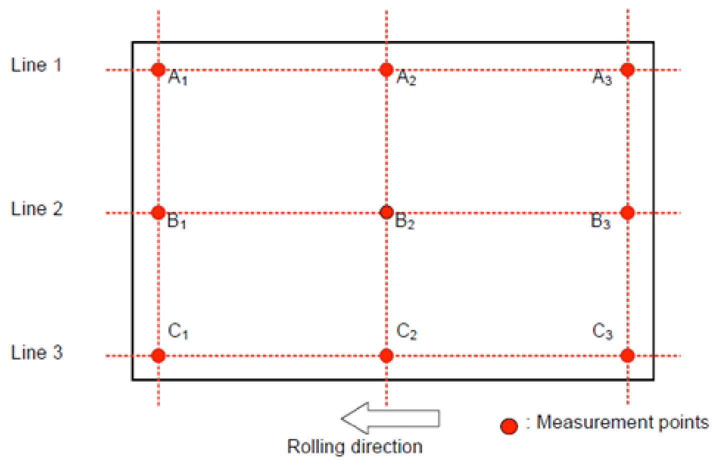


Figure 4.2: Locations of thickness measuring points for the original steel plates

The measurement locations apply to a product rolled directly from one slab or steel ingot even if the product is to be later cut by the manufacturer. Examples of the original measurements relative to later cut products are shown in Fig. 4.3. It is to be noted that the examples shown are not representative of all possible cutting scenarios.

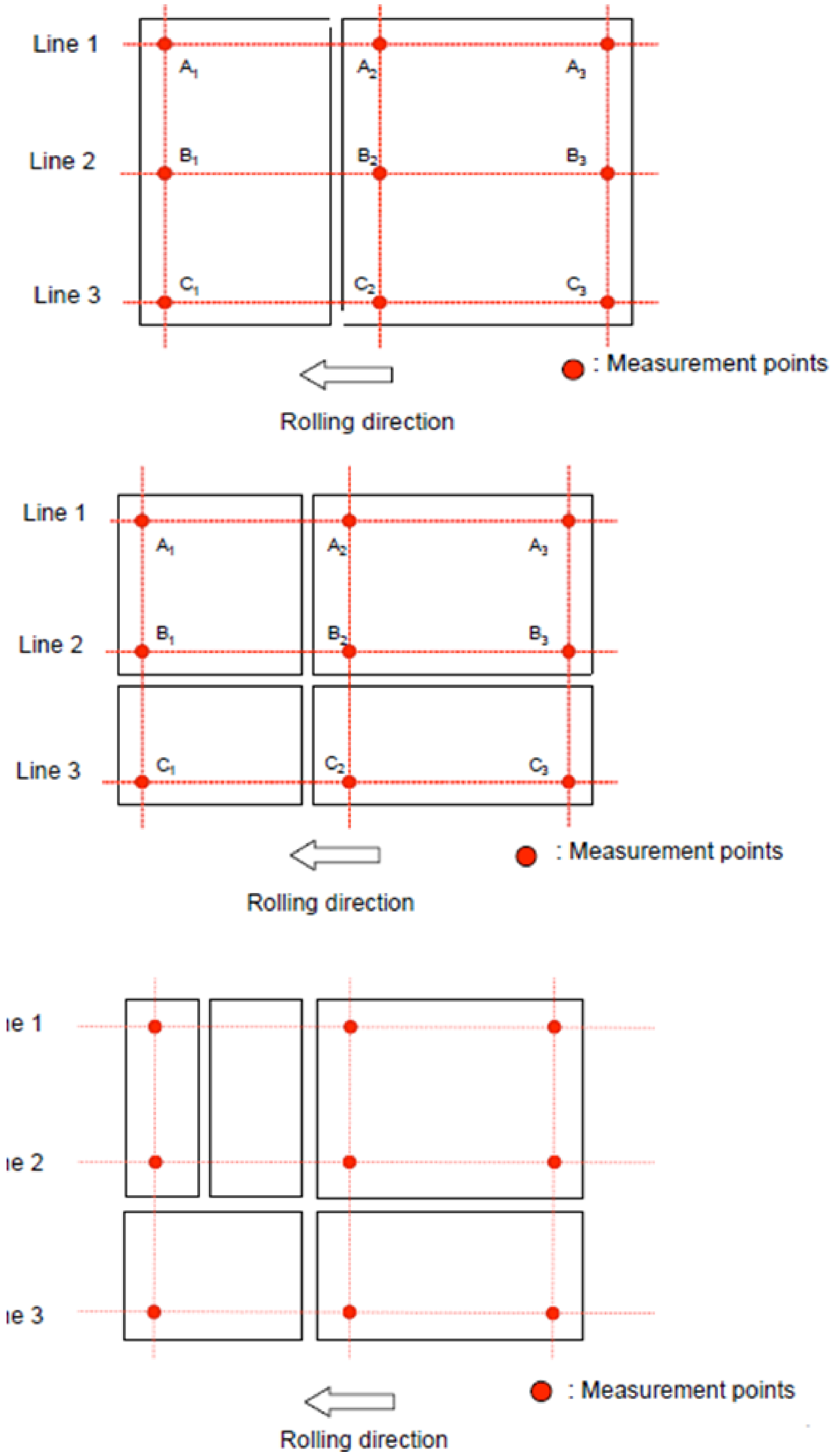


Figure 4.3: Locations of thickness measuring points for the cut steel products

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

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

10.5 Testing of surface finish and dimensions

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

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

10.5.3 For plates and wide flats, at least two lines along the longitudinal edge of the product are to be selected for the thickness measurements and at least three points on each selected line are to be selected for thickness measurement. If more than three points are taken on each line the number of points shall be equal on each line.

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

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

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 specimens

The dimensions of the tensile test specimens are to be selected from those given in 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 Table 4.7 and Table 4.8. 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 BKI, 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 Number of impact tests (Except for Grades KI–E, KI–E 32, KI–E 36, KI–E 40, KI–F 32, KI–F 36 and KI–F 40)

13.2.1 Except where otherwise specially agreed by BKI, 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 KI–A 40 and KI-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 KI–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 BKI, 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 KI-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 Table 4.9 and Table 4.10.

13.3 Number of impact tests for Grades KI-E, KI–E 32, KI–E 36, KI–E 40, KI–F 32, KI–F 36 and KI–F 40

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 BKI, sections other than those in grade KI–E 40 and KI–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.

Table 4.9: Required condition of supply and number of impact tests for normal strength steels

<table>
<tr><th rowspan="2">Grade</th><th rowspan="2">Deoxidation practice</th><th rowspan="2">Product</th><th colspan="5">Condition of supply batch for impact test [1) 2)]</th></tr>
<tr><th colspan="5">Thickness (mm)
10 12,5 20 25 30 35 40 50 100</th></tr>
<tr><td rowspan="3">KI-A</td><td>Rimmed</td><td>Section</td><td>A(-)</td><td colspan="4">Not Applicable</td></tr>
<tr><td rowspan="2">For t ≤ 50 mm
Any method except rimmed
For t > 50 mm
Killed</td><td>Plates</td><td colspan="4">A(-)</td><td>N(-)
TM(-) [3)]
NR(50), AR*(50)</td></tr>
<tr><td>Section</td><td colspan="4">A(-)</td><td>Not Applicable</td></tr>
<tr><td rowspan="2">KI-B</td><td rowspan="2">For t ≤ 50 mm
Any method except rimmed
For t > 50 mm
Killed</td><td>Plates</td><td colspan="2">A(-)</td><td colspan="2">A(50)</td><td>N(50)
TM(50)
NR(25), AR*(25)</td></tr>
<tr><td>Section</td><td colspan="2">A(-)</td><td colspan="2">A(50)</td><td>Not Applicable</td></tr>
<tr><td rowspan="3">KI-D</td><td>Killed</td><td>Plates
Section</td><td colspan="2">A(50)</td><td colspan="3">Not Applicable</td></tr>
<tr><td rowspan="2">Plates
Killed and fine grain treated</td><td>Plates</td><td colspan="3">A(50)</td><td>N (50)
NR(50)
TM(50)</td><td>N (50)
TM(50)
NR(25)</td></tr>
<tr><td>Section</td><td colspan="3">A(50)</td><td>N (50)
NR(50)
TM(50)
AR*(25)</td><td>Not Applicable</td></tr>
<tr><td rowspan="2">KI-E</td><td rowspan="2">Killed and fine grain treated</td><td>Plates</td><td colspan="5">N (each rolled length)
TM (each rolled length)</td></tr>
<tr><td>Section</td><td colspan="4">N (25)
TM(25)
AR*(15), NR*(15)</td><td>Not Applicable</td></tr>
</table>

[1)] Supply condition:

A = any method
N = normalised condition
NR = normalising rolled condition
TM = thermo-mechanically rolled condition
AR* = as rolled condition subject to special approval of BKI
NR* = normalising rolled condition subject to special approval of BKI

[2)] Number of impact test

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 ( ).

Sign (-) means that the impact test is omitted.

[3)] Subject to special approval of BKI, see Table 4.7 note 4.

Table 4.10: Required condition of supply and number of impact tests for higher strength steels

<table>
<tr><th rowspan="2">Grade</th><th rowspan="2">Deoxidation practice</th><th rowspan="2">Grain refining elements</th><th rowspan="2">Product shape</th><th colspan="6">Condition of supply (Batch for impact test) 1) 2)</th></tr>
<tr><th colspan="6">Thickness of product t (mm)
10 12,5 20 25 30 35 40 50 100</th></tr>
<tr><td rowspan="5">KI-A32
KI-A36</td><td rowspan="5">Killed and fine grain treated</td><td rowspan="2">Nb or V</td><td>Plates</td><td>A(50)</td><td colspan="4">N(50)
NR(50), TM(50)</td><td>N(50), NR(25), TM(50)</td></tr>
<tr><td>Sections</td><td>A(50)</td><td colspan="4">N(50)
NR(50), TM(50)
AR*(25)</td><td>Not applicable</td></tr>
<tr><td rowspan="3">Al only or with Ti</td><td rowspan="2">Plates</td><td colspan="2" rowspan="2">A(50)</td><td colspan="2">AR*(25)</td><td colspan="2">Not applicable</td></tr>
<tr><td colspan="3">N(50), NR(50)
TM(50)</td><td>N(50), NR(25), TM(50)</td></tr>
<tr><td>Sections</td><td>A(50)</td><td colspan="4">N(50)
NR(50)
TM(50)
AR*(25)</td><td>Not applicable</td></tr>
<tr><td rowspan="2">KI-A40</td><td rowspan="2">Killed and fine grain treated</td><td rowspan="2">Any</td><td>Plates</td><td>A(50)</td><td colspan="4">N(50)
NR(50)
TM(50)</td><td>N(50)
TM(50)
QT (for each unit heat treated)</td></tr>
<tr><td>Sections</td><td>A(50)</td><td colspan="4">N(50)
NR(50)
TM(50)</td><td>Not applicable</td></tr>
<tr><td rowspan="5">KI-D32
KI-D36</td><td rowspan="5">Killed and fine grain treated</td><td rowspan="2">Nb and/or V</td><td>Plates</td><td>A(50)</td><td colspan="4">N(50)
NR(50), TM(50)</td><td>N(50), NR(25), TM(50)</td></tr>
<tr><td>Sections</td><td>A(50)</td><td colspan="4">N(50)
NR(50), TM(50)
AR*(25)</td><td>Not applicable</td></tr>
<tr><td rowspan="3">Al only or with Ti</td><td rowspan="2">Plates</td><td colspan="2" rowspan="2">A(50)</td><td>AR*(25)</td><td colspan="3">Not applicable</td></tr>
<tr><td colspan="3">N(50), NR(50) TM(50)</td><td>N(50), NR(25), TM(50)</td></tr>
<tr><td>Sections</td><td>A(50)</td><td colspan="4">N(50)
NR(50), TM(50)
AR*(25)</td><td>Not applicable</td></tr>
<tr><td rowspan="2">KI-D40</td><td rowspan="2">Killed and fine grain treated</td><td rowspan="2">Any</td><td>Plates</td><td colspan="5">N(50)
NR(50)
TM(50)</td><td>N(50)
TM(50)
QT (for each unit heat treated)</td></tr>
<tr><td>Sections</td><td colspan="5">N(50)
NR(50)
TM(50)</td><td>Not applicable</td></tr>
<tr><td rowspan="2">KI-E32
KI-E36</td><td rowspan="2">Killed and fine grain treated</td><td rowspan="2">Any</td><td>Plates</td><td colspan="6">N (each rolled length)
TM (each rolled length)</td></tr>
<tr><td>Sections</td><td colspan="5">N(25)
TM(25)
AR*(15), NR*(15)</td><td>Not applicable</td></tr>
</table>

Table 4.10: Required condition of supply and number of impact tests for higher strength steels *(continued)*

Grade	Deoxidation practice	Grain refining elements	Product shape	Condition of supply (Batch for impact test) [1) 2)]	
				Thickness of product t (mm): 10 12,5 20 25 30 35 40 50	100
KI-E40	Killed and fine grain treated	Any	Plates	N (each rolled length) TM (each rolled length) QT (for each unit heat treated)	
			Sections	N(25) TM(25) QT(25)	Not applicable
KI-F32 KI-F36	Killed and fine grain treated	Any	Plates	N (each rolled length) TM (each rolled length) QT (for each unit heat treated)	
			Sections	N(25) TM(25) QT(25) NR*(15)	Not applicable
KI-F40	Killed and fine grain treated	Any	Plates	N (each rolled length) TM (each rolled length) QT (for each unit heat treated)	
			Sections	N(25) TM(25) QT(25)	Not applicable

[1)] Supply condition:

A = any method

N = normalised condition

NR = normalising rolled condition

TM = thermo-mechanically rolled condition

QT = quenched and tempered condition

AR* = as rolled condition subject to special approval of BKI

NR* = normalising rolled condition subject to special approval of BKI

[2)] Number of impact test

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 KI-A 32 and KI-A 36 steels a relaxation in the number of impact tests may be permitted by special agreement with BKI provided that satisfactory results are obtained from occasional check tests.

13.3.4 The specimens taken as described in 13.3.2 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 Table 4.9 and Table 4.10.

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 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 BKI's brand and the following particulars:

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

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

— material supplied in the thermo-mechanically controlled processed condition is to have the letters TM added after the identification mark (e.g. KI–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 BKI, 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 BKI brand but has not satisfied the test conditions, said brand shall be unequivocally removed by the manufacturer.

15.5 Steel plates that have complied with the requirements for corrosion resistant steel will be identified by adding a corrosion designation to the unified identification mark for the grade of steel. The corrosion resistant steel is to be designated according to its area of application as follows:

— Lower surface of strength deck and surrounding structures; RCU

— Upper surface of inner bottom plating and surrounding structures; RCB

— For both strength deck and inner bottom plating; RCW

— Example of designation: KI-A36 TM RCB

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 dispatch 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

— composition of the melt for the elements shown in Table 4.2 and Table 4.3.

— for steel with a corrosion resistant steel designation the weight percentage of each element added or intentionally controlled for improving corrosion resistance.

— delivery condition, where not supplied in the as-rolled condition, e.g. normalised, normalizing rolled, thermo-mechanically rolled or quenched and tempered

— in the case of grade KI–A steel sections up to 12,5 mm, details of whether it is rimmed steel

— marking of the products

— test results.

16.2 Before the acceptance test certificates or dispatch documents are signed by the Surveyor, the manufacturer shall hand over written confirmation that the steel has been produced by an approved method has successfully passed the tests prescribed in the presence of the Surveyor or his representative appointed by BKI. In this regard, the following text may be also accepted, either stamped or printed on the certificate or dispatch 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 BKI 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/mm^2 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 6, 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 10025:2019, EN 10210:2019 and EN 10219:2019 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 10025-3:2019, in the grades:

— S275 N, S 275 NL, S355 N, S355 NL (normalised or normalising rolled)

and conforming to EN 10025-4:2019 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 BKI, 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:

C	Mn	Si	P	S	Cu	Cr	Ni	Mo
0,22	1,70	0,55	0,040	0,040	0,30	0,20	0,40	0,08

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 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, normalizing 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 4.1 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 $\geq$ 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 $\geq$ 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 hot rolled, fine grain, weldable high strength structural steels, intended for use in marine and structural applications. These requirements do not apply to steels intended for hull structure of commercial ships whose requirements are specified in B.

1.2 Steels covered by the scope of these Rules are classed into 8 groups indicated by the nominal yield strengths 420, 460, 500, 550, 620, 690, 890 and 960 N/mm^2. Each group is further subdivided into the grades A, D, E and F based on the temperature for notched bar impact testing. Except for yield strength level of 890 and 960 N/mm^2 for which grade F is not applicable.

1.3 Steels covered by the scope may be delivered in Normalised (N)/Normalised rolled (NR), Thermo-mechanical controlled rolled (TM) or Quenched and Tempered (QT) condition.

Note :

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

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

1.5 Steels with a thickness beyond the maximum thicknesses as given in Table 4.12 may be approved at the discretion of BKI.

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

2. Approval

2.1 For applications subjected BKI, all steels are to be manufactured at manufacturer which have been approved by BKI for the type and grade of steel which is being supplied. The procedure for approval is shown in Guidance for The Approval and Type Approval of Materials and Equipment for Marine Use (Pt.1, Vol.W).

2.2 It is the manufacturer's responsibility to assure that effective quality, process and production controls during manufacturing are adhered to within the manufacturing specification. The manufacturing specification shall be submitted to the BKI at the time of initial approval.

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

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

Note :

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

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

3. Requirements

3.1 Manufacturing process

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

Note :

A fine grain structure has an equivalent index $\geq$ 6 determined by micrographic examination in accordance with ISO 643:2019 or alternative test method.

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

A) All steels with enhanced through-thickness properties, and
B) All steels of grade H690, H890 and H960.

3.1.3 The steels shall contain nitrogen binding elements as detailed in the manufacturing specification.

3.2 Chemical composition

3.2.1 The chemical composition shall satisfy the requirements stated in the authorized specification and in Table 4.11.1

Elements used for alloying, nitrogen binding, and fine grain treatment, and as well as the residual elements are to be as detailed in the manufacturing specification, e.g. when boron is deliberately added for enhancement of hardenability of the steels, the maximum content of the boron content shall not be higher than 0,005%; and the analysis result shall be reported.

3.2.2 To assess weldability, carbon equivalent (Ceq), CET sensitivity to cold cracking (Pcm) may be calculated from the ladle analysis according to the following formula. The maximum values are specified in Table 4.11.2.

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

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

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

$$CET = C + \frac{(Mn+Mo)}{10} + \frac{(Cr+Cu)}{20} + \frac{Ni}{40}\ [\%]$$

c) For TM and QT steels with carbon content not more than 0,12%, the cold cracking susceptibility Pcm for evaluating weldability may be used instead of carbon equivalent of Ceq or CET at manufacturer's discretion and is to be calculated using the following formula:

$$P_{cm} = C + \frac{Si}{30} + \frac{Mn}{20} + \frac{Cu}{20} + \frac{Ni}{60} + \frac{Cr}{20} + \frac{Mo}{15} + \frac{V}{10} + 58\ [\%]$$

Table 4.11.1: Chemical Composition

Delivery condition[1]	N/NR		TM		QT	
Steel grade / Chemical Composition(%) [2]	KI-A 420 KI-D 420 KI-A 460 KI-D 460	KI-E 420 KI-E 460	KI-A 420 KI-D 420 KI-A 460 KI-D 460 KI-A 500 KI-D 500 KI-A 550 KI-D 550 KI-A 620 KI-D 620 KI-A 690 KI-D 690 KI-A 890	KI-E 420 KI-F 420 KI-E 460 KI-F 460 KI-E 500 KI-F 500 KI-E 550 KI-F 550 KI-E 620 KI-F 620 KI-E 690 KI-F 690 KI-E 890 KI-F 890	KI-A 420 KI-D 420 KI-A 460 KI-D 460 KI-A 500 KI-D 500 KI-A 550 KI-D 550 KI-A 620 KI-D 620 KI-A 690 KI-D 690 KI-A 890 KI-D 960	KI-E 420 KI-F 420 KI-E 460 KI-F 460 KI-E 500 KI-F 500 KI-E 550 KI-F 550 KI-E 620 KI-F 620 KI-E 690 KI-F 690 KI-E 890 KI-F 890 KI-E 960 KI-F 890
C (max)	0,20	0,18	0,16	0,14	0,18	
Mn	1,0 - 1,70		1,0 - 1,70		1,70	
Silicon (max)	0,60		0,60		0,80	
Phosphorus (max) [3]	0,030	0,025	0,025	0,020	0,025	0,020
Sulphur (max) [3]	0,025	0,020	0,015	0,010	0,015	0,010
Aluminium total (min) [4]	0,02		0,02		0,018	
Niobium (max) [5]	0,05		0,05		0,06	
Vanadium (max) [5]	0,20		0,12		0,12	
Titanium (max) [5]	0,05		0,05		0,05	
Ni (max)	0,80		2,00 [6]		2,00 [6]	
Copper (max)	0,55		0,55		0,50	
Chromium (max) [5]	0,30		0,50		1,50	
Molybdenum (max) [5]	0,10		0,50		0,70	
Nitrogen (max)	0,025		0,025		0,015	
Oxygen ppm (max) [7]	Not applicable		Not applicable	50	Not applicable	50

1) See 3.3 for delivery condition.

2) The chemical composition is to be determined by ladle analysis and shall meet the approved manufacturing specification at the time of approval.

3) For sections the P and S content can be 0,005% higher than the value specified in the table.

4) The total aluminium to nitrogen ratio shall be a minimum of 2:1. When other nitrogen binding elements are used, the minimum Al value and Al/N ratio do not apply.

5) Total Nb + V + Ti $\leq$ 0,26% and Mo + Cr $\leq$ 0,65%, not applicable for QT steels.

6) Higher Ni content may be approved at the discretion of BKI.

7) The requirement on maximum oxygen content is only applicable to KI-D 890, KI-E 890, KI-D 960 and KI-E 960.

Table 4.11.2: Maximum C_{eq}, CET and P_{cm} values

Steel Grade	Delivery Condition	C_{eq}, CET, P_{cm} (%)							
		C_{eq}						CET	P_{cm}
		Plates			Sections	Bars	Tubulars	all	all
		$t \leq 50$ (mm)	$50 < t \leq 100$ (mm)	$100 < t \leq 250$ (mm)	$t \leq 50$ (mm)	$t \leq 250$ or $d \leq 250$ (mm)	$t \leq 65$ (mm)	all	all
420	N/NR	0,46	0,48	0,52	0,47	0,53	0,47	–	–
	TM	0,43	0,45	0,47	0,44	–	–	–	–
	QT	0,45	0,47	0,49	–	–	0,46	–	–
460	N/NR	0,50	0,52	0,54	0,51	0,55	0,51	0,25	–
	TM	0,45	0,47	0,48	0,46	–	–	0,30	0,23
	QT	0,47	0,48	0,50	–	–	0,48	0,32	0,24
500	TM	0,46	0,48	0,50	–	–	–	0,32	0,24
	QT	0,48	0,50	0,54	–	–	0,50	0,34	0,25
550	TM	0,48	0,50	0,54	–	–	–	0,34	0,25
	QT	0,56	0,60	0,64	–	–	0,58	0,36	0,28
620	TM	0,50	0,52	–	–	–	–	0,34	0,26
	QT	0,56	0,60	0,64	–	–	0,58	0,38	0,30
690	TM	0,56	–	–	–	–	–	0,36	0,30
	QT	0,64	0,66	0,70	–	–	0,68	0,40	0,33
890	TM	0,60	–	–	–	–	–	0,38	0,28
	QT	0,68	0,75	–	–	–	–	0,40	–
960	QT	0,75	–	–	–	–	–	0,40	–

3.3 Heat treatment

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

— Normalized (N)/Normalized rolled (NR)

— Thermo-mechanical controlled rolled (TM)/with Accelerated cooling (TM+AcC)/with direct quenching followed by tempering (TM+DQ), or

— Quenched and Tempered condition (QT)

Note :

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

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

3.3.3 Thickness limits for approval

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

.2 Maximum thickness of plates, sections, bars and tubulars over which a specific delivery condition is applicable are shown in Table 4.11.3.

3.4 Mechanical properties

The requirements applicable to the mechanical proper ties and the impact energy shall conform to the data in Table 4.12.

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 BKI.

— 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

The provisions of A.6. are applicable. Unless otherwise specified in the order, the permitted lower deviation from the nominal thickness for all product thicknesses is uniformly – 0,3 mm. However, the average thickness, calculated as arithmetic mean from the measurements made in accordance with 4.5.5, shall not be less than the nominal thickness.

Alternatively Class C given in Table 4.1 may be considered as the permitted lower deviation from the nominal thickness. In this case the provisions of 4.5.5 are not applicable.

Table 4.11.3: Maximum thickness approval

<table>
<tr><th rowspan="2">Delivery condition</th><th colspan="4">Maximum thickness (mm)</th></tr>
<tr><th>Plates</th><th>Sections</th><th>Bars</th><th>Tubulars</th></tr>
<tr><td>N</td><td>250 [2)]</td><td>50</td><td>250</td><td>65</td></tr>
<tr><td>NR</td><td>150</td><td colspan="3">1)</td></tr>
<tr><td>TM</td><td>150</td><td>50</td><td>Not applicable</td><td>Not applicable</td></tr>
<tr><td>QT</td><td>150 [2)]</td><td>50</td><td>Not applicable</td><td>50</td></tr>
<tr><td colspan="5">1) The maximum thickness limits of sections, bars and tubulars produced by NR process route are less than those manufactured by N route, and shall be at the discretion of BKI.
2) Approval for N steels with thickness larger than 250 mm and QT steels with thickness larger than 150 mm is subject to the special consideration of BKI.</td></tr>
</table>

Table 4.12: Mechanical and technological properties for all steel grade

Grades	Delivery condition	Yield strength [1) 2)] R_{eH} [N/mm^2] min.			Tensile strength R_m [N/mm^2]		Elongation [3)] A (at $L_0 = 5,65 \cdot \sqrt{S_0}$) [%] min.		Impact energy		
									Test temp. [°C]	KV [J] min.	
		≥ 3 ≤ 50	> 50 ≤ 100	> 100 ≤ 250	≥ 3 ≤ 100	> 100 ≤ 250	L	T		L	T
KI-A 420	N/NR	420	390	365	520 - 680	470 - 650	21	19	0	42	28
KI-D 420	TM								– 20		
KI-E 420	QT								– 40		
KI-F 420	–								– 60		
KI-A 460	N/NR	460	430	390	540 - 720	500 - 710	19	17	0	46	31
KI-D 460	TM								– 20		
KI-E 460	QT								– 40		
KI-F 460	–								– 60		
KI-A 500	TM	500	480	440	590 - 770	540 - 720	19	17	0	50	33
KI-D 500	QT								– 20		
KI-E 500	–								– 40		
KI-F 500	–								– 60		
KI-A 550	TM	550	530	490	640 - 820	590 - 770	18	16	0	55	37
KI-D 550	QT								– 20		
KI-E 550	–								– 40		
KI-F 550	–								– 60		
KI-A 620	TM	620	580	560	700 - 890	650 - 830	17	15	0	62	41
KI-D 620	QT								– 20		
KI-E 620	–								– 40		
KI-F 620	–								– 60		
KI-A 690	TM	690	650	630	770 - 940	710 - 900	16	14	0	69	46
KI-D 690	QT								– 20		
KI-E 690	–								– 40		
KI-F 690	–								– 60		
KI-A 890	TM	890	830	–	940 - 1100	–	13	11	0	69	46
KI-D 890	QT								– 20		
KI-E 890	–								– 40		
KI-A 960	QT	960	–	–	980 - 1150	–	12	10	0	69	46
KI-D 960	–								– 20		
KI-E 960	–								– 40		

1) For tensile test either the upper yield stress (R_{eH}) or where R_{eH} cannot be determined, the 0,2 percent proof stress ($Rp_{0.2}$) is to be determined and the material is consi dered to comply with the requirement if either value meets or exceeds the specified minimum value of yield strength.

2) For full thickness flat test specimens with a width of 25 mm and a gauge length of 200 mm the elongation is to comply with the minimum values shown in Table 4.13.

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

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

Table 4.13: Minimum values in respect of elongation when using specimens 25 mm wide and with a gauge length of 200 mm [1)]

Nominal yield strength R_{eH} [N/mm^2]	Elongation A_{200}mm [%]						
	Thickness of product t [mm]						
	≤ 10	> 10 ≤ 15	> 15 ≤ 20	> 20 ≤ 25	> 25 ≤ 40	> 40 ≤ 50	> 50 ≤ 70
420	11	13	14	15	16	17	18
460	11	12	13	14	15	16	17
500	10	11	12	13	14	15	16
550	10	11	12	13	14	15	16
620	9	11	12	12	13	14	15
690	9 [2)]	10 [2)]	11 [2)]	11	12	13	14

[1)] The tabulated elongation minimum values are the requirements for testing specimen in transverse direction. H890 and 960 specimens and specimens which are not included in this table shall be proportional specimens with a gauge length of $L_0 = 5,65 \cdot \sqrt{S_0}$.

[2)] For H690 plates with thickness $\leq$ 20 mm, round specimen in accordance with Section 2 may be used instead of the flat tensile specimen. The minimum elongation for testing specimen in transverse direction is 14%.

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 Tensile test specimen is to be randomly selected from each batch, as defined in Section 2, B., that is to be less than or equal to 25 tonnes, and to be from the same heat, in the same delivery condition and of the same thickness.

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 BKI. 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 For impact test, at least one set of three Charpy V-notch impact test specimens in accordance with Section 2, E.2. is to be taken and tested from:

a) Each piece for steels plates in N/NR or TM condition.

b) Each individually heat treated part thereof for steels in QT condition.

c) Each batch of 25 tonnes for fraction thereof for sections, bars and tubulars.

For continuous heat treated plates special consideration may be given to the number and location of test specimens required by the manufacturer to be agreed by BKI.

4.3.2 Unless otherwise accepted by BKI, the V- notch impact test specimens for plates and wide flats $\geq$ 600 mm are to be taken with their axes transverse to the main rolling direction and the results should comply with the appropriate requirements for transverse direction of Table 4.12. For other product form the impact tests are to be in the longitudinal direction and the results of the tests are to comply with the appropriate requirements for longitudinal direction of Table 4.12.

4.3.3 The specimen axes shall be positioned at a distance not more than 2 mm from a rolled surface, however, for material with a thickness in excess of 50 mm, impact tests shall be taken at the quarter thickness (t/4) location and mid-thickness (t/2).

4.3.4 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 BKI or sub-size specimens with reduced requirements may be taken as follows:

Specimen dimensions 10 mm x 7,5 mm:

— 5/6 of the tabulated value

Specimen dimensions 10 mm x 5,0 mm:

— 2/3 of the tabulated value

4.4 Through thickness tensile test

4.4.1 If required by BKI, through thickness tensile tests are to be performed using test specimens taken at right angles to the surface of the product in accordance with Section 4, I.

4.4.2 Subject to the discretion of BKI, through thickness tensile strength may be required to be not less than 80% of the specified minimum tensile strength.

4.5 Surface inspection and dimensions

4.5.1 All materials are to be free from cracks, injurious surface flaws, injurious laminations and similar defects.

4.5.2 The surface quality inspection method shall be in accordance with recognized national or international standards agreed between purchaser and manufacturer

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

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

4.5.3 Inspections of surface finish and dimensional checks are in the responsibility of the rolling mill. Acceptance testing by the Surveyor does not release the manufacturer from this responsibility. Surface finish requirement shall be in accordance with the relevant requirements in B.7.

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

4.5.5 For plates and wide flats, at least two lines along the longitudinal edge of the product are to be selected for the thickness measurements and at least three points on each selected line are to be selected for thickness measurement. If more than three points are taken on each line the number of points shall be equal on each line.

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

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

4.6 Non-destructive testing

4.6.1 Verification of internal soundness is the responsibility of the manufacturer. The acceptance by the BKI's Surveyor shall not absolve the manufacturer of this responsibility.

4.6.2 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 BKI, e.g. EN 10160:1999. The quality class is to be defined at the time of the order.

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

.1 Electrical welded hollow sections

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

— ISO 10893-2:2011, acceptance category E4, except that the technique of rotating pipes or with rotating saddle coils is not permitted

— ISO 10893-3:2011, acceptance category F5, or ISO 10893-11:2011, acceptance category U5

.2 Submerged-arc welded hollow sections

The weld seam of hollow sections is to be examined according to acceptance category U4 in accordance with ISO 10893-6:2019, 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.

4.7 Facilities for Inspection

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

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

4.8 Retest procedures

4.8.1 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.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.

4.8.2 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 Section 2, H. is to be followed.

4.9 Traceability

Traceability of test material, specimen sampling and test procedures including test equipment with respect to mechanical properties testing, is to be in accordance with Section 2, C.2.

5. Stress relieving heat treatment and other heat treatments

5.1 Steels covered in this subsection are suitable for stress relieving heat treatment such as post-weld heat treatment and stress relieving heat treatment after cold forming for the purpose of reducing the risk of brittle fracture, increasing the fatigue lifetime and dimensional stability for machining.

5.2 Products can be susceptible to deterioration in mechanical strength and toughness if they are subjected to incorrect post-weld heat treatment procedures or other processes involving heating such as flame straightening, rerolling, etc. where the heating temperature and the holding time exceed the limits given by the manufacturer.

6. Identification of materials

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

7. Marking

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

- Marks of the manufacturer
- Unified identification mark for the grade of steel (e.g. KI–E 620) or manufacturer's trade name
- Heat number, plate number or equivalent identification mark.
- Delivery condition (N, NR, TM and QT)

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

8. Certificates

The manufacturer shall hand over to the Surveyor either works acceptance test certificates (e.g. in accordance with EN 10204-3.1) or dispatch 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 Table 4.11.1
- Ceq, CET or Pcm value
- delivery condition with heat treatment temperatures

— marking of the products

— test results (include mechanical properties, surface quality and inspection)

— UT result, if applicable.

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.

2. Approved steel grades

The materials listed below may be used:

2.1 Flat products made of steel used for pressure vessels conforming to EN 10028-2:2017 “Alloyed and Unalloyed High Temperature Steels”.

2.2 Flat products made of steel used for pressure vessels conforming to EN 10028-3:2017, “Weldable fine- grained structural steels, normalized”.

2.3 Flat products made of KI-steels used for pressure vessels according to Table 4.14 and Table 4.15. For the 0,2 % proof stress at elevated temperatures, Table 4.16 applies.

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

2.4.1 The elongation (A) shall have the minimum values which characterize the grade of steel, as specified in the BKI 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 -3:2017 respectively for flat products of the same strength, see Table 4.14. 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.

Table 4.14: Mechanical and technological properties of flat products made of KI-steels used for pressure vessels

Steel grade	Normal delivery condition [1]	Yield strength R_{eH} and $R_{p0,2}$ respectively [N/mm^2] min.	Tensile strength R_m [N/mm^2]	Elongation A [%] min.	Notched bar impact energy	
					Test temp. [°C]	KV [J] min. transv.
KI-P235W	N	235	360 – 480	25	0	34
KI-P265W	N	265	410 – 530	23	0	34
KI-P295W	N	295	460 – 580	22	0	34
KI-P335W	N	355	510 – 650	21	0	34

[1] N = normalized.

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 4.16.

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 $\pm$ 0°C in tests performed on the finished component, if in the case of plate thicknesses $\geq$ 50 mm the yield strength of these steels is $\geq$ 310 N/mm^2 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 $\pm$ 0 °C is a minimum requirement. In addition, the individual steels shall exhibit their characteristic impact energies.

Table 4.15: Chemical composition of KI-steels used for pressure vessels

Steel grade	Chemical composition [%]							
	C	Si	Mn	P	S	Al_{tot}	Cr	Mo
all	$\leq$ 0,23	$\leq$ 0,55	0,60 – 1,70	$\leq$ 0,025	$\leq$ 0,015	$\geq$ 0,020	$\leq$ 0,30	$\leq$ 0,08

Table 4.16: 0,2 %-Proof stress at elevated temperatures for flat products made of KI-steels used for pressure vessels

Steel grade	$R_{p0,2}$ - Yield strength [N/mm^2] min.							
	Temperature [°C]							
	50	100	150	200	250	300	350	400
KI-P235W	227	214	198	182	167	153	142	133
KI-P265W	256	241	223	205	188	173	160	150
KI-P295W	285	268	249	228	209	192	178	167
KI-P335W	343	323	299	275	252	232	214	202

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

3. Condition of supply and heat treatment Vessels

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 4.1. 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 10025:2019 are given in the standard.

For other steels as per 2.4, the test temperature will be stipulated in the BKI 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 I., 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 pre- scribed 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 Parts 2 and 3:2017, the values stated in these standards.

For flat products made of KI-steels used for pressure vessels according to 2.3, the values stated in Table 4.16.

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

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 Vessels

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,
- nickel alloy steels which are tough at low temperatures
- austenitic steels

which are intended for the fabrication of cargo tanks and process pressure vessels for carrying liquefied gases.

1.2 Steels conforming to these Rules shall be approved by BKI for the above-mentioned purpose and design temperature.

To this end, the steels listed under 1.1 above shall be subjected to an approval test by BKI. BKI shall decide on a case to case basis on the need for an approval test on austenitic steels and other special structural steels.

2. Approved steel grades

The following steel grades may be used considering the minimum design temperatures stated in Table 4.17 provided that they satisfy the additional requirements stipulated in these Rules.

2.1 Weldable, fine-grained structural steels conforming to EN 10028-3:2017.

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 355 N/mm^2 in accordance with EN 10028-3, -5 and -6:2017.

2.3 Nickel alloy steels which are tough at low temperatures, conforming to EN 10028-4:2017.

2.4 Stainless, austenitic steels conforming to EN 10028-7:2016, 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 BKI.

Table 4.17: Minimum design temperatures for steels used in the fabrication of cargo tanks

Steel designation	References to standards and rules	Minimum design temperature [°C]
Fine-grained structural steels for ammonia which has been liquefied under pressure	For chemical composition, see Table 4.18	0
Normalized, TM rolled and fine- grained structural steels with nominal yield strengths above 355 N/mm^2	e.g. according to EN 10028-3, -5 or -6:2017	0
Other fine-grained structural steels with nominal yield strengths up to 355 N/mm^2	e.g. according to EN 10028-3, -5 or -6:2017	– 45 [1)]
Nickel alloy steels containing : 0,5 % Nickel	Steels according to EN 10028-4:2017 11MnNi5-3, 13MnNi6-3	– 55
1,5 % Nickel	15NiMn6	– 60 [2)]
3,5 % Nickel	12Ni14	– 90 [2)]
5 % Nickel	X12Ni5	– 105 [2)]
9 % Nickel	X7Ni9, X8Ni9	– 165
Austenitic steels	e.g. steels according to EN 10028-7:2016 1.4306 (AISI 304 L)	- 165
	1.4404 (AISI 316 L)	
	1.4541 (AISI 321)	
	1.4550 (AISI 347)	

1) BKI reserves 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%, 3,5% and 5% nickel if the steels are quenched and tempered. In these cases, the test temperatures will be specially stipulated by BKI.

3. Approval test Vessels

3.1 On the subject of approval of materials, the material manufacturer or tank manufacturer shall provide BKI 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 BKI 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/mm^2 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 4.17 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 4.1, 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 recognized standard or the material specification authorized by BKI.

In addition the limiting values for the chemical composition of fine-grained structural steels with nominal yield strength of up to 355 N/mm^2 used in the fabrication of tanks carrying pressure-liquefied ammonia as given in Table 4.18 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:

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

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

Table 4.18: Chemical composition for fine-grained structural steels suitable for ammonia which has been liquefied under pressure (ladle analysis)

[%] maximum in the absence of any other indication [1]										
C	Si	Mn	P	S	Al	Cr	Cu	Mo	Ni [2]	V
0,18	0,10 – 0,50	1,65	0,03	0,025	min. 0,020	0,2	0,35	0,04	0,4	0,02

1) For steels with nominal yield strengths of 355 N/mm^2, the chemical composition shall be set so that an upper yield strength figure of 440 N/mm^2 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 recognized standard or the authorized 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_{eH} may not exceed 440 N/mm^2 or 470 N/mm^2 in the case of hot-formed dished ends.

Elongation A shall be at least 22%.

8.3 Impact energy

The required impact energy values specified in Tables 4.19 and 4.20 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 ≤ 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 ≥ 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:

— normalized 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 mm 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 ≥ 10 m: 60 N/mm^2

— Rolled lengths of > 10 m: N/mm^2

9.3 Notched bar impact test

9.3.1 All products with thicknesses of ≥ 6 mm shall be subjected to the notched bar impact test performed on Charpy V-notch specimens at the test temperatures specified in Table 4.19 and Table 4.20 respectively. In the case of plates and wide flats with a width of ≥ 600 mm the specimens shall be taken transverse to the direction of rolling. For all other products they may be taken parallel or transverse to the rolling direction. The number of sets (each comprising 3 specimens) required shall be determined in the same way as the number of tensile specimens prescribed in 9.2.2.

9.3.2 Where the thickness of the products precludes the preparation of specimens with the standard dimensions (10 mm × 10 mm), specimens measuring 7,5 mm × 10 mm or 5 mm × 10 mm should be used wherever possible. These specimens are subject to the requirements stated in Table 4.20.

Table 4.19: Impact energy requirements for steels used for cargo tanks

<table>
<tr><th rowspan="4">Steel designation</th><th rowspan="4">Product thickness
[mm]</th><th colspan="3">Notched bar impact energy</th></tr>
<tr><th rowspan="3">Test temperature
[°C]</th><th colspan="2">KV</th></tr>
<tr><th colspan="2">[J] [1] min.</th></tr>
<tr><th>long.</th><th>transv.</th></tr>
<tr><td>Fine-grained structural steels for ammonia liquefied under pressure</td><td>≤ 40</td><td>– 20</td><td rowspan="5">41 (29)</td><td rowspan="5">27 (19)</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></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></tr>
<tr><td>Nickel alloy steels containing:
1,5 % Nickel
3,5 % Nickel
5 % Nickel
9 % Nickel</td><td>≤ 25 [3]</td><td>
– 65
– 95
– 110 (– 196) [4]
– 196</td></tr>
<tr><td>Austenitic steels</td><td>≤ 50</td><td>– 196</td></tr>
</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>
<tr><th>Product thickness
[mm]</th><th colspan="2">Test temperature</th></tr>
<tr><td>25 < t ≤ 30
30 < t ≤ 35
35 < t ≤ 40</td><td>10 K
15 K
20 K</td><td>below minimum design temperature but not higher than –20°C</td></tr>
</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 BKI.

[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 4.20: Requirements applicable to specimens of reduced size according to impact energy for standard specimens

Necessary impact acc. to Table 4.19 (standar specimens)	Necessary impact energy KV with specimens measuring			
	7,5 mm × 10 mm		5 mm × 10 mm	
average value [J] [1)] min.	average value [J] min.	minimum individual value [J]	average value [J] min.	minimum individual value [J]
27 (19)	22	16	18	13
41 (29)	34	24	27	19
[1)] Average value of 3 specimens; figures in booklets are minimum individual values.				

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. EN 10274 or ASTM E-208, see also Section 2, G.3.

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 10160:1999 as follows :

Test grid $\leq$ 200 mm or in lines 100 mm apart.

	EN 10160:1999
Surface test	S_1
Marginal zone test	E_3

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 quality class E3 according to EN 10160:1999.

Areas for the connection of supporting brackets, lifting lugs and floating securing devices 100% in accordance with quality class S3 according to EN 10160:1999.

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 BKI 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 10088:2014 relating to stainless steels, where the products are not required to be supplied in accordance with a specification which has been examined by BKI.

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

3. Condition of supply and heat treatment Plates

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 4.1 (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 Chemical composition The limit values for the chemical composition stated in the standards or in the specifications approved by BKI 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 ≤ 0,03%.

6.2 Mechanical properties

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

6.3 Impact energy

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

7. Testing and scope of tests

The following tests shall be performed:

7.1 Testing of chemical composition

The manufacturer shall determine the chemical com- position 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 ISO 3651:1998 on specimens in the following condition:

— stabilized steels and steels with a carbon content ≤ 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 thereof: 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 ≥ 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 BKI 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 ≥ 6 mm

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

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 BKI 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 BKI 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 BKI.

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 4.21.

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.

Table 4.21: Minus tolerances in relation to the thickness of the cladding material

Nominal thickness [mm]	Minus tolerance [mm]
≥ 2,0 < 2,5	– 0,20
≥ 2,5 < 3	– 0,25
≥ 3,0 < 3,5	– 0,35
≥ 3,5 < 4,0	– 0,45
≥ 4,0	– 0,50

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 cm^2 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 cm^2 may be repaired by welding provided that the defects are isolated and separated from each other, do not exceed 1200 cm^2 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 BKI.

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 A 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/mm^2, 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/mm^2, 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 cm^2. 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:

$$\sigma_{\mathrm{pl}} = \frac{\sigma_{\mathrm{G}} \times \mathrm{S}_{\mathrm{G}} + \sigma_{\mathrm{A}} \cdot \mathrm{S}_{\mathrm{A}}}{\mathrm{S}_{\mathrm{pl}}}$$

σ = specified minimum value of tensile strength or yield strength or 0,2 % proof stress [N/mm^2]

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 180^0 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 test batches 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 Fig. 4.4.

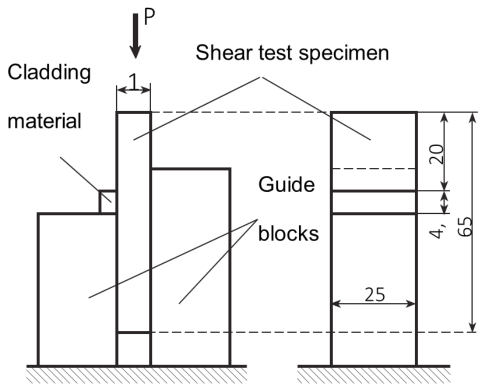


Figure 4.4: Shear test

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 Fig. 4.5. Where the product thickness exceeds 80 mm, the specimens may be reduced to 80 mm by machining the base material side.

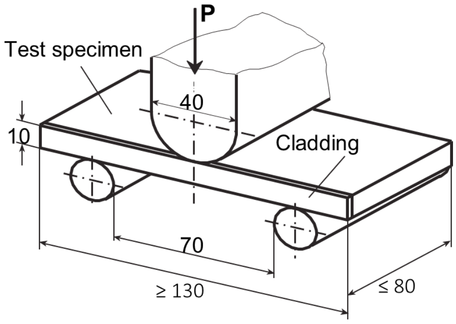


Figure 4.5: Side bend test

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.

I. 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 BKI.

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

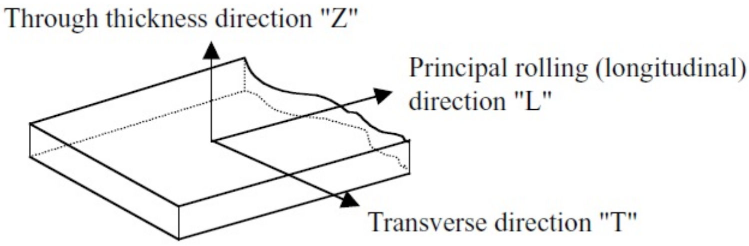


Figure 4.6: Schematic of testing directions

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 as shown in Table 4.22.

Table 4.22: Reduction of area acceptance values

Grade	Z25	Z35
Minimum average	25%	35%
Minimum individual	15%	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 10160:1999. For sections Class 1.2/23 test requirements according to EN 10306:2002 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 cm^2*
Maximum permissible flaw size:	*1,0 cm^2*
Permissible incidence of flawsin relation to area:	
locally:	*up to 30 m^2*
in relation to total plate area:	*up to 15 m^2*
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 4.23 and consist of products of the same heat, same thickness and same heat treatment.

Table 4.23: Unit testing quantities

Product	Sulphur content	
	S > 0,005%	S ≤ 0,005%
Plates	rolled length	50 t
Wide flats up to and including 25mm thickness	10 t	
Wide flats exceeding 25 mm thickness	20 t	

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. 4.7. 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. 4.7.

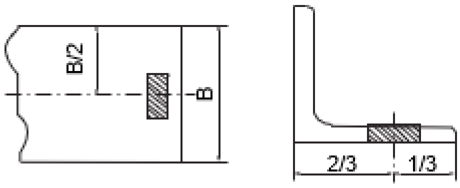


Figure 4.7: Sampling of Z specimens

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. 4.8. Examples of permissible welding processes are stud or friction welding.

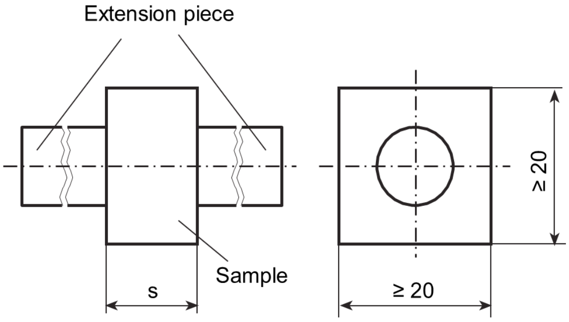


Figure 4.8: Specimen blank, consisting of test piece and welded-on extension pieces

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. 4.9

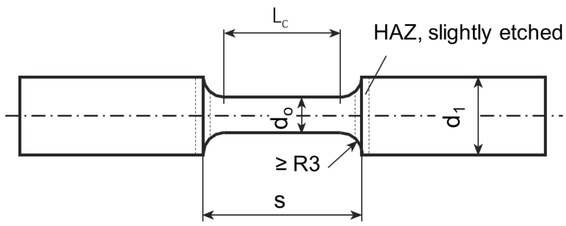


Figure 4.9: Tensile test specimen with extension pieces

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 ≤ 25 mm,
= 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 · d_O and shall not exceed 150 mm.

Note:

For further details see EN 10164:2018.

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 ≤ 150 mm its total length Lt is generally equal to the product thickness. The shape and dimensions of the tensile test specimen are shown in Fig. 4.10. The diameter do of the tensile test specimen is 6 mm in the case of product thicknesses s of ≤ 40 mm and 10 mm in the case of product thicknesses s of > 40 mm.

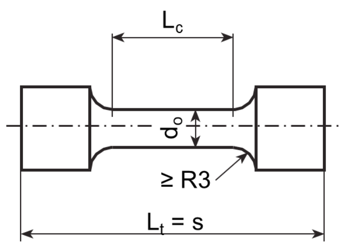


Figure 4.10: Tensile test specimen without extension pieces

The test length L_c of the tensile test specimen shall be at least 1,5 · d_O and shall not exceed 150 mm.

3.1.5 f 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 BKI 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 KI-E hull structural steel is given the designation KI-E Z25.

5. Certification

The following information is required to be included on the certificate in addition to the appropriate steel requirement given in Section 4, B. or Section 4, D. :

a) Through thickness reduction in area (%)

b) Steel grade with Z25 or Z35 notation.

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 7. 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 Section 10, A. come into question.

4. Method of manufacture and condition of supply

4.1 Cladding is performed by explosive cladding without additional heat transfer or change of thickness.

4.2 In general clad materials are to be delivered in untreated, smoothed condition.

5. Dimensions and tolerances

5.1 Where no other tolerances are specified in the order, the specifications in Table 4.24 apply.

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/mm^2 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 mm^2. 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/mm^2, 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.

Table 4.24: Permissible tolerances

<table>
<tr><th rowspan="2"></th><th rowspan="2" colspan="2">Product</th><th colspan="2">Tolerance [mm]</th></tr>
<tr><th>lower</th><th>upper</th></tr>
<tr><td>Thickness</td><td colspan="2">all</td><td>−2</td><td>+ 1</td></tr>
<tr><td>Length</td><td colspan="2">all</td><td>0</td><td>+ 10</td></tr>
<tr><td rowspan="3">Width</td><td colspan="2">plates</td><td>0</td><td>+ 10</td></tr>
<tr><td rowspan="2">rods 1)</td><td>≤ 25 mm width</td><td>−1,5</td><td>+ 1,5</td></tr>
<tr><td>>25 mm width</td><td>−2</td><td>+ 2</td></tr>
<tr><td rowspan="2">Diameter</td><td rowspan="2">circular blanks</td><td>≤ 500 mm diameter</td><td>0</td><td>+ 2</td></tr>
<tr><td>>500 mm diameter</td><td>0</td><td>+ 5</td></tr>
<tr><td rowspan="2">Rectangularity</td><td colspan="2">plates
(difference between the diagonals)</td><td colspan="2">max. 10</td></tr>
<tr><td colspan="2">rods 1)
(perpendicular projection of a longitudinal edge or a transverse edge)</td><td colspan="2">max. 1,5</td></tr>
<tr><td rowspan="2">Evenness (aluminium side)</td><td colspan="2">≥ 1 m length</td><td colspan="2">max. 5</td></tr>
<tr><td colspan="2">< 1 m length</td><td colspan="2">max. 0,5% of length</td></tr>
<tr><td>Straightness of longitudinal edges</td><td colspan="2">rods 1)</td><td colspan="2">max. 5</td></tr>
<tr><td colspan="5">1) Rods are contrary to plates flat products of a width ≤ 300 mm.</td></tr>
</table>

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 the test specimen and the test arrangement are shown in Fig. 4.4.

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. 4.5. 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.

K. Normal and Higher Strength Corrosion Resistant Steels for Cargo Oil Tanks

Deleted, replaced by Section 4, B.

L. YP47 and Brittle Crack Arrest Steel

1. Scope

1.1 General

This Sub-Section defines the requirements on YP47 steels and brittle crack arrest steels as required in Rules for Container Ships (Pt. 1, Vol. XVIII), Sec. 27 and Rules for Hull (Pt. 1, Vol. II), Sec. 39.

Unless otherwise specified in this subsection, requirements in B. are to be followed.

1.2 YP47 steels

1.2.1 Steels designated as YP47 refer to steel with a specified minimum yield point of 460 N/mm^2.

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

1.2.3 This Sub-section gives the requirements for YP47 steels in thickness greater than 50 mm and not greater than 100 mm intended for the upper deck region of container carriers. For YP47 steels outside scope of the said thickness range, special consideration is to be given by BKI.

1.3 Brittle crack arrest steels

1.3.1 The brittle crack designation can be assigned to steel grades KI-E36 and KI-E40 as specified in B. and YP47 steels specified in this subsection, which meet the additional brittle crack arrest requirements and properties defined in 3.

1.3.2 The application of brittle crack arrest steels is to comply with Rules for Container Ships (Pt. 1, Vol. XVIII), Section 27 and Rules for Hull (Pt. 1, Vol. II), Section 39, which covers longitudinal structural members in the upper deck region of container carriers (such as hatch side coaming, hatch coaming top and the attached longitudinals).

1.3.3 The thickness range of brittle crack arrest steels is over 50 mm and not greater than 100 mm as specified in Table 4.28.

2. Approval

The steels shall be approved by BKI, the approval is to follow a scheme given in Guidance for The Approval and Type Approval of Materials and Equipment for Marine Use (Pt.1, Vol. W). For this purpose, the steel manufacturer shall send to BKI 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. BKI 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 BKI by the basic oxygen process, in electric arc furnaces, or by another process approved by BKI.

3.2 Chemical composition

The chemical composition of YP47 and brittle crack arrest steels shall satisfy the requirements stated in Table 4.25 and Table 4.26 respectively.

Table 4.25: Chemical compositions and deoxidation practice for YP47 steel without specified brittle crack arrest properties

Grade	KI-E47
Deoxidation Practice	**Killed and fine grain treated**
Chemical composition % (ladle samples) [6) 7)]	
C max	0,18
Mn	0,90 – 2,00
Si max	0,55
P max	0,02
S max	0,02
Al (acid soluble min)	0,015 [1) 2)]
Nb	0,02 – 0,05 [2) 3)]
V	0,05 – 0,10 [2) 3)]
Ti max	0,023)
Cu max	0,35
Cr max	0,25
Ni max	1,0
Mo max	0,08
C_{eq} max [4)]	0,49
P_{cm} max [5)]	0,22

1) The total aluminium content may be determined instead of the acid soluble content. In such cases the total aluminium content is to be not less than 0,020%.

2) The steel is to contain aluminium, niobium, vanadium or other suitable grain refining elements, either singly or in any combination. When used singly the steel is to contain the specified minimum content of the grain refining element. When used in combination, the specified minimum content of a fine graining element is not applicable.

3) The total niobium, vanadium and titanium content is not to exceed 0,12%.

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

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

5) Cold cracking susceptibility Pcm value is to be calculated using the following formula:

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

6) Where additions of any other element have been made as part of the steelmaking practice subject to approval by BKI, the content is to be indicated on product inspection certificate.

7) Variations in the specified chemical composition may be allowed subject to approval of BKI.

Table 4.26: Chemical composition and deoxidation practice for brittle crack arrest steels

Grade	KI-E36 BCA KI-E40 BCA	KI-E47 BCA
Deoxidation Practice	Killed and fine grain treated	
Chemical Composition % [1) 7) 8)] (ladle samples)		
C max	0,18	0,18
Mn	0,90 – 2,00	0,90 – 2,00
Si max	0,5	0,55
P max	0,02	0,02
S max	0,02	0,02
Al (acid soluble min)	0,015 [2) 3)]	0,015 [2) 3)]
Nb	0,02 – 0,05 [3) 4)]	0,02 – 0,05 [3) 4)]
V	0,05 – 0,10 [3) 4)]	0,05 – 0,10 [3) 4)]
Ti max	0,02 [4)]	0,02 [4)]
Cu max	0,5	0,5
Cr max	0,25	0,5
Ni max	2	2
Mo max	0,08	0,08
C_{eq} max [5)]	0,47 – 0,49	0,55
P_{cm} max [6)]	–	0,24

Notes:

1) Chemical composition of brittle crack arrest steels shall comply with Table 4.26, regardless of chemical composition specified in B. and Table 4.25.

2) The total aluminium content may be determined instead of the acid soluble content. In such cases the total aluminium content is to be not less than 0,020%.

3) The steel is to contain aluminium, niobium, vanadium or other suitable grain refining elements, either singly or in any combination. When used singly the steel is to contain the specified minimum content of the grain refining element. When used in combination, the specified minimum content of a fine graining element is not applicable.

4) The total niobium, vanadium and titanium content is not to exceed 0,12%.

5) The carbon equivalent C_{eq} value is to be calculated from the ladle analysis using the following formula:

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

6) Cold cracking susceptibility P_{cm} value is to be calculated using the following formula:

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

7) Where additions of any other element have been made as part of the steelmaking practice subject to approval by BKI, the content is to be indicated on product inspection certificate.

8) Variations in the specified chemical composition may be allowed subject to approval of BKI.

3.3 Condition of Supply

The condition in which YP47 steels are supplied shall correspond to the data given in Table 4.27.

3.4 Mechanical Properties

3.4.1 YP47 steels properties

The mechanical properties of YP47 steels shall satisfy the requirements stated in Table 4.27.

Table 4.27: Conditions of supply, grade and mechanical properties for YP47 steels without specified brittle crack arrest properties [1)]

Supply condition	Grade	Mechanical properties			Impact test			
		Yield strength (N/mm^2) min.	Tensile strength (N/mm^2)	Elongation (%) min.	Test temp. (°C)	Average impact energy (J) min.		
						50 < t ≤ 70	70 < t ≤ 85	85 < t ≤ 100
						Longitudinal		
TMCP [2)]	KI-E47	460	570 - 720	17	−40°C	53	64	75

t: thickness (mm)

Note :

1) The additional requirements for YP47 steels with brittle crack arrest properties is specified in 3.4.2.

2) Other conditions of supply are to be in accordance with BKI's procedures.

3.4.2 Brittle crack arrest properties

.1 Brittle crack arrest steels are defined as steel plate with the specified brittle crack arrest properties measured by either the brittle crack arrest toughness K_{ca} or Crack Arrest Temperature (CAT).

.2 In addition to the required mechanical properties in B. for KI-E36 and KI-E40 and Table 4.27 for YP47, brittle crack arrest steels are to comply with the requirements specified in Table 4.26 and Table 4.28.

.3 The brittle crack arrest properties specified in Table 4.28 are to be evaluated for the products in accordance with the procedure approved by BKI. Test specimens are to be taken from each piece (means "the rolled product from a single slab or ingot if this is rolled directly into plates" as defined in B.), unless otherwise agreed by BKI.

Table 4.28: Requirement of brittle crack arrest properties for brittle crack arrest steels

Suffix to the steel grade [1)]	Thickness range (mm)	Brittle crack arrest properties [2) 6)]	
		Brittle Crack Arrest Toughness K_{ca} at -10°C ($N/mm^{3/2}$)[3)]	Crack Arrest Temperature CAT (°C) [4)]
BCA1	50 < t ≤ 100	min. 6000	-10 or below
BCA2	80 < t ≤ 100 [7)]	min. 8000	[5)]

t: thickness (mm)

Notes:

1) Suffix "BCA1" or "BCA2" is to be affixed to the steel grade designation (e.g. KI-E40-BCA1, KI-E47-BCA1, KI-E47-BCA2, etc.).

2) Brittle crack arrest properties for brittle crack arrest steels are to be verified by either the brittle crack arrest toughness Kca or Crack Arrest Temperature (CAT).

3) K_{ca} value is to be obtained by the brittle crack arrest test specified in Annex 4.

4) CAT is to be obtained by the test method specified in Annex 5.

5) Criterion of CAT for brittle crack arrest steels corresponding to K_{ca} = 8000 $N/mm^{3/2}$ is to be approved by BKI.

6) Where small-scale tests are used for product testing (batch release testing), these test methods are to be approved by BKI in accordance with Guidance for The Approval and Type Approval of Materials and Equipment for Marine Use (Pt.1, Vol.W) Sec.2, B.IX.

7) Lower thicknesses may be approved at the discretion of BKI.

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 The mechanical properties shall be verified by tensile test. For this purpose, specimens shall be taken transverse to the direction of rolling.

4.2.2 For each batch presented, except where specially agreed by BKI, 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.

4.3 Impact Test

Steel plates with thicknesses of ≥ 6 mm shall be subjected to the notched bar impact test performed on Charpy V-notch specimens at the test temperatures specified in Table 4.27. The specimens shall be taken to the direction of rolling . The extent of testing is to be one set of three specimens taken from each piece.

4.4 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.

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

5. Marking

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

- Marks of the manufacturer
  grade of steel and condition of supply (KI–E47 TM)
- Heat number, plate number or equivalent identification mark.

Steel having brittle crack arrest (BCA) properties is to have letters BCA added after the identification mark. (KI – E47 TM BCA).

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

M. High Manganese Austenitic Steel for Cryogenic Service

1. Application

1.1 This sub-section provides requirements for manufacturing approval and batch release testing ofhigh manganese austenitic steel as plate for cryogenic service with thickness between 6 mm to 40 mm. Forgreater thickness, special consideration shall be given by each BKI.

1.2 High manganese austenitic steels differing in chemical composition, deoxidation practice,condition of supply and mechanical properties may be considered, subject to the special approval of the BKI.

2. Definitions

2.1 High manganese austenitic steel means the steel with a high amount of manganese in order toretain austenite as its primary phase at atmospheric and service temperature.

2.2 For meaning of piece see B.11.1.1.

3. Approval

3.1 High manganese austenitic steel shall be manufactured at steel works which have been approved by the BKI. The suitability of steel for forming and welding shall be demonstrated during the initial approval test at the steelworks. Approval of the steelworks shall follow a scheme given in Guidance for The Approval and Type Approval of Materials and Equipment for Marine Use (Pt.1, Vol.W).

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

3.3 Where non-conformities arise, the manufacturer shall identify the cause and establish countermeasures to prevent its recurrence. The non-conformities and the countermeasures are to be documented and reported to BKI.

4. Method of manufacture

4.1 Steel shall be manufactured by the basic oxygen, electric furnace or open hearth processes or by other processes specially approved by BKI.

4.2 The deoxidation practice shall be fully killed for steel.

4.3 The steel shall be fine grain treated and shall have a fine grain structure. The fine grain practice shall be as detailed in the manufacturing specification.

5. Chemical composition

5.1 The chemical composition of samples taken from each ladle of each cast shall be determined by the steelmaker in an adequately equipped and competently staffed laboratory and shall comply with the appropriate requirements of Table 4.29.

5.2 The aim analysis shall be in accordance with the manufacturing specification. All the elements listed in Table 4.29 shall be reported.

Table 4.29: Chemical composition for high manganese austenitic steel

Chemical composition [%] [1]								
C	Si [2]	Mn	P	S	Cr	B	N	Cu
0,35 – 0,55	0,10 – 0,50	22,50 – 25,50	≤ 0,030	≤ 0,010	3,00 – 4,00	≤ 0,005	≤ 0,050	0,30 – 0,70

1) The content of other elements used for alloying and fine grain treatment may be specified by steelmaker, as appropriate.

2) Silicon (Si) may be less than 0,1%, provided total aluminium is 0,03% or higher, or provided acid soluble aluminium is 0,025% or higher.

6. Condition of supply

6.1 Condition of supply for all material is hot rolled and subsequent controlled cooling if necessary. Other conditions of supply are to be in accordance with BKI's procedure.

6.2 The reduction ratio of slab to finished product thickness shall be not less than 3:1.

7. Mechanical properties

7.1 Material specifications for high manganese austenitic steel plates are defined in Table 4.30.

Table 4.30: Conditions of grade and mechanical properties for high manganese austenitic steel plates

Grade	Yield Strength (N/mm^2)	Tensile Strength (N/mm^2)	Elongation (%) min	Charpy Impact Energy, Average		
				Test Temp. (°C)	Transverse (J)	Longitudinal (J)
HMA400	≥ 400	800 – 970	≥ 22	−196	≥ 27	≥ 41

8. Surface quality and internal soundness

8.1 The steel shall be reasonably free from segregations and non-metallic inclusions.

8.2 The finished material shall have a workmanlike finish and shall be free from internal and surface defects prejudicial to the use of the material for the intended application.

8.3 Surface finish of steel shall be in accordance with the relevant requirements in B.7.

8.4 Verification of internal soundness is the responsibility of manufacturer. The acceptance by the BKI's Surveyor shall not absolve the manufacturer of this responsibility.

9. Tolerances

9.1 Unless otherwise agreed or specially required, the thickness tolerances of high manganese austenitic steel plate shall be in accordance with A.6.

10. Identification of materials

10.1 The steelmaker shall adopt a system for the identification of ingots, slabs and finished pieces which will enable the material to be traced to its original cast.

10.2 The surveyor shall be given full facilities for so tracing the material when required.

11. Testing and inspection

11.1 Facilities for inspection

Testing shall be carried out under the witness of the surveyor, or an authorized deputy, in order to verify whether the test results meet the specified requirements.

The manufacturer shall afford the surveyor all necessary facilities and access to all relevant parts of the steel works to enable him to verify the approved process is adhered to, for the selection of test materials, the witnessing of tests, and verifying the accuracy of the testing, calibration of inspection equipment.

11.2 Testing procedures

The tests and inspections may be carried out at the manufacturing place before dispatch

The test specimens and test methods shall comply with the information given in Section 2. All the test specimens are to be tested in his presence, unless otherwise agreed.

11.3 Ultrasonic examination

If required by the BKI, the manufacturer shall perform ultrasonic examination in accordance with an approved standard.

11.4 Surface inspection and dimensions

Surface inspection and verification of dimensions are the responsibility of the steelmaker.

The acceptance by BKI's surveyor shall not absolve the steelmaker of this responsibility in case defective material is found later.

12. Test material

12.1 All material in a batch presented for acceptance tests shall be of the same product form from the same cast and in the same condition of supply.

12.2 The test samples are to be fully representative of the material and, where appropriate, are not to be cut from the material until heat treatment has been completed.

12.3 The test specimens are not to be heat treated separately from the test samples in any way.

12.4 Unless otherwise agreed, the test samples are to be taken from one end at a position approximately midway between the axis in the direction of the rolling and the edge of the rolled product (see Fig. 4.1).

Unless otherwise agreed, the tensile test specimens are to be prepared with their longitudinal axis transverse to the final direction of rolling.

13. Mechanical test specimens

13.1 Tensile Test Specimens

The dimensions of the tensile test specimens are to be in accordance with Section 2, D. Test specimens of full product thickness are to be used.

13.2 Impact test specimens

The impact test specimens are to be of the Charpy V-notch type cut with their longitudinal axis as near as practicable to a point midway between the surface and the centre of the thickness and with their longitudinal axis either parallel or transverse to the final direction of rolling of the material. The notch shall be cut in a face of the test specimen which was originally perpendicular to the rolled surface. The position of the notch is not to be nearer than 25 mm to a flame cut or sheared edge.

14. Number of test specimens

14.1 Number of tensile tests

One tensile test shall be made from each piece.

14.2 Number of impact tests

At least one set of three charpy V-notch test specimens shall be made from each piece.

15. Retest procedures

15.1 Retest procedures for tensile tests and charpy impact tests are to be in accordance with Section 2, H.

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

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

16. Marking

16.1 Each finished piece shall be clearly marked by the manufacturer with the following particulars:

1) Name or mark to identify the steel works
2) Unified identification mark for the grade of steel
3) Cast number/Heat number, plate number or equivalent identification mark
4) Delivery condition
5) BKI's brand mark

16.2 The marking particulars, but excluding the manufacturer's name or trade mark where this is embossed on finished products shall be enriched with paint or otherwise marked so as to be easily recognizable.

17. Documentation

17.1 The surveyor shall be supplied with the number of copies of the test certificates or shipping statements for all accepted materials. In addition to the description, dimensions, etc., of material, the following particulars shall be included:

1) Purchaser's order number and if known the hull number for which the material is intended
2) Identification of the cast and piece including, where appropriate, the test specimen number
3) Steelwork's identification
4) Chemical analysis
5) Condition of supply with heat treatment temperatures
6) Mechanical properties test result, including traceable test identification
7) Surface quality and inspection results
8) UT result, where applicable
9) Identification of the grade of steel

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

"We hereby certify that the material has been made by an approved process and has been satisfactorily tested in accordance with the Rules of BKI"

Section 5 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 4, 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 Rules for Welding (Pt.1, Vol.VI).

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 BKI. Such approval is conditional upon their fulfilling the requirements stated in Section 1, C. and demonstrating this to BKI 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 BKI on a case to case basis.

BKI 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 BKI. 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 $1 + 0{,}1 \times$ 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 Rules for Welding (Pt.1, Vol.VI).

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 ≤ 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.

8.5 Technological tests

8.5.1 The pipes selected for testing shall be subjected to one of the ring tests specified in Table 5.1 provided that the wall thickness of the pipe does not exceed 40 mm. For the performance of the test, see 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.

Table 5.1: Types of ring test

Outside diameter of pipe	Nominal wall thickness t [mm]		
	t < 2	2 ≤ t ≤ 16	16 < t ≤ 40
≤ 21,3	ring flattening test 1) 3)	ring flattening test 1) 3)	—
> 21,3 ≤ 146	ring flattening test 1) 3)	ring expanding test 1) 3)	ring flattening
> 146	—	ring tensile test 2)	ring tensile test 2)

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.

8.5.2 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 5.2, depending on the material.

Table 5.2: Diameter change in the ring expanding test

Pipe material	Minimum expansion [%] for ID/OD ratios of					
	≥ 0,9	≥ 0,8 < 0,9	≥ 0,7 < 0,8	≥ 0,6 < 0,7	≥ 0,5 < 0,6	< 0,5
C- and CMn-steels	8	10	12	20	25	30
Mo-, CrMo- and Ni-steels	6	8	10	15	30	30
Austenitic steels	30					

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.

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 BKI.

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 BKI 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 ≤ 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. ISO 10893-1) or to an approved test specification. The efficiency of the method shall be initially demonstrated to BKI.

8.9 Retest 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 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 5.3. 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.

Table 5.3: Standardized pipe grades

Strength category or pipe grade to Table 5.5	Corresponding pipe grade to			
	EN 10216-1 [1] or EN 10217-1 [2]	EN 10216-3 [1] or EN 10217-3 [2]	EN 10305-1	EN 10305-2
KI–R 360	P235TR2		E235+N	E235+N
KI–R 410	P265TR2	P275NL1		E275+N
KI–R 490		P355N	E355+N	E355+N

[1] Seamless.
[2] Welded.

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 5.4 or, where appropriate, in the relevant standards or specifications.

Table 5.4: Chemical composition of unalloyed steel pipes

Strength category or pipe grade	Chemical composition [%]					
	$C_{max.}$	$Si_{max.}$	$Mn_{max.}$	$P_{max.}$	$S_{max.}$	$Al_{tot.}$
KI–R 360	0,17	0,35	1,20	0,025	0,020	$\geq$ 0,020 [1]
KI–R 410	0,21	0,35	1,40			
KI–R 490	0,22	0,55	1,60			

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

3.2 Mechanical properties

The required values of tensile strength, yield strength and elongation specified in Table 5.5 or, where appropriate, in the relevant standards or specifications shall be met under test at room temperature.

Table 5.5: Mechanical and technological properties of unalloyed steel pipes

Strength category or pipe grade	Tensile strength R_m [N/mm^2]	Yield strength R_{eH} [N/mm^2] min.	Elongation A [%] min.		Impact energy KV [1] at 0°C [J] min.	
			long.	transv.	long.	transv.
KI–R 360	360 – 500	235	25	23	41	27
KI–R 410	410 – 570	255	21	19		
KI–R 490	490 – 650	310	19	17		

[1] For pipes with wall thickness >10 mm.

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 5.5.

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

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 KI–R 490 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 Rules for Welding (Pt.1, Vol.VI) Sec. 11, 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 mm, 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 ISO 10893-1.

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 ISO 10893-10, acceptance category U2, subcategory C or ISO 10893-3, acceptance category F2. Areas in way of pipe ends which have not been tested automatically, shall be subjected either to a manual or semiautomatic ultrasonic test in accordance with ISO 10893-10, acceptance category U2, subcategory C or shall be cut off.

4.6.2 Non-destructive testing of pressure-welded pipes

KI-R 360 and KI-R 410:

The weld seam of pipe grades KI-R 360 and KI-R 410 shall be tested over its entire length according to either ISO 10893-2, acceptance category E3 or ISO 10893-3, acceptance category F3 or ISO 10893-10, acceptance category U3, subcategory C or ISO 10893-11, 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 ISO 10893-11, acceptance category U3 or shall be cut off.

KI-R 490:

Pipes of grade KI-R 490 shall be subjected to an ultra-sonic test for detection of longitudinal defects according to ISO 10893-10, 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 ISO 10893-10, acceptance category U2, subcategory C or shall be cut off.

4.6.3 Non-destructive testing of fusion-welded pipes

KI-R 360 and KI-R 410:

The weld seam of SAW pipes of grades KI-R 360 and KI-R 410 shall be tested either according to ISO 10893-11, acceptance category U3 or ISO 10893-6 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 ISO 10893-11, acceptance category U3 or shall be examined by means of radiographic testing according to ISO 10893-6, image quality class R2 or shall be cut off.

KI-R 490:

The weld seam of pipes of grade KI-R 490 shall be tested over its entire length according to ISO 10893-11, acceptance category U2 or ISO 10893-6 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 radio-graphic testing as specified above or shall be cut off.

The base material is to be tested according to ISO 10893-9, acceptance category U2.

The pipe ends have to be tested in accordance with ISO 10893-8. 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 ISO 10893-9 or ISO 10893-8, 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 5.6.

Table 5.6: Standardized pipes made of high-temperature steel grades

Strength category or pipe grade	Corresponding pipe grade to			
	EN 10216-2	EN 10217-2	ISO 9329-2	ISO 9330-2
KI–R 360 W	P235GH	P235GH	PH 23	PH 23
KI–R 410 W	P265GH	P265GH	PH 26	PH 26
KI–R 460 W	—	—	PH 29	—
KI–R 510 W	20MnNb6	—	PH 35	PH 35
0,3Mo	16Mo3	16Mo3	16Mo3	16Mo3
1Cr0,5Mo	13CrMo4-5	—	13CrMo4-5	13CrMo4-5
2,25Cr1Mo	10CrMo9-10	—	11CrMo9-10	11CrMo9-10

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 1Cr0,5Mo and 2,25Cr1Mo 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).

3. Requirements applicable to the material

3.1 Chemical composition

The chemical composition shall conform to the data given in Table 5.7 or, where appropriate, the relevant standards or specifications.

Table 5.7: Chemical compositions of high-temperature steel pipes

<table>
<tr><th rowspan="2">Strength category or pipe grade</th><th colspan="8">Chemical composition [%]</th></tr>
<tr><th>C</th><th>Si max.</th><th>Mn</th><th>P max.</th><th>S max.</th><th>Cr</th><th>Mo</th><th>Al tot.</th></tr>
<tr><td>KI-R 360 W</td><td>≤ 0,16</td><td>0,35</td><td>≤ 1,20</td><td rowspan="7">0,025</td><td rowspan="7">0,020</td><td rowspan="4">≤ 0,30</td><td rowspan="4">≤ 0,08</td><td rowspan="4">≥ 0,020 1)</td></tr>
<tr><td>KI-R 410 W</td><td>≤ 0,20</td><td>0,40</td><td>≤ 1,40</td></tr>
<tr><td>KI-R 460 W</td><td>≤ 0,22</td><td>0,40</td><td>≤ 1,40</td></tr>
<tr><td>KI-R 510 W</td><td>≤ 0,23</td><td>0,55</td><td>0,80 – 1,50</td></tr>
<tr><td>0,3Mo</td><td>0,12 – 0,20</td><td>0,35</td><td>0,40 – 0,90</td><td>–</td><td>0,25 – 0,35</td><td rowspan="3">≤ 0,040</td></tr>
<tr><td>1Cr0,5Mo</td><td>0,10 – 0,17</td><td>0,35</td><td>0,40 – 0,70</td><td>0,70 – 1,15</td><td>0,40 – 0,60</td></tr>
<tr><td>2,25Cr1Mo</td><td>0,08 – 0,14</td><td>0,50</td><td>0,30 – 0,70</td><td>2,00 – 2,50</td><td>0,90 – 1,10</td></tr>
<tr><td colspan="9">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. $\left(\text{Al} + \frac{\text{Ti}}{2}\right) \geq 0,20\%$</td></tr>
</table>

3.2 Mechanical properties

The required values of tensile strength, yield strength and elongation specified in Table 5.8 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 5.8.

3.5 High-temperature characteristics

The 0,2 % proof stress at elevated temperatures shall satisfy the requirements specified in Table 5.9 or in the other relevant standards or specifications.

Table 5.8: Mechanical and technological properties of pipes made of high-temperature steel at room temperature

Strength category or pipe grade	Tensile strength R_m [N/mm^2]	Yield strength R_{eH} [N/mm^2] min.	Elongation (at $L_0 = 5,65 \cdot \sqrt{S_0}$) A [%] min.		Impact energy KV [J] min.	
			Long.	Trans.	Long.	Trans.
KI–R 360 W	360 – 500	235	25	23	41	27
KI–R 410 W	410 – 570	255	21	19		
KI–R 460 W	460 – 580	270	23	21		
KI–R 510 W	510 – 650	355	19	17		
0,3Mo	450 – 600	270	22	20		
1Cr0,5Mo	440 – 590	290	22	20		
2,25Cr1Mo	480 – 630	280	20	18		

Table 5.9: Minimum values of yield strength $R_{P0,2}$ at elevated temperatures

Steel grade		Minimum yield strength $R_{p0,2}$ [N/mm^2] at a temperature [°C] of								
Material code	Material Number	100	150	200	250	300	350	400	450	500
KI-R 360W	10.345	198	187	170	150	132	120	112	108	–
KI-R 410W	10.425	226	213	192	171	154	141	134	128	–
KI-R 460W	–	–	–	235	215	175	155	145	135	–
KI-R 510W	10.471	312	292	264	241	219	200	186	174	–
0,3Mo	15.415	243	237	224	205	173	159	156	150	146
1Cr0,5Mo	17.335	264	253	245	236	192	182	174	168	166
2,25Cr1Mo	17.380	249	241	234	224	219	212	207	193	180

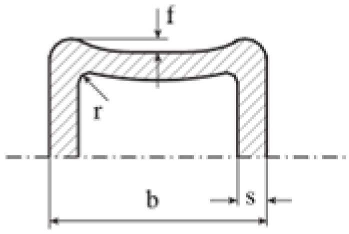
3.6 Dimensional tolerances for collectors

Seamless collector pipes and collectors with inside diameters $\leq$ 600 mm are subject to the following dimensional tolerances:

— On the inner or outer clear width: $\pm$ 1,0 % where the outer clear width is $\leq$ 225 mm, or $\pm$ 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. 5.1



b [mm]	up to 100	101 to 200	201 to 300	301 and over
f [mm]	0,75	1,0	1,5	2,0

Figure 5.1: 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 com- position 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 5.1 as follows:

For fusion-welded pipes a weld seam bend test in accordance with Rules for Welding (Pt.1, Vol.VI) Sec. 11, 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 ISO 10893-1 over their whole length and cross section, see 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 ISO 10893-10, 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 ISO 10893-12, acceptance category U2 or ISO 10893-6, 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 ISO 10893-9, acceptance category U2.

The pipe ends have to be tested in accordance with ISO 10893-8. 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 ISO 10893-9 or ISO 10893-8, 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.

D. Pipes Tough at Sub-Zero Temperatures

1. Scope

1.1 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 processing 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 5.10

Table 5.10: Comparably suitable pipe grades of steels tough at sub-zero temperatures according to standard

Strength category or pipe grade	EN 10216-4 [1] or EN 10217-4 [2]	EN 10216-3 [1] or EN 10217-3 [2]	EN 10216-5 [1] or EN 10217-7 [2]	ISO 9329-3 [1] or ISO 9330-3 [2]	ISO 9329-4 [1] or ISO 9330-6 [2]	ASTM A312M [3]
KI–R 360 T	P215NL P255QL			PL25		
KI–R 390 T	P265NL	P275NL1 P275NL2				
KI–R 490 T		P355NL1 P355NL2				
KI–R 0,5 Ni	13MnNi6-3			13MnNi6-3		
KI–R 3,5 Ni	12Ni14			12Ni14		
KI–R 9 Ni	X10Ni9			X10NiMn9		
14.306			X2CrNi19-11		X2CrNi18-10	TP 304 L
14.404			X2CrNiMo17-13-2		X2CrNiMo17-12	TP 316 L
14.541			X6CrNiTi18-10		X6CrNiTi18-10	TP 321
14.550			X6CrNiNb18-10		X6CrNiNb18-10	TP 347
14.571			X6CrNiMoTi17-12-2		X6CrNiMoTi17-12	

1) Seamless pipes.
2) Welded pipes
3) The notched bar impact energies according to Table 5.14 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 4, 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 BKI.

1.3 If the pipes are used for cargo and process equipment on gas tankers, the minimum design temperatures specified in Table 5.11 are applicable.

Table 5.11: Minimum design temperatures

Strength category or pipe grade	Minimum design temperature [°C]
KI – R 360 T KI – R 390 T KI – R 490 T	– 55 [1]
KI – R 0,5 Ni KI – R 3,5 Ni	– 55 – 90
KI – R 9 Ni	– 165
Austenitic pipes	– 165

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 5.12.

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

Welded austenitic pipes may be delivered in the welded state without post-weld heat treatment provided that a test of the procedure has demonstrated that the characteristics of the material are satisfactory and that the strips or plates used for their manufacture are solution annealed. In addition, any scale, residual slag and temper colours on the inner and outer surfaces shall be carefully removed, e.g. by pickling, grinding or sand blasting.

Table 5.12: Heat treatment of steel pipes tough at sub-zero temperatures

Strength category or pipe grade	Type of heat treatment
KI– R 360 T KI– R 390 T KI– R 490 T	Normalized or quenched and tempered
KI– R 0,5 Ni	Normalized
KI– R 3,5 Ni	Normalized and tempered or quenched and tempered
KI– R 9 Ni	Double normalized and tempered or quenched and tempered
Seamless austenitic pipes	Solution annealed and quenched
Welded austenitic pipes	Solution annealed and quenched or in the welded condition

3. Requirements applicable to the material

3.1 Chemical composition

The chemical composition of the pipe steels shall conform to the data in Table 5.13 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 $\leq$ 0,03%, see Table 5.13.

3.3 Mechanical properties

The values for tensile strength, yield strength or 0,2 % or 1 % proof stress, and elongation specified in Table 5.14 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 5.14 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.

Table 5.13: Chemical composition of steel pipes tough at sub-zero temperatures

Strength category or pipe grade	Chemical composition [%]								
	C_{max}	Si	Mn	P_{max}	S_{max}	Cr	Ni	Mo	Other elements
KI–R 360 T	0,16	≤ 0,40	0,40 – 1,20	0,025	0,02	≤ 0,30	≤ 0,30	≤ 0,08	Al_{met} ≤ 0,015 [1], [2]
KI–R 390 T	0,16	≤ 0,40	0,50 – 1,50						
KI–R 490 T	0,18	0,10 – 0,50	≤ 0,90						
KI–R 0,5 Ni	0,16	≤ 0,50	0,85 – 1,70	0,025	0,015	≤ 0,15	0,30 – 0,85	≤ 0,10	Al_{met} ≤ 0,015 [1], [3]
KI–R 3,5 Ni	0,15	0,15 – 0,35	0,30 – 0,85	0,025	0,01	–	3,25 – 3,75	–	V ≤ 0,05
KI–R 9 Ni	0,13			0,02			8,50 – 9,50	≤ 0,10	
14.306	0,03	≤ 1,00	≤ 2,00	0,04	0,03	17,0 – 19,0	9,0 – 12,0	–	–
14.404	0,03					16,5 – 18,5	11,0 – 14,0	2,0 – 2,5	
14.541	0,08					17,0 – 19,0	9,0 – 12,0	–	Ti ≥ 5 × % C ≤ 0,70
14.550	0,08					17,0 – 19,0	9,0 – 12,0	–	Nb ≥ 10× % C ≤ 1,00
14.571	0,08					16,5 – 18,5	11,0 – 14,0	2,0 – 2,5	Ti ≥ 5 × % C ≤ 0,80

[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 5.14: Mechanical and technological properties of steel pipes tough at sub-zero temperatures

Strength category or pipe grade	Tensile strength R_m [N/mm^2]	Yield strength or proof stress R_{eH} or $R_{p0,2}$, $R_{p1,0}$ [1] [N/mm^2] min.	Elongation A [%] min.		Impact energy KV [2] [J] min.		
			Long.	Trans.	Test temperature [°C]	Long. [J]	Trans. [J]
KI–R 360 T	360 – 490	255	25	23	5 K below design temperature, min. –20°C	41(29)	27(19)
KI–R 390 T	390 – 510	275	24	22			
KI–R 490 T	490 – 630	355	22	20			
KI–R 0,5 Ni	490 – 610	355	22	20	– 60		
KI–R 3,5 Ni	440 – 620	345	22	20	– 95		
KI–R 9 Ni	690 – 840	510	20	18	– 196		
14.306	480 – 680	215	40	35	– 196		
14.404	490 – 690	225	40	35			
14.541	510 – 710	235	35	30			
14.550	510 – 740	240	35	30			
14.571	510 – 710	245	35	30			

[1] $R_{p0,2}$ or R_{eH} applies to ferritic steels, $R_{p1,0}$ to austenitic steels.

[2] Average value of 3 specimens; values in brackets apply to the min. individual value.

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 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 5.1. 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 5.15 shall be assigned to the constant C in the formula given in A.8.5.2.

4.5 Notched bar impact test

4.5.1 On pipes with wall thicknesses $\geq$ 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 5.16.

Table 5.15: Values of constant C

Strength category or pipe grade	Constant C
KI– R 360 T	0,09
KI– R 390 T and KI– R 490 T	0,07
KI– R 0,5 Ni	
KI– R 3,5 Ni	0,08
KI– R 9 Ni	0,06
Austenitic pipes	0,1

Table 5.16: Impact energy for specimens of reduced size

Required impact energy [1)] in Table 5.14 (standard specimens)	Required impact energy KV with specimens measuring			
	7,5 mm × 10 mm		5 mm × 10 mm	
[J] min.	average value [J] *min.*	minimum individual value [J]	average value [J] min.	minimum individual value [J]
27 (19)	22	16	18	13
41 (29)	34	24	27	19

[1)] Average value of 3 specimens; values in brackets apply to the min. individual value.

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 a non-destructive test over their whole length according to ISO 10893-1

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 ISO 10893-10, acceptance category U2, subcategory C or ISO 10893-3 (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 ISO 10893-10, 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 ISO 10893-12, acceptance category U2 or ISO 10893-6, 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 ISO 10893-9, acceptance category U2.

The pipe ends have to be tested in accordance with ISO 10893-8. 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 ISO 10893-9 or ISO 10893-8, 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 Table 5.13 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 Table 5.17 or other 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 Table 5.18 or other recognized standards or specifications.

Table 5.17: Chemical composition of standard grade of austenitic stainless steel

<table>
<tr><th rowspan="2">Grade</th><th colspan="9">Chemical composition (%)</th></tr>
<tr><th>C
max</th><th>Si
max</th><th>Mn
max</th><th>P
max</th><th>S
max</th><th>Ni</th><th>Cr</th><th>Mn</th><th>Others</th></tr>
<tr><td>KI 304TP</td><td>0,08</td><td rowspan="3">1,00</td><td rowspan="10">2,00</td><td rowspan="10">0,04</td><td rowspan="10">0,03</td><td>8,0 – 11,0</td><td rowspan="2">18,0 – 20,0</td><td rowspan="4">–</td><td rowspan="8">–</td></tr>
<tr><td>KI 304LTP</td><td>0,03</td><td>9,0 – 13,0</td></tr>
<tr><td>KI 309STP</td><td rowspan="3">0,08</td><td>12,0 – 15,0</td><td>22,0 – 24,0</td></tr>
<tr><td>KI 310STP</td><td>1,50</td><td>19,0 – 22,0</td><td>24,0 – 26,0</td></tr>
<tr><td>KI 316TP</td><td rowspan="6">1,00</td><td>10,0 – 14,0</td><td rowspan="2">16,0 – 18,0</td><td rowspan="2">2,0 – 3,0</td></tr>
<tr><td>KI 316LTP</td><td>0,03</td><td>12,0 – 16,0</td></tr>
<tr><td>KI 317TP</td><td>0,08</td><td rowspan="2">11,0 – 15,0</td><td rowspan="2">18,0 – 20,0</td><td rowspan="2">3,0 – 4,0</td></tr>
<tr><td>KI 317LTP</td><td>0,03</td></tr>
<tr><td>KI 321TP</td><td rowspan="2">0,08</td><td rowspan="2">9,0 – 13,0</td><td rowspan="2">17,0 – 19,0</td><td rowspan="2">–</td><td>Ti ≥ 5 × C</td></tr>
<tr><td>KI 347TP</td><td>Nb ≥ 10 × C</td></tr>
</table>

Table 5.18: Mechanical properties of austenitic stainless steel grades [2),3)]

Steel grade	Yield point or proof stress [N/mm^2] min.	Tensile strength [N/mm^2] min.	Elongation [%] A (L_0 = 5,65 $\cdot \sqrt{S_0}$) min.	
			L [1)]	T [1)]
KI 304TP	205	520	26	22
KI 304LTP	175	480		
KI 309STP	205	520		
KI 310STP				
KI 316TP				
KI 316LTP	175	480		
KI 317TP	205	520		
KI 317LTP	175	480		
KI 321TP	205	520		
KI 347TP				

[1)] L (or T) denotes that the longitudinal axis of the test specimen is arranged parallel (or normal) to the final direction of rolling.

Where the nominal diameter of stainless steel pipe is 200 mm and over, tensions test specimen maybe taken transversely.

Where test specimen of non-tubular section are taken from welded pipes, test specimens are to be from the part that does not included welded line.

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 Table 5.1 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 ISO 10893-1.

The pipes shall be subjected to a non-destructive test in order to detect longitudinal defects according to ISO 10893-10, 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 ISO 10893-10, 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 6 Steel Forgings

A. General Rules

1. Scope

1.1 This sub-section contains general rules to be applied in the manufacture and testing of steel forgings.

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

1.2 The preparation of test specimens and the procedures used for mechanical testing are to comply with the relevant requirements of Section 2. Unless otherwise agreed all tests are to be carried out in the presence of the Surveyor.

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 which comply with national or proprietary specifications may be accepted , provided that the specifications give reasonable equivalence to these requirements or are otherwise specially approved or required by BKI. As a minimum the following particulars shall be specified:

- Manufacturing process
- Chemical composition
- Heat treatment
- Mechanical properties and
- Non-destructive testing

(IACS UR W7 1.3)

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 fulfill the conditions stated in Section 1, C. 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 BKI on a case to case basis.

(IACS UR W7 2.1)

3.2 The works at which the steel was produced is to be approved by BKI. Forges without their own steelmaking facility may only use starting material supplied by producers who have been approved by BKI.

(IACS UR W7 2.2)

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 BKI and shall be killed. On request, BKI shall be informed of the steelmaking process used.

(IACS UR W7 2.2)

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

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

(IACS UR W7 2.3)

4.4 The material shall be progressively hot worked by hammer or press, and shall be forged as close as practical to the finished shape and size in order to give reasonable machining allowance.

Excessive machining to give the forging its final shape may impair its characteristics, e.g. by exposing the core zone. The core zone may have lower mechanical properties, as well as higher density of inclusions and other imperfections. The manufacturer is responsible for evaluation of the machining allowance suitable for their products. As a general advice, machining allowance should not exceed 20% of final dimension.

Necks of shafts, pinions and journals exceeding 1/10 of the outer diameter 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.

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

4.5 The plastic deformation is to be such as to ensure soundness, uniformity of structure and satisfactory mechanical properties after heat treatment. The reduction ratio is to be calculated with reference to the average cross-sectional area of the cast material. Where the cast material is initially upset, this reference area may be taken as the average cross-sectional area after this operation. However, the initial free upsetting operation of the ingot shall not be considered as part of the total forging reduction ratio.

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.

(IACS UR W7 2.4)

4.6 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 BKI. Depending on its composition and/or thickness the workpiece shall be preheated. Where necessary, surfaces produced by flame cutting shall be machined.

(IACS UR W7 2.6)

4.7 Where two or more forgings are to be welded together to form a composite component, details of the welding procedure specification shall be submitted for approval. BKI reserves the right to call for a welding procedure approval test in these cases.

(IACS UR W7 2.7)

4.8 The requirements in Rules for Welding (Pt.1 Vol.VI) Sec.12, F. are applicable for welding procedure qualification tests of steel forgings intended to be used for the components of hull construction and marine structures. Requirements for type approval of welding consumables are to be in accordance with Rules for Welding (Pt.1 Vol.VI) Sec.5.

(IACS UR W7 2.8)

4.9 Welders intended to be engaged in fusion welding of steel forgings for hull structures are to be qualified in accordance with Rules for Welding (Pt.1 Vol.VI) Sec.3.

(IACS UR W7 2.9)

5. Condition of supply and heat treatment

5.1 At an appropriate stage of manufacture, after completion of all hot working operations, forgings shall be suitably heat treated for obtaining a fine grain homogeneous microstructure condition as well as the required mechanical properties.

(IACS UR W7 5.1)

5.2 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. In the case of very large forgings alternative methods of heat treatment will be specially considered by BKI.

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

(IACS UR W7 5.3)

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

(IACS UR W7 5.9)

5.4 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.

(IACS UR W7 5.4)

5.5 Where a forging is locally reheated or any straightening operation is performed after the final heat treatment, subsequent stress relief heat treatment to remove the residual stresses may be required. The manufacturer shall have strict control of this temperature in order to avoid any detrimental effects to the final heat trea tment and resultant microstructure and mechanical properties of the forging.

(IACS UR W7 5.8)

5.6 Where it is intended to surface harden forgings, full details of the proposed procedure and specification are to be submitted for the approval of BKI. For the purposes of this approval, the manufacture r may be required to demonstrate by test that the proposed procedure gives a uniform surface layer of the required hardness and depth and that it does not impair the soundness and properties of the steel.

(IACS UR W7 5.5)

5.7 Where induction hardening or nitriding is to be carried out, forgings are to be heat treated at an appropriate stage to a condition suitable for this subsequent surface hardening.

(IACS UR W7 5.6)

5.8 Where carburizing is to be carried out, forgings are to be heat treated at an appropriate stage (generally either by full annealing or by normalizing and tempering) to a condition suitable for subsequent machining and carburizing.

(IACS UR W7 5.7)

5.9 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 BKI 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.

(IACS UR W7 3.1)

6.2 Defects may be removed by grinding or chipping and grinding provided the component dimensions are acceptable. The resulting grooves are to have a bottom radius of approximately three times the groove depth and are to be blended into the surrounding surface so as to avoid any sharp contours. The complete removal of the defects shall be proved by a magnetic particle or dye penetrant test with the consent of the Surveyor.

(IACS UR W7 9.1)

6.3 Repair welding of forgings except those subjected to torsional fatigue, such as crankshaft forgings and propeller shaft forgings, may be permitted subject to prior approval of BKI.

In these cases, full details of the extent and location of the repair, the proposed welding procedure, heat treatment and subsequent inspection procedures shall be submitted to BKI 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 testings applied.

(IACS UR W7 9.2)

6.4 The forging manufacturer is to maintain records of repairs and subsequent inspections traceable to each forging repaired. The records are to be presented to the surveyor on request.

(IACS UR W7 9.3)

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 leak-proof at the specified test pressure.

9. General requirements applicable to the material

9.1 Chemical composition

9.1.1 The chemical composition of each heat is to be determined by the manufacturer on a sample taken preferably during the pouring of the heat. When multiple heats are tapped into a common ladle, the ladle analysis shall apply

(IACS UR W7 4.2)

9.1.2 At the option of the manufacturer, suitable grain refining elements such as aluminium, niobium or vanadium may be added. The content of such elements is to be reported.

(IACS UR W7 4.4)

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

(IACS UR W7 4.5)

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 on a sample taken preferably during the pouring of the 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.

When multiple heats are tapped into a common ladle, the ladle analysis shall apply.

(IACS UR W7 4.2)

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:

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

.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. A batch is to consist of forgings of similar shape and dimensions, made from the same heat of steel, heat treated in the same furnace charge and with a total mass not exceeding 6 tonnes for normalized forgings and 3 tonnes for quenched and tempered forgings, respectively.

(IACS UR W7 6.11)

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

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

(IACS UR W7 6.8)

.4 Test specimens are normally to be cut with their axes either mainly parallel (longitudinal test) or mainly tangential (tangential test) to the principal axial direction of each product.

(IACS UR W7 6.3)

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

a) For forgings having a thickness, t, or diameter D up to a maximum of 50 mm, the longitudinal axis of the test specimen is to be located at a distance of t/2 or D/2 below the heat-treated surfaces.

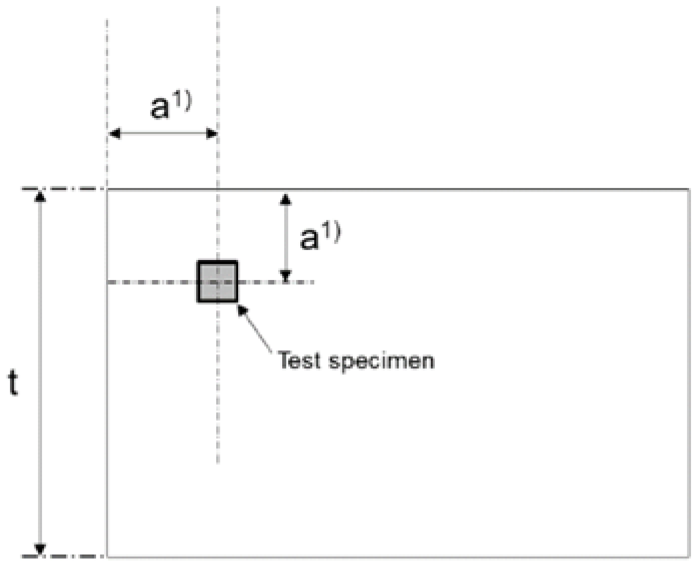
b) For forgings having a thickness,t, or diameter D greater than 50 mm, the longitudinal axis of the test specimen is to be located at a distance of t/4 or D/4 (mid-radius) or 80 mm, whichever is less, below any heat-treated surface.

   Test specimen is to be located with its longitudinal axis at a distance from any heat-treated surface as shown in Fig. 6.1a.

c) For ring and disc forgings (noting that the test specimen locations for these shaped forgings may be different to elongated or free-form forgings), tangential sample shall be taken at t/2 for thickness ≤ 25 mm and 12,5 mm below the surface for thickness > 25 mm, in both the vertical and horizontal direction.

Where achievable, for thickness > 25 mm, no part of the test specimen shall be closer than 12,5 mm to any heat treated surface, as shown in Fig. 6.1a.

(IACS UR W7 6.4)



[1] "a" is the distance from the test specimen to heat treated surface based on the above b) or c).

Figure 6.1a: Position of the test specimen

Where the manufacturer can demonstrate that a proposed testing location or orientation is more representative of the required mechanical properties of a component, this may be agreed with BKI. In such cases, the heat treatment process, a proposed testing location or orientation, and technical justification shall be submitted to BKI for approval.

(IACS UR W7 6.5)

.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 test specimen is parallel to the main direction of fibre deformation;
Tangential	:	The longitudinal axis of the test specimen perpendicular to the principal direction of fibre deformation.

.7 Normally, test specimens shall be taken from the test sections forged together with the work pieces. 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. Except for components which are to be carburized or for hollow forgings where the ends are to be subsequently closed, test material is not to be cut from a forging until all heat treatment has been completed . In these circumstances, the forging and the test section shall be heat treated together.

(IACS UR W7 6.9)

.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.

This test section is to be integral with each forging except as provided in 10.2.3.2 and 10.2.3.3. Where batch testing is permitted according to 10.2.3.2, the test section may alternatively be a production part or separately forged. The separately forged test section is to have a reduction ratio similar to that used for the forgings represented.

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

(IACS UR W7 6.1)

10.2.4 For forgings whose method of manufacture is subject to special approval by BKI, 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.

(IACS UR W7 8.1)

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 testings

10.4.1 Where non-destructive testings are called for, these are to be performed before acceptance and the results are to be reported by the manufacturer.

(IACS UR W7 8.2)

10.4.2 Ultrasonic examination is to be carried out after the forgings have been machined to a condition suitable for this type of examination and after the final heat treatment. Both radial and axial scanning are to be carried out where appropriate for the shape and the dimensions of the forgings being examined.

(IACS UR W7 8.3)

10.4.3 Non-destructive testings are to be performed in accordance with the specifications stated in H. in consideration of the specifications in Section 3. Unless otherwise agreed, acceptance criteria stated in H. shall be complied with. Alternatively, acceptance criteria complying with national or international standards or specifications may be agreed with BKI provided such standards or specifications give reasonable equivalence to the requirements stated in H. or are especially approved.

(IACS UR W7 8.4)

10.4.4 Unless otherwise agreed, examinations are to be carried out by the manufacturer, although Surveyors may request to be present in order to verify that the examination is being carried out in accordance with the agreed procedure.

(IACS UR W7 8.5)

10.4.5 If the forging is supplied in the 'as forged' condition for machining at a separate works, the manufacturer is to ensure that a suitable ultrasonic examination is carried out to verify the internal quality of the forging.

(IACS UR W7 8.6)

10.4.6 Where advanced ultrasonic testing methods are applied, e.g. PAUT or TOFD, reference is made to Section 3, M., for general approach in adopting and application of these advanced methods.

In such cases, acceptance levels regarding accept/reject criteria may be as per the applicable requirements in H.

(IACS UR W7 8.7)

10.4.7 In the event of any forging proving defective during subsequent machining or testing, it is to be rejected notwithstanding any previous certification.

(IACS UR W7 8.9)

10.5 Retests in the event of failure of specimens

10.5.1 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 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 forging or test batch concerned.

(IACS UR W7 7.6, 7.7, 7.8)

10.5.2 At the option of the manufacturer, when a forging or a batch of forgings has failed to meet the test requirements, it may be reheat-treated and re-submitted for acceptance tests. They may not be reaustenitized or solution treated more than twice. All the tests previously performed shall be repeated after re-heat treatment and the results shall meet the specified requirements.

(IACS UR W7 7.9)

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.

(IACS UR W7 10.1)

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
- Test pressure where applicable
- Date of final inspection

The area receiving the stamp marks shall be ground.

(IACS UR W7 10.2)

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.

(IACS UR W7 10.3)

12. Certificates

For each consignment the manufacturer shall supply to the Surveyor a certificate containing at least the following details:

- purchaser's name 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
- steelmaking process, heat number
- chemical composition of the heat
- condition of supply
- details of heat treatment, including temperature and holding times
- 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 testings.

(IACS UR W7 11.1)

B. Forgings for Machine Construction and Shipbuilding

1. Scope

1.1 These requirements are applicable to steel forgings made of unalloyed and low alloy steels intended for the manufacture of hull and machinery components, e.g. shafts, piston rods, connecting rods, rudder stocks, heel pintles, etc.

These requirements are also applicable to material for forging stock and to rolled bars intended to be machined into components of simple shape e.g. shafts, pins, tie-rods and similar components.

(IACS UR W7 1.1)

1.2 These requirements are applicable only to steel forgings where the design and acceptance tests are related to mechanical properties at ambient temperature. For other applications, additional requirements may be necessary especially when the forgings are intended for service at low or elevated temperatures.

(IACS UR W7 1.2)

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. ISO 683-1, ISO 683-2, EN 10250-2, EN 10250-3.

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

3. Condition of supply and heat treatment

3.1 Except as provided in A.5.7 and A.5.8 forgings are to be supplied in one of the following conditions:

a) Carbon and carbon-manganese steels

— Fully annealed

— Normalized

— Normalized and tempered at temperature of not less than 550°C

— Quenched and tempered at temperature of not less than 550°C

b) Alloy steels

— Normalized

— Normalized and tempered at temperature of not less than 550°C

— Quenched and tempered at temperature of not less than 550°C

The delivery condition shall meet the design and application requirements, it is the manufacturer's responsibility to select the appropriate heat treatment method to obtain the required mechanical properties.

(IACS UR W7 5.2)

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 shall comply with the overall limits given in Table 6.1 and Table 6.2 or, where applicable, the requirements of the approved specification.

(IACS UR W7 4.3)

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 BKI for approval.

4.2 Mechanical and technological properties

4.2.1 The required values of yield strength, reduction in area, elongation and impact test energy shown in Table 6.3 and Table 6.4 respectively in relation to the prescribed minimum tensile strength or, where applicable, the requirements of the approved specification shall be met.

(IACS UR W7 7.3)

Table 6.1: Limit values for the chemical composition 1) of forging steels for hull 6)

Steel type	C	Si	Mn	P	S	Cr 4)	Mo 4)	Ni 4)	Cu 4)	Total residuals
C- and CMn	0,23 2),3)	0,45	0,30 – 1,50	0,035	0,035	0,30	0,15	0,40	0,30	0,85
Alloy	5)	0,45	5)	0,035	0,035	5)	5)	5)	0,30	-

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

2) The carbon content may be increased above this level provided that the carbon equivalent (C_{eq}) is not more than 0,41%, calculated using the following formula:

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

3) The carbon content of C and C-Mn steel forgings not intended for welded construction may be 0,65 maximum.

4) Elements are considered as residual elements.

5) Specification is to be submitted for approval.

6) Rudder stocks and pintles should be of weldable quality.

Table 6.2: Limit values for the chemical composition 1) of forging steels for machinery 6)

Steel type	C	Si	Mn	P	S	Cr 4)	Mo 4)	Ni 4)	Cu 4)	Total residuals
C- and CMn	0,23 2),3)	0,45	0,30 – 1,50	0,035	0,035	0,30	0,15	0,40	0,30	0,85
Alloy 5)	0,45	0,45	0,30 – 1,00	0,035	0,035	Min. 0,40 6)	Min. 0,15 6)	Min. 0,40 6)	0,30	-

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

2) The carbon content may be increased above this level provided that the carbon equivalent (C_{eq}) is not more than 0,41%.

3) The carbon content of C and C-Mn steel forgings not intended for welded construction may be 0,65 maximum.

4) Elements are considered as residual elements unless shown as a minimum.

5) Where alloy steel forgings are intended for welded constructions, the proposed chemical composition is subject to approval by BKI.

6) One or more of the elements is to comply with the minimum content.

4.2.2 The strength levels stated in Tables 6.3 and 6.4 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.

(IACS UR W7 7.1)

4.2.3 Forgings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Tables 6.3 or 6.4 but subject to any additional requirements of the relevant Construction Rules.

(IACS UR W7 7.2)

4.3 Impact energy

The required impact energy values shown in Tables 6.3 and 6.4 in relation to the specified minimum tensile strength shall be met.

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 Table 6.4 is guide values only.

Table 6.3: Mechanical properties for hull steel forgings

Steel type	Tensile strength, R_m [1] min. [N/mm^2]	Yield stress, R_e min. [N/mm^2]	Elongation, A_5 min. [%]		Reduction of area, Z min. [%]		Charpy V-notch impact test [2]		
			Long.	Tang.	Long.	Tang.	Test temperature [°C]	Minimum average energy [J] Long.	Tang.
C and C-Mn	400	200	26	19	50	35	0	27	18
	440	220	24	18	50	35			
	480	240	22	16	45	30			
	520	260	21	15	45	30			
	560	280	20	14	40	27			
	600	300	18	13	40	27			
Alloy	550	350	20	14	50	35			
	600	400	18	13	50	35			
	650	450	17	12	50	35			

1) The following ranges for tensile strength may be additionally specified:

specified minimum tensile strength:	< 600 N/mm^2	≥ 600 N/mm^2
tensile strength range:	120 N/mm^2	150 N/mm^2

2) Special consideration may be given to alternative requirements for Charpy V-notch test, depending on design and application, and subject to agreement by BKI.

Table 6.4: Mechanical properties for machinery steel forgings

Steel type	Tensile strength, R_m [1] min. [N/mm^2]	Yield stress, R_e min. [N/mm^2]	Elongation, A_5 min. [%]		Reduction of area, Z min. [%]		Charpy V-notch impact test [2),4)]			Hardness [3] (Brinell)
			Long.	Tang.	Long.	Tang.	Test temperature [°C]	Minimum average energy [J] Long.	Tang.	
C and C-Mn	400	200	26	19	50	35	AT [5]	27	18	110 – 150
	440	220	24	18	50	35				125 – 160
	480	240	22	16	45	30				135 – 175
	520	260	21	15	45	30				150 – 185
	560	280	20	14	40	27				160 – 200
	600	300	18	13	40	27				175 – 215
	640	320	17	12	40	27				185 – 230
	680	340	16	12	35	24				200 – 240
	720	360	15	11	35	24				210 – 250
	760	380	14	10	35	24				225 – 265
Alloy	600	360	18	14	50	35	AT [5]	27	18	175 – 215
	700	420	16	12	45	30				205 – 245
	800	480	14	10	40	30				235 – 275
	900	630	13	9	40	27				260 – 320
	1000	700	12	8	35	24				290 – 365
	1100	770	11	7	35	24				320 – 385

1) The following ranges for tensile strength may be additionally specified:

specified minimum tensile strength:	< 900 N/mm^2	≥ 900 N/mm^2
tensile strength range:	150 N/mm^2	200 N/mm^2

2) For materials used for machinery exposed to sea water temperature, such as propeller shafts and shaft bolts, intended for ships with ice class notation **ES1**, **ES2**, **ES3** and **ES4**, Charpy V-notch impact testing is to be carried out for all steel types at −10°C and the average energy value is to be minimum 20 J (longitudinal test). One individual value may be less than the required average value provided that it is not less than 70% of this average value.

3) The hardness values are typical and are given for information purposes only.

4) Special consideration may be given to alternative requirements for Charpy V-notch test, depending on design and application, and subject to agreement by BKI.

5) AT refers to ambient temperature (i.e. 23°C $\pm$ 5°C), which is specified in ISO 148-1:2016.

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. For forgings which have been induction hardened, nitrided or carburized may also be subjected to additional hardness testing.

(IACS UR W7 7.5)

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 Section 2, E.1. and E.2. shall be at the manufacturer's discretion.

5.1.3 The test specimens shall be taken from the end of each forging in a longitudinal direction except that, at the discretion of the manufacture r, the alternative directions or positions as shown in Fig. 6.1 to Fig. 6.3 may be used. Where a forging exceeds both 4000 kg in mass and 3 m in length, one set of tests is to be taken from each end. These limits refer to the 'as forged' mass and length but excluding the test material.

(IACS UR W7 6.6(a))

5.1.4 A batch testing procedure may be used for hot rolled bars. A batch is to consist of either:

- material from the same rolled ingot or bloom provided that where this is cut into individual lengths, these are all heat treated in the same furnace charge, or
- bars of the same diameter and heat, heat treated in the same furnace charge and with a total mass not exceeding 2,5 tonnes.

(IACS UR W7 6.12)

5.2 Non-destructive testings

The specifications in H. do apply. The components indicated in I. 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.

Figure 6.1: Location of specimens in unflanged shafts and rods

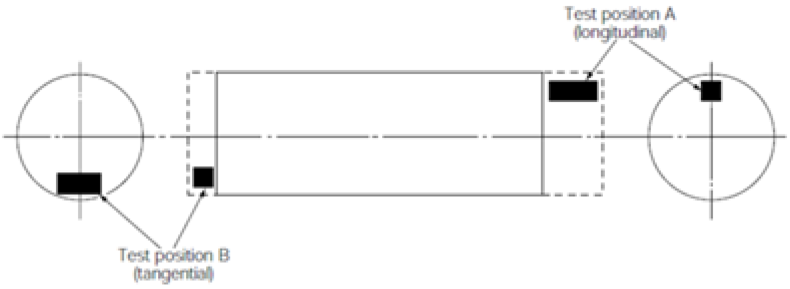


Figure 6.2: Location of specimens in unflanged shafts and rods

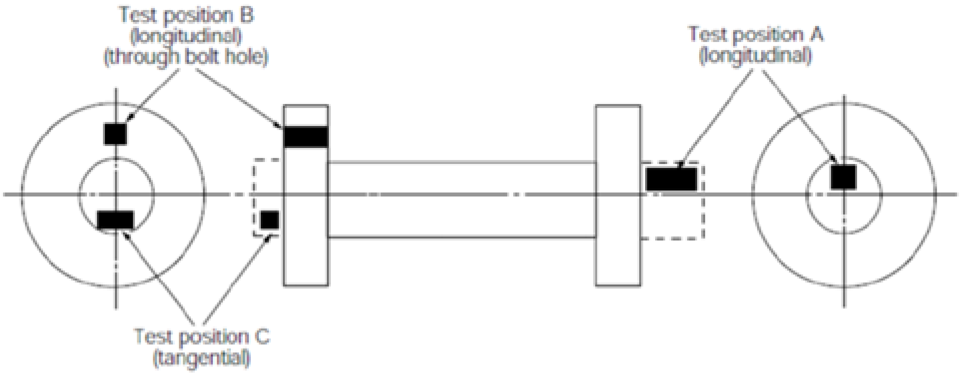


Figure 6.3: Location of specimens in flanged shafts

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 BKI as suitable for the intended application may be used. To this end, the engine manufacturer shall submit to BKI 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 Table 6.4 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 Table 6.1 to Table 6.4 or the requirements of the approved specifications or drawings 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. BKI 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, crank- shafts 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.

4.4 Where grain flow is required in the most favourable direction having regard to the mode of stressing in service, the proposed method of manufacture may require special approval by BKI. In such cases, tests may be required to demonstrate that a satisfactory structure and grain flow are obtained.

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 5.1.5.

5.1.1 Independently of the selection of test specimens according to test batches as prescribed in 5.1.4, for solid open die forged crankshafts at least one longitudinal 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 (test positions A and B in Fig. 6.4), 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.

(IACS UR W7 6.6 (h))

5.1.2 For closed die crankshaft forgings and crankshaft forgings where the method of manufacture has been specially approved in accordance with 4.4, the number and position of test specimens is to be agreed with BKI having regard to the method of manufacture employed.

(IACS UR W7 6.7)

5.1.3 Where the throws are machined or flame cut from a preforged crankshaft, a second set of test specimens shall be taken in the tangential direction from the material removed from the throw at the end opposite the driving shaft end (test position C in Fig. 6.4). For this test, the material affected by the flame cutting (heat affected zone) shall be completely removed by machining. This rule does not apply to webs which are cut out of the starting material before the specified heat treatment is applied.

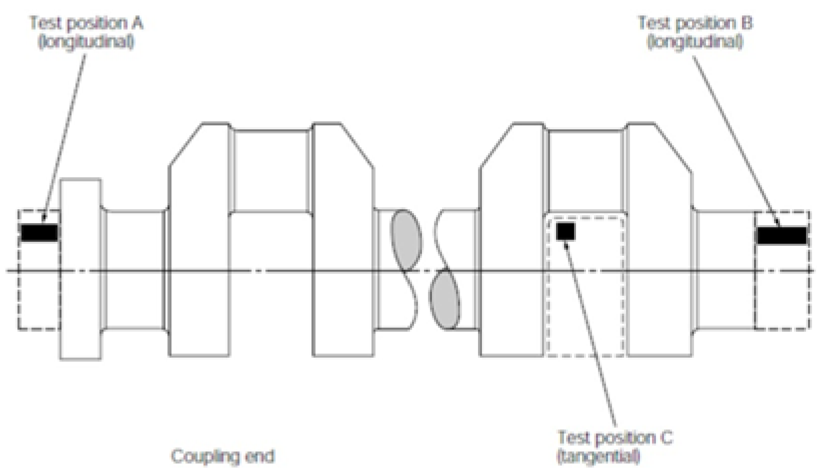


Figure 6.4: Location of test specimens in crankshafts

(IACS UR W7 6.6 (h))

5.1.4 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. For quenched and tempered crankshafts, two tensile test specimens shall be taken from each test batch; for normalized shafts, one specimen is sufficient.

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

(IACS UR W7 6.6 (g))

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 positions are subject to the conditions stated in 5.1.1 to 5.1.5 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. For small crankshaft at least one hardness test is to be carried out on each forging.

The method of hardness testing, the position of the hardness testing impressions on the forgings and acceptance criteria shall be agreed with BKI.

5.3.2 Hardness tests may also be required on forgings which have been induction hardened, nitride or carburized.

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 H.

D. Forgings for Gears

1. Scope

These requirements 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 ISO 683-2:2016, case hardening steels conforming to ISO 683-3:2016 and nitriding steels conforming to ISO 683-5:2017, provided that proof has been furnished of the suitability of the individual grade of steel for the intended purpose. Table 6.5 contains a selection of suitable steel grades.

Table 6.5: Suitable steel grades for gears

Steel grade	Standard
42CrMo4	ISO 683-2:2016
16MnCr5	ISO 683-3:2016
20MnCr5	
18CrNiMo7-6	

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.

2.3 Steels conforming to particular material specifications, provided that BKI has authorized 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 BKI 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 either fully annealed or normalised and tempered. Tempering temperature shall be not less than 550°C. The depth of case hardening, the time-temperature cycle and the hardness range (min/max) shall be stated in the specification.

(IACS UR W7 5.7)

4.2.2 Steels for induction hardening shall normally be quenched and tempered at a temperature not less than 550°C 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.

(IACS UR W7 5.6)

4.2.3 Nitriding steels shall be quenched and tempered at a temperature not less than 550°C prior to nitriding. Where possible, nitriding shall be affected 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.

(IACS UR W7 5.6)

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. BKI reserves the right to require the manufacture of samples on which the uniformity, depth and hardness of the surface layer shall be demonstrated.

(IACS UR W7 8.8)

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 Table 6.2 or, where applicable, the requirements of 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 BKI for approval.

6.2 Mechanical and technological properties

The minimum required values for the yield strength, elongation and reduction in area specified in Table 6.4. shall be met in relation to the prescribed minimum tensile strength or, where applicable, the requirements of the approved specification.

For case-hardening steels, the requirements specified in Table 6.6 apply to specimens which have undergone heat treatment together with the forging (coupons).

Table 6.6: Required values for mechanical and technological properties of specimens made of coupons

Steel grade	Sample dia. Ø [mm]	Yield strength R_{eH} [N/mm^2] min.	Tensile strength Rm [N/mm^2]	Elongation A [1)] [%] min.		Reduction in area Z [1)] [%] min.		Impact energy KV [1)] [J] min.		Impact energy KU [1)] [J] min.	
				l	t, q	l	t, q	l	t, q	l	t, q
16MnCr5	30	590	780 – 1080	10	8	40	27	22	16	24	18
20MnCr5		690	980 – 1280	8	6	35	27	18	13	20	15
18CrNiMo7-6		785	1080 – 1320	8	6	35	27	18	13	20	15
16MnCr5	63	440	640 – 940	11	9	40	27	22	16	24	18
20MnCr5		540	780 – 1080	10	8	35	27	22	16	24	18
18CrNiMo7-6		685	980 – 1280	8	6	35	27	18	13	20	15

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

If the finished machined diameter of the toothed portion is greater than 200 mm, one test specimen shall be taken from each forging in a tangential direction adjacent to the toothed portion (test position B in Fig. 6.5). If the dimensions preclude the preparation of tests from this position, tests in a tangential direction are to be taken from the end of the journal (test position C in Fig. 6.5). If, however, the journal diameter is 200 mm or less, then a longitudinal specimen shall be taken (test position A in Fig. 6.5). If the length of the finished toothed portion is more than 1250 mm, one test specimen shall be taken from both ends of the blank.

(IACS UR W7 6.6(b))

7.2.2 Small pinions

In the case of small pinions with diameters of up to 200 mm in the area of the teeth, one test specimen shall be taken in a longitudinal direction (test position A in Fig. 6.5).

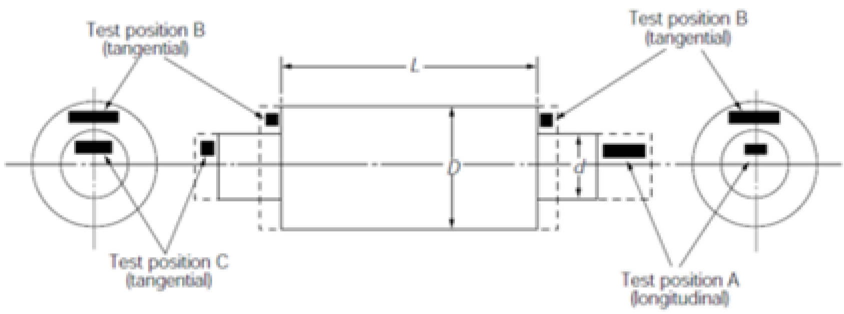


Figure 6.5: Pinion

7.2.3 Gear wheels

A tangential test specimen shall be taken from gear wheel blanks (test position A or B in Fig. 6.6).

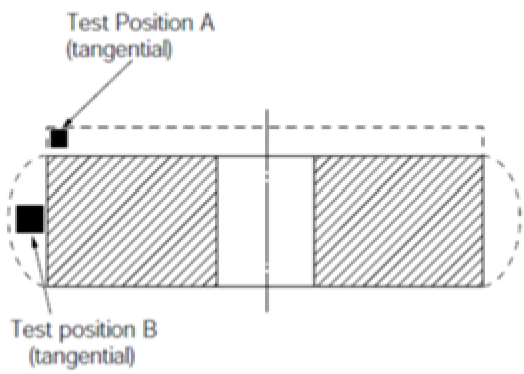


Figure 6.6: Gear wheel

7.2.4 Gear wheel rims (made by expanding)

In the case of wheel rims which are normally made by piercing a bar and enlarging the hole by forging or rolling, one test specimen shall be taken from each forging in a tangential direction (test position A or B in Fig. 6.7). Where the finished diameter exceeds 2,5 m or the mass (as heat treated including test material) exceeds 3 tonnes, two test specimens are to be taken from diametrically opposite positions (test positions A and B in Fig. 6.7). The mechanical properties for longitudinal test are to be applied.

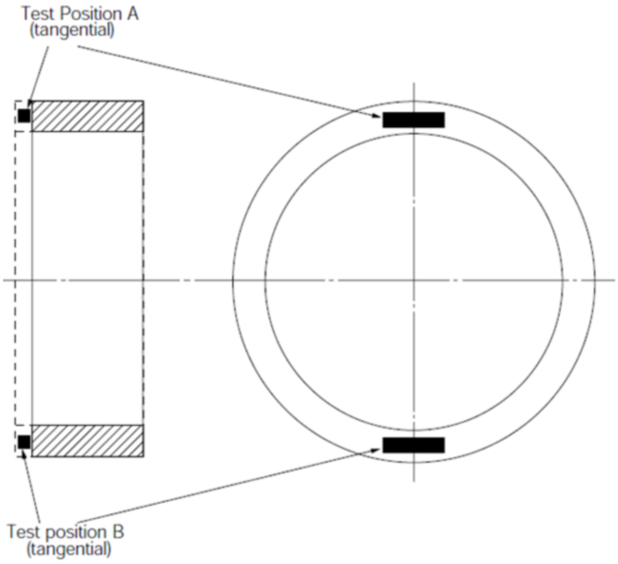


Figure 6.7: Gear rim (made by expanding)

7.2.5 Hollow pinion

One test specimen shall be taken from each forging in a tangential direction (test position A or B in Fig. 6.8). Where the length of the tooth system is more than 1250 mm, specimens shall be taken from both ends.

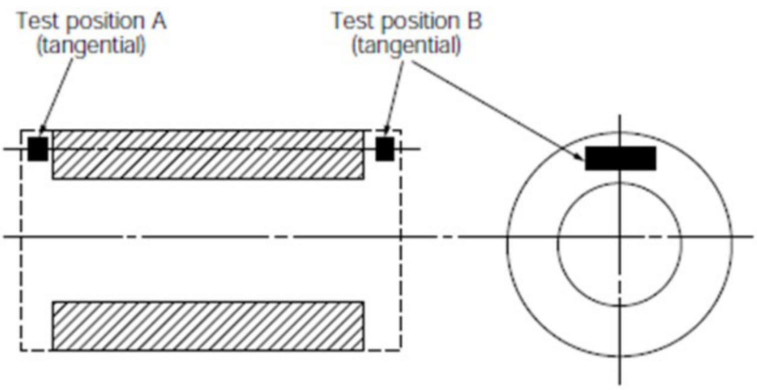


Figure 6.8: Hollow pinion

(IACS UR W7 6.6(f))

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 tangential sample will be transverse to the grain flow, and the requirements for direction given in Table 6.4 apply, but where the blank is expanded over a mandrel the tangential sample will be parallel to the grain flow and the requirements for longitudinal direction given in Table 6.4 apply.

7.2.6 Forged rings (such as slewing rings)

One set of test specimen is to be taken from each forging in a tangential direction (test positions are shown in Fig. 6.9). Where the finished diameter exceeds 2,5 m or the mass (as heat treated, including test material) exceeds 3 tonnes then two sets of tests are to be taken in diametrically opposite positions.

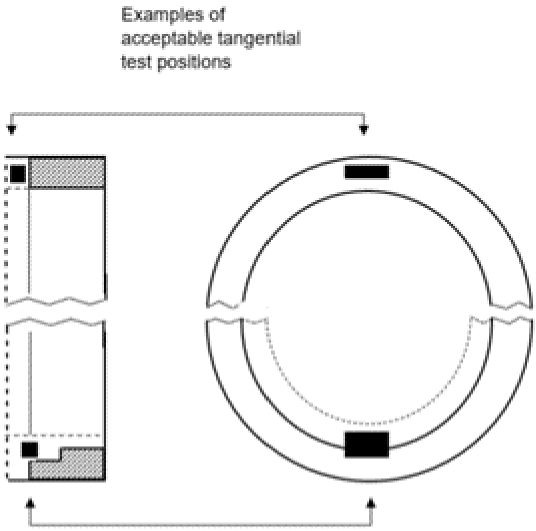


Figure 6.9: Forged rings

(IACS UR W7 6.6(i))

7.3 Tensile test on case-hardening steels

7.3.1 When forgings are to be carburized, sufficient test section is to be provided for both preliminary tests at the forge and for final tests after completion of carburizing. For this purpose, duplicate sets of test sections are to be taken from positions as detailed in 7.2, except that irrespective of the dimensions or mass of the forging, tests are required from one position only and, in the case of forgings with integral journals, are to be cut in a longitudinal direction.

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

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

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

(IACS UR W7 6.10)

7.3.2 At the discretion of the forgemaster or gear manufacturer, test sections with a cross section greater than that specified in 7.3.1 may be either carburized or blank carburized, but these are to be machined to the required diameter prior to the final quenching and tempering heat treatment.

Alternative procedures for testing of forgings which are to be carburized may be specially agreed with BKI.

(IACS UR W7 6.10)

7.4 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.

7.5 Hardness test

7.5.1 After heat treatment but before the cutting of the teeth, hardness tests are to be carried out at four positions equally spaced around the circumference of the surface where teeth will subsequently be cut. Where the finished diameter of the toothed portion exceeds 2,5 m, the above number of test positions is to be increased to eight. Where the width of a gear wheel rim forging exceeds 1,25 m, the hardness is to be determined at eight positions at each end of the forging.

For small gear forgings at least one hardness test is to be carried out on each forging.

(IACS UR W7 7.4)

7.5.2 On all surface-hardened gear parts, additional hardness tests are to be carried out on the teeth where applicable, they have been ground to the finished profile. The results of such tests are to comply with the approved specifications (see 4.3). 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.

(IACS UR W7 7.5)

7.6 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.

7.7 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.10.2.3. 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.

7.8 Non-destructive testings

7.8.1 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.

7.8.2 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 H.

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 Indonesian flag, the related Regulation 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 the equivalent standard.

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 BKI; 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 BKI; 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 BKI 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 materia

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 ≤ 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 1000 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.10.2.3. 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.

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 1000 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 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 H.

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 ≤ 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 tankers, 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 Table 4.18 for chemical composition and in Sec. 4, F.8.2.2 for mechanical properties are to be observed. The required values for impact energy given in Sec. 4, 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/mm^2 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 6.7, provided that they satisfy the requirements of 5.

2.1 Standardized steels conforming to Table 6.7.

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.

Table 6.7: Approved grades of forging steels tough at sub-zero temperatures

Type of steel	Approved minimum design temperature	Steel grade or Material no.	Standard
Weldable fine-grained structural steels	−20°C [1]	P285NH	EN 10222-4
		P285QH	
		P355N	
		P355QH	
0,5 % nickel steel	−55°C	13MnNi6-3	EN 10222-3
2,25 % nickel steel	−65°C	--	EN 10222-3
3,5 % nickel steel	−90°C	12Ni14	
5 % nickel steel	−105°C	12Ni19	
	−165°C [2]	X12Ni5	
9 % nickel steel	−165°C	X8Ni9	
Austenitic steel	−165°C	1.4301 (304) [3]	EN 10222-5
		1.4307 (304 L)	
		1.4401 (316)	
		1.4404 (316 L)	
		1.4541 (321)	
		1.4550 (347)	

[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.

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 6.8 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 ≤ 0,03%.

Table 6.8: Required impact energy values for steel forgings tough at sub-zero temperatures

Type of steel	Test temperature	Impact energy KV [J] [1) min. longitudinal	Impact energy KV [J] [1) min. transverse
Weldable fine-grained structural steels and 0,5 % nickel steel	5 K below minimum design temperature but at least – 20°C	27 (19)	22 (15)
2,25 % nickel steel	– 70°C	34 (24)	24 (17)
3,5 % nickel steel	– 95°C		
5 % nickel steel	– 110°C		
5 % nickel steel	– 196°C [2)		
9 % nickel steel	– 196°C		
Austenitic steels	– 196°C	41 (27)	27 (19)

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 1000 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.10.2.3.

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 or quantities of ≤ 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 1000 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 6.8.

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 H.

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. Stainless Steel Forgings

1. Scope

1.1 These requirements are applicable to the stainless steel forgings for propeller shafts, rudder stock, valves and pipe fittings in piping systems used at low temperature service (-165°C and over in design temperature) or corrosion resisting service.

1.2 Stainless steel forgings having characteristics differing from those specified in this sub-section are to comply with the requirements in Sec. 1, B.

1.3 In addition to the requirements given in this sub-section general requirements may be considered by BKI.

2. Grade of steel

The stainless steel forging are classified into 9 grades as specified in Table 6.9.

3. Condition of supply and heat treatment

3.1 The stainless steel forgings are generally to receive a solid solution treatment. In generally, temperature of solid solution treatment is accordance with Table 6.10.

3.2 Stainless steel forgings which are subjected to any hot work likely to cause change in the crystal structure of metal or to generate residual stress after hear treatment are to be heat treated again.

3.3 Stainless steel forgings which are subjected to any cold work involving an excessive degree of straightening are to be stress relieved accordingly.

3.4 The furnace intended to be used for heat treatment is to have sufficient size for uniformly heating the stainless steel forging to the required temperature. The furnace is to be equipped with a device capable of regulating and recording the furnace temperature.

4. Requirements applicable to the material

4.1 Chemical composition

Stainless steel forgings are have the chemical composition given in Table 6.9.

Table 6.9: Chemical composition of standard grade of stainless steel forgings

Grade	Chemical Composition (%)							
	C_{max}	Mn_{max}	P_{max}	S_{max}	Si_{max}	Cr	Ni	Others
KI SUSF 304	0,08	2,00	0,04	0,03	1,00	18,00-20,00	8,00-12,00	-
KI SUSF 304L	0,03					18,00-20,00	8,00-12,00	
KI SUSF 309S	0,08					22,00-24,00	12,00-15,00	
KI SUSF 310S	0,08					24,00-26,00	19,00-22,00	
KI SUSF 316	0,08					16,00-18,00	10,00-14,00	Mo = 2,00 ∼ 3,00
KI SUSF 316L	0,03					16,00-18,00	10,00-14,00	Mo = 2,00 ∼ 3,00
KI SUSF 317	0,08					18,00-20,00	10,00-15,00	Mo = 3,00 ∼ 4,00
KI SUSF 321	0,08					17,00-19,00	9,00-12,00	Ti ≥ 5 x C
KI SUSF 347	0,08					17,00-19,00	9,00-13,00	Nb + Ta ≥ 10 x C

Table 6.10: Temperature of Solid Solution Treatment

Grade	Temperature of solid solution treatment (° C)	Cooling rate
KI SUSF 304	1010 – 1150	Rapid cooling
KI SUSF 304L	1010 – 1150	
KI SUSF 309S	1030 – 1150	
KI SUSF 310S	1030 – 1180	
KI SUSF 316	1010 – 1150	
KI SUSF 316L	1010 – 1150	
KI SUSF 317	1010 – 1150	
KI SUSF 321	920 – 1150	
KI SUSF 347	980 – 1150	

4.2 Mechanical properties

4.2.1 The mechanical properties of stainless steel forgings are to conform to the requirements given in Table 6.11. For the application of the Table, the stainless steel forgings are to receive a solid solution treatment.

4.2.2 Notwithstanding in 4.2.1, for stainless steel forgings for valves and pipe fittings in piping systems used at low temperature, hardness tests may be omitted.

4.2.3 Where deemed necessary by BKI, other tests on notch toughness or corrosion resistance may be required in addition to the specified test.

Table 6.11: Mechanical properties of stainless steel forgings

Grade	Tensile test				Hardness test			Notch bar impact test [1)]		
	Yield Point or Proof Stress [N/mm^2] min	Tensile Strength [N/mm^2] min	Elongation [%] min	Reduction of Area [%] min	H_B max	H_{RB} max	H_V max	Test Temp [°C]	[J] min Long.	[J] min Trans.
KI SUSF 304L	175	450	37	50	187	90	200	-196	41	27
KI SUSF 316L										
Others	205	520	37	50						

1) For austenitic stainless steel forging for use at design temperature of - 105°C or higher verification of impact values may be dispensed with.

5. Mechanical testing

5.1 Mechanical tests for stainless steel forgings are to be carried out in accordance with the requirements given in Section 2.

5.2 Where the tensile test or hardness test fail to meet the requirements, retest may be carried out in accordance with the requirements of A.10.5.

5.3 The difference in tensile strength between the maximum and minimum values in case where two or more tensile test specimens were taken from one stainless steel forgings is not to exceed 70 N/mm^2.

5.4 The difference in measured hardness between the maximum and minimum values of the stainless steel forgings of the same lot is not to exceed 20(HB).

6. Selection of test specimens

6.1 Unless otherwise specially specified, the test specimens are, after final heat treatment, to be taken longitudinal from a part having a sectional area not less than that of the body of forging, but they are to be taken tangential where deemed necessary according to the form of the forgings.

6.2 The test specimens are not to be separated from the body before the final heat treatment has been completed. In the case of stamp forging or other case of forging requiring the surface hardening process, the test specimens may be separated at proper stage before the final heat treatment providing that such is approved by the Surveyor.

6.3 Number of test specimens is to be as given in 6.3.1 to 6.3.4. In this case, "one set of specimens" means one tensile test specimen.

6.3.1 Where a steel forging is 4 tons and over in mass as heat treated, one set of test specimens is to be taken from both ends of the steel forging

6.3.2 Where a steel forging is 500 kg up to 4 tons (exclusive) in mass as heat treated, one set of test specimens is to be taken from one end of the forging.

6.3.3 Where a number of steel forgings of similar form and size, each of which is 250 kg up to 500 kg (exclusive) in mass as heat treated, are made from the same ingot (or bloom) and heat treated simultaneously, one set of test specimens is to be taken from each three forgings or a fraction thereof.

6.3.4 Where a number of steel forgings of similar form and size, each of which is less than 250 kg in mass as heat treated, are made from the same ingot (or bloom) and heat treated simultaneously in the same furnace, one set of test specimens is to be taken from each ingot (or bloom). Where approved by BKI, test specimens may be taken from the test samples which forged from same ingot and same condition, and heat treated by same furnace on same time.

6.4 The tensile test specimens are to be cut with their longitudinal axes parallel to the direction of forging, unless otherwise specially provided. The longitudinal axis of test specimens is to be positioned in accordance with the requirements in A.10.2.3.5.

6.5 Where tests are carried out in accordance with 6.3.3 or 6.3.4, Surveyor may require a hardness test for each steel forging.

6.6 The steel forgings heat treated with continuous heat treatment furnace, without changing the heat treatment condition are to be considered that they have been simultaneously heat treated.

7. Non-destructive testings

7.1 Stainless steel forgings used for propeller shafts, rudder stocks and so on are to be subjected to non-destructive testing in accordance with a) and b) of the following requirements:

a) Ultrasonic Test

- The stainless steel forgings are to be subjected to ultrasonic test at an appropriate stage of the manufacturing process and the test reports are to be shown or submitted to the Surveyor
- Performances of ultrasonic testing apparatus are to be of good efficiency for testing of these forgings
- Operator engaged in the ultrasonic test is to have sufficient technique and experience for the testing of the stainless steel forgings.

b) The important parts of the stainless steel forgings are to be subjected to liquid penetrant test at an appropriate stage of the manufacturing process.

7.2 In place of the test methods given in 7.1, BKI may accept the application of other non-destructive test considered adequate by BKI.

8. Test of surface finish and dimensions

8.1 When heat treatment and final machining are completed and, if necessary, at a proper stage during machining, surface inspection is to be carried out.

8.2 Dimensions inspection of the stainless steel forgings is to be conducted under the responsibility of the manufacture.

9. Repair of defects

The repair of defects of the stainless steel forgings are to be in accordance with the requirements given in A.6.2 to A.6.4.

10. Marking

The marking of the stainless steel forgings are to be in accordance with the requirements given in A.11.

H. Non-Destructive Testing of Forged Components

The requirements for non-destructive testing of forged components can be seen in Guidance for Marine Industry (Pt.1, Vol.AC), Sec. 4, R-68.

I. List of Forged Components for which Non-Destructive Tests are Required

Name of the forged component	Test methods to be employed			
	VT	MT	PT	UT
Structural parts concerning the hull:				
– rudder stocks	X	X [5]	X [5]	X [9]
– pintles	X	X		X [1]
Parts for diesel engines:				
– crank shafts	X	X [4]	X [4]	X [3]
– connecting rods	X	X [6]	X [6]	X [2]
– piston rods	X	X [6]	X [6]	X [2]
– crossheads	X	X [6]	X [6]	X [10]
– piston crowns	X	X [2]		X
– cylinder covers	X	X [2]		X
– piston pins	X	X [2]		
– tie rods	X	X [2]		
– bolts ≥ M50 which are subjected to dynamic stresses such as:				
– main bearing	X	X [2]	X	
– connecting rod bearing	X	X [2]	X	
– cross heads	X	X [2]	X	
– cylinder covers	X	X [2]	X	
– camshaft drive gear wheels and chain wheels	X			
Main shafting and gears:				
– propeller shafts	X	X [5]	X [5]	X [9]
– intermediate shafts	X	X [5]	X [5]	X [9]
– thrust shafts	X	X [5]	X [5]	X [9]
– gear wheels	X	X		X [4]
– gear shafts	X	X		X [4]
– pinions	X	X		X [4]
– wheel rims	X	X		X [4]
Turbo machinery (main drive):				
– rotors	X	X		X
– rotor discs	X			X
– shafts	X	X		X
– blades guide vanes and blades	X	X [7] [8]		
– turbine casing bolt ≥ M50	X	X [7]		
Other components:				
– shafts for e-engines (main)	X	X		
– forged components:				
– made of steels for use at elevated temperatures	X	X [5] [6]		X [5]
– made of steels tough at sub-zero temperatures	X	X [5] [6]		X [5]
– bolts for fixing of propeller blades ≥ M50	X	X [6]		
– bolts for superheated steam pipelines	X	X [6]		

[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] With minimum crankpin diameter not less than 100 mm.
[5] With minimum diameter not less than 100 mm.
[6] With minimum diameter not less than 75 mm or equivalent cross section.
[7] With minimum diameter not less than 200 mm.
[8] For diameter of the gearing or of the shafts > 200 mm.
[9] For finished weights > 300 kg.
[10] For austenitic or austenitic-ferritic steels penetrant testing (PT) instead of magnetic particle testing (MT).
[11] For main steam temperatures > 350°C.
[12] Instead of surface crack testing (MT, PT) eddy current testing may be considered, too.

J. Classifying of Inspection Zones for Magnetic Particle Testing (MT) / Penetrant Testing (PT)

The classifying of inspection zones for magnetic particle testing (MT) or penetrant test (PT) of forged components can be seen in Guidance for Marine Industry (Pt.1, Vol.AC), Sec. 4, R-68.

K. Classifying of Inspection Zones for Ultrasonic Testing (UT)

The classifying of inspection zones for Ultrasonic Testing (UT) can be seen in Guidance for Marine Industry (Pt.1, Vol.AC), Sec.4, R-68.

Section 7 Cast Steel

A. General Rules

1. Scope

1.1 This Section contains general rules to be applied in the manufacture and testing of steel castings. Also applicable are Sections 1 - 3.

1.2 Additional requirements will typically be required for castings for offshore units depending on applicable service temperature and environment.

(IACS UR W8 1.2)

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 BKI may be used provided such standards or specifications give reasonable equivalence to these requirements.

(IACS UR W8 1.3)

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 BKI. This is conditional upon their fulfilling the manufacturing and quality control requirements stated in Section 1, C. and furnishing proof of this to BKI prior to the commencement of supplies.

(IACS UR W8 2.1)

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 BKI.

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 BKI and shall be killed. On request, the steel-making process shall be made known to BKI for approval. For certain components including steel castings subjected to surface hardening process, the proposed method of manufacture may require special approval by BKI.

(IACS UR W8 2.2 2.4)

4.2 The requirements for welding procedure qualification tests specified in Rules for Welding (Pt.1, Vol VI) Section 4 and for welder qualification tests specified in Rules for Welding (Pt.1, Vol VI) Section 3 are to be followed, unless otherwise agreed.

(IACS UR W8 2.5)

4.3 Temporary welds made for operations such as lifting, handling, staging, etc., are to be in accordance with approved welding procedures and qualified welders, and are to be removed, ground and inspected using suitable NDT methods.

(IACS UR W8 2.6)

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 which are efficiently maintained and have adequate thermocouples which are connected to the furnace charge to measure and record that its temperature is adequately uniform unless the temperature uniformity of the furnace is verified at regular intervals.

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 BKI.

(IACS UR W8 5.3)

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. The manufacturer shall have strict control of this temperature in order to avoid any detrimental effects to the final heat treatment and resultant microstructure and mechanical properties of the casting.

(IACS UR W8 5.4)

5.3 The foundry is to maintain records of heat treatment identifying the furnace used, furnace charge, date, temperature, and holding time temperature. The records are to be presented to the Surveyor on request.

(IACS UR W8 5.5)

5.4 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.

(IACS UR W8 2.3)

6. General characteristics of castings

6.1 All castings shall have a surface finish compatible with the conditions of manufacture and be free from surface or internal defects, which would be prejudicial to their proper application in service. 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.

(IACS UR W8 3.1)

6.2 Defects liable to impair the use and workability of the material to a more than minor degree is 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 leak-proof 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 on a sample taken preferably during the pouring of the heat or of each ladle when multiple heats are tapped into a common ladle and shall present corresponding certificates to the Surveyor.

(IACS UR W8 4.1)

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.

The preparation of test specimens and the procedures used for mechanical testing are to comply with the relevant requirements of Section 2. Unless otherwise agreed all tests are to be carried out in the presence of the Surveyors.

(IACS UR W8 6.11)

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.

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 or gated to 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.

(IACS UR W8 6.1, 6.2, 6.9)

10.2.4 Where a number of small castings of approximately the same dimensions, each of which is under 1000 kg in mass, 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.

(IACS UR W8 6.8)

10.2.5 If the casting is of complex design or the finished weight exceeds 10000 kg, two test samples shall be taken from the heaviest section. For this purpose, test samples spaced as widely as possible shall be cast integrally with the casting.

(IACS UR W8 6.5)

10.2.6 Where large castings are made from two or more casts, which are not mixed in a ladle prior to pouring, two or more test samples are to be provided corresponding to the number of casts involved. These are to be integrally cast at locations as widely separated as possible.

(IACS UR W8 6.6)

10.2.7 The size of the test samples for mechanical testing is to be such that the heat treatment and microstructure are representative for the section of the casting with the ruling section, i.e. the section for which the specified mechanical properties apply, see also ISO 683-1:2018 and ISO 683-2:2018, respectively.

For C, C-Mn steel castings, the thickness of the sample (t_S) shall be matched to the ruling section of the casting, but shall be at least 30 mm. In the case of thick-walled steel castings other than stern tube, stern frame, anchor and rudder horn, the sample thickness (t_S) need not exceed 150 mm. Length and width of the test sample is normally to be at least three times (t_S), unless otherwise agreed with BKI, as shown in Fig. 7.1. (Longer or wider test samples may be necessary in order to accommodate the required test specimens.)

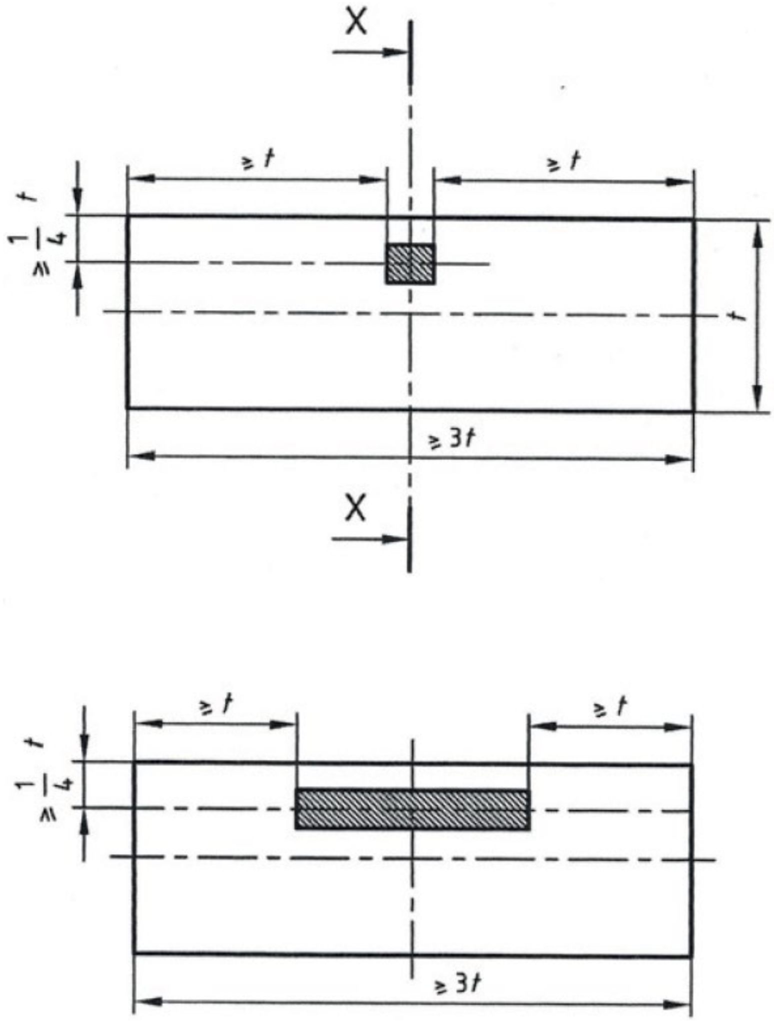


Figure 7.1: Specimen positions relative to the test sample

For castings for stern tube, stern frame, anchor and rudder horn the test sample thickness (t_S) shall represent the ruling section, as shown in Fig. 7.2.

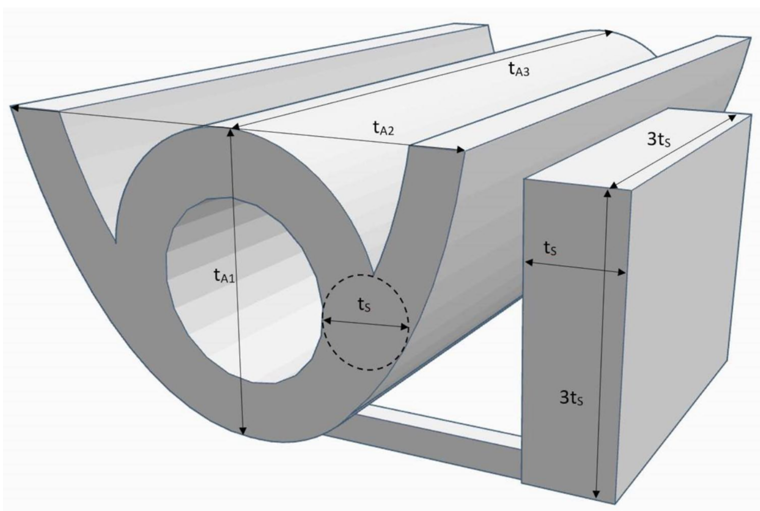


Figure 7.2: Test sample gated to stern tube casting

Guidance:

Shorter width or length may be accepted for test samples where the actual casting width or length (t_A) is in the range between t_S and $3t_S$.

Example: For a general casting with dimensions 140 x 160 x 1250 mm the required test sample size would typically be 140 x 160 x 420 mm (that is: t_S x t_A x $3t_S$).

For alloy steel castings the manufacturer shall propose dimensions for the test sample and demonstrate the representative nature of it.

(IACS UR W8 6.3)

10.2.8 For test samples with thickness ≤ 56 mm, the longitudinal axis of the test specimens is to be located at ≥ 14 mm from the surface in the thickness direction. For test samples with thickness > 56 mm, the longitudinal axis of the test specimens is to be located at ≥ ¼ t_S from the surface. Test specimens shall be taken in such a way that no part of the gauge length is machined from material closer than t_S to any of the other surfaces. For impact testing, this requirement shall apply to the complete test specimen - refer to Fig. 7.1 for the location of test specimens in relation to the test sample.

(IACS UR W8 6.4)

10.2.9 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.

10.2.10 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.

10.2.11 Where castings are manufactured by a method subject to the special approval of BKI, see 4.1, the number and position of the samples shall be specially agreed so as to take account of the method of manufacture.

(IACS UR W8 6.7)

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.

(IACS UR W8 8.2)

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 condition 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.

(IACS UR W8 8.1)

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 testings

10.4.1 Where non-destructive testings are required, these shall be performed before acceptance and the results are to be reported by the manufacturer.

10.4.2 Non-destructive testings shall be performed in accordance with the specifications stated in G. in consideration of the specifications in Section 3. Unless otherwise agreed, acceptance criteria stated in G. shall be complied with. Alternatively, acceptance criteria complying with national or international standards or specifications may be agreed with BKI provided such standards or specifications give reasonable equivalence to the requirements stated in G. or are especially approved.

(IACS UR W8 8.3)

10.5 In the event of any casting proving to be defective during subsequent machining or testing, it is to be rejected notwithstanding any previous certification.

(IACS UR W8 8.5)

10.6 Retests in the event of failure

10.6.1 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 Section 2, H. may be applied.

(IACS UR W8 7.4)

10.6.2 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.

(IACS UR W8 7.5)

10.6.3 At the option of the manufacturer, when a casting or batch of castings has failed to meet the test requirements, it may be reheat treated but it may not be solution treated or re-austenitized more than twice. All the tests previously performed shall be repeated after reheat treatment and the results shall meet the specified requirements.

(IACS UR W8 7.6)

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.

(IACS UR W8 10.1)

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

— Test pressure, where applicable

(IACS UR W8 10.2)

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.

(IACS UR W8 10.3)

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

— new building and project number, as applicable, if known

— nature of castings and grade of cast steel

— purpose and drawing number, if necessary

— ptem numbers and numbers of units

— weight of delivery

— method of manufacture

— heat numbers

— chemical composition

— details of heat treatment, including temperatures and holding times

— test pressures, where applicable

— results of the mechanical tests

— results of any special tests applied, e.g. non-destructive testings and test of resistance to inter-crystalline corrosion.

(IACS UR W8 11.1)

13. Repair of defects

13.1 General

13.1.1 Where castings are to be repaired, the manufacturer shall exercise robust controls of all repair operations regarding the repair of castings, with respect to dimensions, heat treatment, inspection and quality control.

13.1.2 The approval of BKI is to be obtained where steel castings from which defects were removed are to be used with or without weld repair.

13.1.3 Defective parts of material may be removed by grinding, or by chipping and grinding, or by arc air-gouging and grinding. Thermal methods of metal removal of defects and weld repair shall only be allowed before the final heat treatment. All grooves shall have a bottom radius of approximately three times the groove depth and should be smoothly blended to the surface area with a finish equal to that of the adjacent surface.

13.1.4 Where the defective area is to be repaired by welding, the excavations are to be suitably shaped to allow good access for welding. The resulting grooves are to be subsequently ground smooth and complete elimination of the defective material is to be verified by magnetic particle test or liquid penetrant test.

13.1.5 Shallow grooves or depressions resulting from the removal of defects may be accepted provided that they will cause no appreciable reduction in the strength of the casting. or affect the intended use, and the depth of defect removal is not over 15 mm or 10% of wall thickness, whichever is less. The resulting grooves or depressions are to be subsequently ground smooth and complete elimination of the defective material is to be verified by magnetic particle test or liquid penetrant test. Small surface irregularities sealed by welding are to be treated as weld repairs, see 13.2.

(IACS UR W8 9.1)

13.2 Weld Repairs

In addition to the requirements given in 13.1, the following apply for weld repairs:

13.2.1 For C and C-Mn steel castings weld repairs shall be suitably classified as major or minor. For alloy steel castings, repair requires approval from BKI.

a) Major repairs are those where:

  — The depth is greater than 25% of the wall thickness or 25 mm whichever is less, or
  — The total weld area on a casting exceeds 0,125 m^2 of the casting surface noting that where a distance between two welds is less than their average width, they are to be considered as one weld.

b) Weld repairs not classified as major are considered as minor and need to be carried out in accordance with a qualified welding procedure.

(IACS UR W8 9.2(i))

13.2.2 The following is required for major repairs:

a) Shall be carried out before the final delivery heat treatment condition

b) Shall comply with the requirements in 13.2.4

c) Before welding is started, full details of the extent and location of the repair, the proposed welding procedure, heat treatment and subsequent inspection procedures are to be submitted for approval.

(IACS UR W8 9.2(ii))

13.2.3 The following is required for minor repairs:

a) Shall be carried out before the final delivery heat treatment condition

b) Shall comply with the requirements in 13.2.4 (also with respect to records, see 13.2.4.f) and g)).

c) With the exception of alloy steels, do not require prior approval by BKI, except as given in d).

d) BKI may request minor repairs in critical areas to be treated as major repairs.

(IACS UR W8 9.2(iii))

13.2.4 The following requirements apply for all weld repairs (major and minor):

a) Steel castings shall be suitably preheated for welding. The level of preheating shall be deter-mined in each case by reference to the chemical composition, the carbon equivalent and the wall thickness. All castings in alloy steels and all castings for crankshafts are to be suitably pre-heated prior to welding. Castings in carbon or carbon-manganese steel may also require to be pre-heated depending on their chemical composition and the dimensions and position of the weld repairs. 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.

b) Welding procedures are to be qualified and shall match the delivery condition of the casting. Qualification of welding procedures shall follow Rules for Welding (Pt.1 Vol.VI) Section 12, F. or, subject to agreement with BKI, a recognized standard e.g. ISO 11970:2016.

Note:

For steels with C ≥ 0,23 or C_{eq} ≥ 0,45, the WPQT on which the WPS is based should be qualified on a base material having a C_{eq} not fall below more than 0,02 of the material to be welded. (e.g. WPQT for a material with actual C_{eq} = 0,50 may be qualified on a material with C_{eq} ≥ 0,48.)

c) 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 feasible, welding shall be performed in the downhand position.

d) The filler materials to be used shall produce a weld deposit with mechanical characteristics similar and in no way inferior to those of the parent 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 controlled, low hydrogen content. Welding procedure tests are to be carried out by the manufacturer to demonstrate that satisfactory mechanical properties can be obtained after heat treatment.

e) When repair welding is done after the castings have been heat treated for mechanical properties, the repaired casting shall be given a furnace stress-relieving heat treatment. Unless otherwise agreed, stress-relieving heat treatment shall be carried out at a temperature in the range of 550°C to 620°C, except for quenched and tempered steels. Quenched and tempered steels shall be stress relieved at a temperature at least 30°C lower than the final tempering temperature, but not below 550°C. The type of heat treatment employed will be dependent on the chemical composition of the casting and the dimensions, positions and nature of the repairs. Subject to prior approval, local stress relieving heat treatment may be accepted for minor repairs. Special consideration may be given to the omission of stress relieving heat treatment for minor repairs in areas of low operating stress and provided that the combination of material and welding procedure is such that tensile residual stresses and hardness are minimised.

f) 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. Satisfactory results are to be obtained from all forms of non-destructive testing used.

g) The manufacturer is to maintain full records detailing the extent and location of repairs made to each casting and details of weld procedures and heat treatments applied for repairs. These records are to be available to the Surveyor and copies provided on request.

(IACS UR W8 9.2(iv))

B. Steel Castings for Machine Construction and Shipbuilding

1. Scope

These requirements are applicable to castings made of C, C-Mn, and alloyed grades of cast steel which are intended for the manufacture of components and structural parts in machine construction and shipbuilding, and offshore units for worldwide services as specified in the relevant requirements of BKI Rules for Classification and Construction.

These requirements also make consideration for grades that are intended for fabrication by welding, as well as grades not intended for welding.

(IACS UR W8 1.1)

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 and quenched and tempered cast steels conforming to EN 10293.

2.2 General-purpose cast steels with enhanced weldability and toughness conforming to EN 10213.

2.3 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 and 2.2 and their suitability has been confirmed by BKI. 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:

a) Carbon and carbon-manganese steels:

- fully annealed
- normalizing

— normalizing and tempering at temperature of not less than 550°C

— quenching and tempering at temperature of not less than 550°C

b) Alloy steels:

— normalizing

— normalizing and tempering at temperature of not less than 550°C

— quenching and tempering at temperature of not less than 550°C.

The condition of supply shall meet the design and application requirements. It is the manufacturer's responsibility to select the appropriate heat treatment method to obtain the required mechanical properties.

(IACS UR W8 5.1)

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. Unless otherwise approved, the heat treatment shall be performed at a temperature of at least 550°C followed by cooling in the furnace to below 300°C. 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.

(IACS UR W8 5.2)

4. Requirements applicable to the material

4.1 Chemical composition

4.1.1 The chemical compositions, including the grades of cast steel described in 2.3, are subject to the limits for the chemical composition of the heat specified in Table 7.1.

(IACS UR W8 4.2)

Where necessary or as agreed with BKI, the manufacturer may add suitable grain refining elements, e. g. aluminium.

(IACS UR W8 4.3)

4.1.2 For grades of cast steel conforming to 2.1 and 2.2, the limits for the chemical composition specified in the standards are applicable.

4.1.3 For cast alloy steels conforming to 2.3, the limits for the chemical composition specified in the recognized standards or material specifications shall apply.

Table 7.1: Chemical composition limits for hull and machinery steel casting [%]

Application	Steel Type	C max.	Si max.	Mn	S max.	P max.	Cu	Cr	Ni	Mo	Total residuals max.
Castings for non-welded construction	C, C-Mn	0,4	0,6	0,50 – 1,60	0,035	0,035	Max. 0,30	Max. 0,30	Max. 0,40	Max. 0,15	0,8
	Alloy	0,45	0,6	0,50 – 1,60	0,03	0,035	Min. 0,30 1)	Min. 0,40 1)	Min. 0,40 1)	Min. 0,15 1)	-
Castings for welded construction	C, C-Mn	0,23	0,6	0,50 – 1,60	0,035	0,035	Max. 0,30	Max. 0,30	Max. 0,40	Max. 0,15	0,8
	Alloy	alloying element values to be agreed with BKI									-

1) for alloy steel type, at least one of the elements shall comply with the minimum content.

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:

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

4.2 Mechanical and technological properties

4.2.1 For grades of cast steel conforming to 2.1 and 2.2, the requirements specified in the respective standards shall apply, see Table 7.2 (grades of cast steel conforming to EN 10293) and Table 7.3 (grades of cast steel conforming to EN 10213).

4.2.2 Other grades of cast steel as per 2.3 shall have the characteristic properties of the respective grade according to the standard or the specification. In addition, the minimum requirements for yield stress, elongation, reduction of area, and impact test energy values corresponding to steel types and different strength levels specified in Table 7.4 are to be complied with.

(IACS UR W8 7.1 7.3)

Table 7.2: Mechanical properties of cast steels conforming to EN 10293

Grade of cast steel	Heat treatment	Yield strength R_{eH} [N/mm^2] min.	Tensile strength R_m [N/mm^2] min.	Elongation A [%] min.	Reduction in area Z [%] min.	Impact energy [1)] KV [J] [2)] min.	
						t ≤ 30 mm [3)]	t >30 mm [3)]
GS–200	N	200	380	25	40	35	35
GS–240	N	230	450	22	31	27	27
G28Mn6	N	260	520	18	25	27	22
	QT	300	600	15	21	27	20

[1)] Testing temperature = room temperature
For castings for welded structures in shipbuilding the requirements according to Table 7.3 do apply.
[2)] Average value of 3 tests.
[3)] t = sample thickness.

Table 7.3: Mechanical properties of cast steels in the style of EN 10213

Grade of cast steel	Heat-treated condition [1)]	Wall thickness [mm]	Yield strength [2)] R_{eH} [N/mm^2] min.	Tensile strength R_m [N/mm^2]	Elongation A [%] min.	Impact energy KV [J] [3)] min.	Transition temp. T [27 J] [5)] ≈
GS-16Mn5	(N)	up to 50	260	430 – 600	25	65	–25°C
		Over 50 to 100	230	430 – 600	25	45	–15°C
GS-20Mn5	(N)	up to 50	300	500 – 650	22	55	–20°C
		over 50 to 100	260	500 – 650	22	40	–10°C
		over 100 to 160	(260) [4)]	480 – 630	20	35	0°C
		over 160	(240) [4)]	450 – 600	20	27	RT
GS-20Mn5	(Q+T)	up to 50	360	500 – 650	24	70	–30°C
		over 50 to 100	300	500 – 650	24	50	–20°C
		over 100 to 160	(280) [4)]	500 – 650	22	40	–10°C
		over 160	(260) [4)]	480 – 630	22	30	RT

[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 7.4: Mechanical properties of cast steels conforming to B.2.3

Application	Steel Type	Minimum tensile strength 1),2) R_m [N/mm^2]	Yield strength R_{eH} [N/mm^2] min.	Elongation A [%] min.	Reduction in area Z [%] min.	Impact energy 3)	
						Test Temp. (°C)	KV [J] min.
Castings for non-welded construction	C, C-Mn	400	200	25	40	AT 4)	27
		440	220	22	30		
		480	240	20	27		
		520	260	18	25		
		560	300	15	20		
		600	320	13	20		
	Alloy	550	340	16	35	AT 4)	27
		600	400	16	35		
		650	450	14	32		
		700	540	12	28		
Castings for welded construction	C, C-Mn	400	200	25	40	0	27
		440	220	22	30		
		480	240	20	27		
		520	260	18	25		
		560	300	15	20		
		600	320	13	20		
	Alloy	550	355	18	30	0	27
		600	400	16	30		
		650	450	14	30		
		700	540	12	28		

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.

3) Average value of 3 tests (individual value not less than 70%).

4) AT refers to Ambient Temperature (i.e. 23°C $\pm$ 5°C), which is specified in ISO 148-1:2016.

4.2.3 The cast steels shown in Table 7.4 may be supplied with to any specified minimum tensile strength within the limits specified in the table, but subject to any additional requirements of the relevant construction Rules.

(IACS UR W8 7.2)

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. One tensile test specimen shall be taken from each test sample. The test specimens shall be prepared in accordance with A.10.2.1.

(IACS UR W8 6.10)

5.2 Notched bar impact test

Notched bar impact testing shall be performed on each test sample. The test specimens shall be prepared in accordance with A.10.2.1. The type of specimen is governed by the relevant standard or specification.

(IACS UR W8 6.10)

5.3 Non-destructive testings

5.3.1 In case non-destructive testings 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 in the presence of the Surveyor. The test shall be performed with the casting in machined condition. The test pressure is to be 1,5 times the service pressure and for stern tubes uniformly 2 bars. The test pressure shall be kept for at least 10 min.

(IACS UR W8 8.4)

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 BKI as suitable for the intended application may be used. To this end, the engine manufacturer shall submit to BKI 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.2.3 and, for special quality steel castings, Table 7.4 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 BKI. The details of the approval test are established by BKI 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:

- fully annealed
- normalizing

- normalizing and tempering at temperature of not less than 550°C
- quenching and tempering at temperature of not less than 550°C

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 BKI 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 requirements 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.

The chemical composition of the commonly used grades of cast steel is given in Table 7.5 and the mechanical properties are stated in Table 7.6.

2.2 Ferritic grades of cast steel GS–200 and GS–240 conforming to EN 10293 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 7.5: Chemical composition (%) of the commonly used grades of cast steel conforming to EN 10213

Grade of cast steel	C	Si max.	Mn	P max.	S max.	Cr	Mo
GP240GH	0,18 – 0,23	0,6	0,50 – 1,20	0,03	0,020 [1]	—	—
GP280GH	0,18 – 0,25 [2]	0,6	0,80 – 1,20 [2]	0,03	0,020 [1]	—	—
G20Mo5	0,15 – 0,23	0,6	0,50 – 1,00	0,025	0,020 [1]	—	0,40 – 0,60
G17CrMo5-5	0,15 – 0,20	0,6	0,50 – 1,00	0,02	0,020 [1]	1,00 – 1,50	0,45 – 0,65
G17CrMo9-10	0,13 – 0,20	0,6	0,50 – 0,90	0,02	0,020 [1]	2,00 – 2,50	0,90 – 1,20

1) In the case of castings having a standard wall thickness of < 28 mm, 0,030% S 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 7.6: Mechanical properties of the commonly used grades of cast steel conforming to EN 10213

Grade of cast steel	Heat treatment symbol [1]	Thickness [mm] max.	Tensile test			Notch bar impact test
			$R_{p0,2}$ [N/mm^2] min.	R_m [N/mm^2]	A [%] min.	KV [2] [J] min.
GP240GH	N	100	240	420 – 600	22	27
	QT					40
GP280GH	N	100	280	480 – 640	22	27
	QT					35
G20Mo5	QT	100	245	440 – 590	22	27
G17CrMo5-5	QT	100	315	490 – 690	20	27
G17CrMo9-10	QT	100	400	590 – 740	18	40

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 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 BKI, 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 to be in accordance with relevant standard or specification, e.g. ASME Section I.

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. In addition the requirements as stated in Section 3 shall be observed.

E. Steel Castings for Use at Low Temperatures

1. Scope

These requirements 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 7.7 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. The chemical composition of commonly used grades of cast steel is shown in Table 7.8 and the mechanical properties are stated in Table 7.9.

Table 7.7: Approved grades of cast steels for use at low temperatures

Grades of cast steel	Permitted minimum design temperature	Designation or material No.	Standard
Weldable cast carbon-manganese steel	–20°C [1]	G17Mn5	EN 10213
	–40°C [1]	G20Mn5	EN 10213
1,5% cast nickel steel	–40°C [1]	GS-10Ni6	SEW 685
2,25% cast nickel steel	–65°C	G9Ni10	EN 10213
3,5% cast nickel steel	–90°C	G9Ni14	EN 10213
Austenitic grades of cast steel	–165°C	1.4308 [2]	EN 10213
		1.4408	EN 10213
		1.4581 [3]	EN 10213

Table 7.8: Chemical composition [%] of the commonly used grades of cast steel conforming to EN 10213

Grades of cast steel	C	Si max.	Mn	P max.	S max.	Ni
G17Mn5	0,15 – 0,20	0,6	1,00 – 1,60	0,02	0,020 [1]	—
G20Mn5	0,17 – 0,23	0,6	1,00 – 1,60	0,02	0,020 [1]	max. 0,80
G9Ni10	0,06 – 0,12	0,6	0,50 – 0,80	0,02	0,015	2,00 – 3,00
G9Ni14	0,06 – 0,12	0,6	0,50 – 0,80	0,02	0,015	3,00 – 4,00

[1] For castings having a standard wall thickness of < 28 mm, 0,030% S is permissible.

Table 7.9: Mechanical properties of the commonly used grades of cast steel conforming to EN 10213

Grade of cast steel	Heat treatment symbol [1]	Thickness [mm] max.	Tensile test at room temperature			Notched bar impact test [2]	
			$R_{p0,2}$ [N/mm^2] min.	R_m [N/mm^2]	A [%] min.	KV [J] min.	Test temp. [°C]
G17Mn5	QT	50	240	450 – 600	24	27	– 40
G20Mn5	N	30	300	480 – 620	20	27	– 30
	QT	100		500 – 650	22		– 40
G9Ni10	QT	35	280	480 – 630	24	34	– 70
G9Ni14	QT	35	360	500 – 650	20	34	– 95

[1] N = denotes normalizing, QT = denotes quenching and tempering

[2] Required impact energy value shown in Table 7.11 shall be complied with.

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 7.9.

4. External and internal condition

The external and internal condition shall be subject to quality levels in accordance with Table 7.10 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 7.10.

5. Requirements applicable to the material

5.1 General requirements

The chemical composition and the mechanical proper- ties are subject to the requirements specified in the standards or the approved specifications (see Tables 7.8 and Table 7.9).

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 7.11 for the relevant grades of cast steel shall be met at the test temperatures stated in the table, using Charpy V-notch specimens.

6. Testing

The castings shall be presented for testing in finished condition (condition of supply) and shall undergo the following tests.

Table 7.10: Assignment of quality levels

Minimum design temperature t [°C]	Quality level according to: [1),2),3),4)]
≥ –105	SM4, LM4, AM4 [1)], SP4, CP3, LP4, AP4 [2)], UV4 [3)], RV4 [4)]
< –105	SM3, LM3, AM3 [1)], SP3, CP3, LP3, AP3 [2)], UV3 [3)], RV3 [4)]
Welding edges [5)]	SM01 [1)] CP01 [2)]

1) EN 1369.
2) EN 1371-1.
3) EN 12680-2.
4) EN 12681 and former EN 1559-2.
5) For surface crack detection linear indications are not allowed.

Table 7.11: Required impact energy values at low temperatures

Grade of cast steel	Notched bar impact test	
	Test temp. [°C]	Impact energy KV [J] [1)] min.
Weldable cast carbon manganese steel	5 K below minimum design temp., not exceeding −20°C	27 (19)
1,5 % cast nickel steel		34 (24)
2,25 % cast nickel steel	−70°C	34 (24)
3,5 % cast nickel steel	−95°C	34 (24)
Austenitic grades of cast steel [2)]	−196°C	41 (27) [3)]

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 7.13.

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 in compliance with the prescribed test temperature according to Table 7.11. 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. In addition the rules as stated in Section 3 shall be observed.

F. Stainless Steel Castings

1. Scope

These requirements 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 requirements also apply to sleeves and bushes for propeller shafts and rudder stocks.

These requirements 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, 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 7.12 and the mechanical properties are given in Table 7.13.

2.2 Other stainless steels conforming to other standards or specifications after their suitability has been established by BKI. 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. 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 7.13 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 Guidance for Marine Industry (Pt.1, Vol.AC), Sec.4.R-69. does apply.

6. Requirements applicable to the material

6.1 Chemical composition

6.1.1 The limits stated in Table 7.12 and/or the specifications approved by BKI 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.

Table 7.12: Chemical composition [%] of suitable grades of cast steel in dependence on EN 10213 and EN 10283

Designation		C	Si	Mn	P	S	Cr	Mo	Ni	Cu	Other elements
Grade of cast steel	Material no.	max.	max.	max.	max.	max.					
GX2CrNi19-11 [1)]	1.4309 [1)]	0,03	1,5	2	0,035	0,025	18,00 to 20,00	-	9,00 to 12,00	-	N: max. 0,20
GX5CrNi19-10 [1)]	1.4308 [1)]	0,07	1,5	1,5	0,04	0,03	18,00 to 20,00	-	8,00 to 11,00	-	-
GX5CrNiNb19-11 [1)]	1.4552 [1)]	0,07	1,5	1,5	0,04	0,03	18,00 to 20,00	-	9,00 to 12,00	-	Nb: 8 x C max. 1,00
GX2CrNiMo19-11-2 [1)]	1.4409 [1)]	0,03	1,5	2	0,035	0,025	18,00 to 20,00	2,00 to 2,50	9,00 to 12,00	-	N: max. 0,20
GX5CrNiMo19-11-2 [1)]	1.4408 [1)]	0,07	1,5	1,5	0,04	0,03	18,00 to 20,00	2,00 to 2,50	9,00 to 12,00	-	-
GX5CrNiMoNb19-11-2 [1)]	1.4581 [1)]	0,07	1,5	1,5	0,04	0,03	18,00 to 20,00	2,00 to 2,50	9,00 to 12,00	-	Nb: 8 x C max. 1,00
GX2NiCrMo28-20-2 [1)]	1.4458 [1)]	0,03	1	2	0,035	0,025	19,00 to 22,00	2,00 to 2,50	26,00 to 30,00	max. 2,00	N: max. 0,20
GX2CrNiMoN22-5-3	1.447	0,03	1	2	0,035	0,025	21,00 to 23,00	2,50 to 3,50	4,50 to 6,50	-	N: 0,12 to 0,20
GX2CrNiMoCuN25-6-3-3	14.517	0,03	1	1,5	0,035	0,025	24,50 to 26,50	2,50 to 3,50	5,00 to 7,00	2,75 to 3,50	N: 0,12 to 0,22
GX2CrNiMoN26-7-4 [2)]	1.4469 [2)]	0,03	1	1	0,035	0,025	25,00 to 27,00	3,00 to 5,00	6,00 to 8,00	max. 1,30	N: 0,12 to 0,22

1) According to the intended purpose, e.g. at high or low temperature, 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” Pf = Cr + 3,3 Mo + 16 N ≥ 40 may be called for.

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:

$$\text{W}\ [\%] = [\%]\text{Cr} + 3,3 \times [\%]\text{Mo}$$

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 7.13 or in the approved specifications are applicable.

Table 7.13: Mechanical properties of suitable grades of cast steel

Designation	Material No.	Heat treatment + AT [1)] [°C]	Thickness [mm] max.	Tensile test at room temperature			Notched bar impact test
				$R_{p1,0}$ [4)] [N/mm^2] min.	R_m [N/mm^2]	A [%] min.	KV [6)] [J] min.
GX2CrNi19-11	1.4309	1050 – 1150	150	210	440 – 640	30	80
GX5CrNi19-10	1.4308	1050 – 1150	150	200	440 – 640	30	60
GX5CrNiNb19-11	1.4552	1050 – 1150	150	200	440 – 640	25	40
GX2CrNiMo19-11-2	1.4409	1080 – 1150	150	220	440 – 640	30	80
GX5CrNiMo19-11-2	1.4408	1080 – 1150	150	210	440 – 640	30	60
GX5CrNiMoNb19-11-2	1.4581	1080 – 1150	150	210	440 – 640	25	40
GX2NiCrMo28-20-2	1.4458	1100 – 1180	150	190	430 – 630	30	60
GX2CrNiMoN22-5-3	1.4470	1120 – 1150 [2),3)]	150	420 [5)]	600 – 800	20	30
GX2CrNiMoCuN25-6-3-3	1.4517	1120 – 1150 [2),3)]	150	480 [5)]	650 – 850	22	50
GX2CrNiMoN26-7-4	1.4469	1140 – 1180 [2),3)]	150	480 [5)]	650 – 850	22	50

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 1040°C and 1010°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 approved 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. The scope of testing shall be approved by BKI. In addition the Rules as stated in Section 3 shall be observed.

G. Non-destructive Testing of Cast Steel Components

For non-destructive testing of cast steel components see Guidance for Marine Industry (Pt.1, Vol.AC), Sec.4.R-69.

H. List of Cast Steel Components for which Non-Destructive Tests are Required

Table 7.14: Test methods to be employed

Name of the component	Test methods to be employed [1]				
	VT	MT	PT	UT	RT
Structural parts concerning the hull					
Stern	X	X	(X) [2]	X	X
Propeller shaft-nut	X	X	(X) [2]	X	X
Rudder horn	X	X	(X) [2]	X	X
Rudder bearing	X	X	(X) [2]	–	–
Rudder coupling	X	X	(X) [2]	X	X
Shaft bracket	X	X	(X) [2]	X	–
Ruder shaft	X	X	–	X	–
Tiller	X	X	(X) [2]	X	–
Diesel engine parts					
Piston crowns	X	X [5]	–	X [5]	–
Cylinder covers	X	X [5]	–	X [5]	–
Camshaft drive gear wheels and chain wheels	X	X [5]	–	X	–
Crank webs and throws	X	X	–	X	–
Connecting rods	X	X	–	X	–
Bearing transverse girders	X	X	–	X	–
Main bearings and bearing covers for main, crossheads and piston rod bearings	X	X	–	X	–
Starting valve casings	X	X	–	–	X
Further components of the propulsion plant					
Turbine casings	X	X	–	X	X
Gear wheels	X	X	–	X	X
Valve casings					
Valve casings for pipe class I [3] with DN ≥ 100	X	X	–	–	X [4]

[1] Testing in the prescribed areas.

[2] PT may be employed instead of MT.

[3] Compare Rules for Machinery Installations (Pt.1, Vol.III) Sec.11.A.3.

[4] Random testing according to testing plan

[5] For diesel engines with cylinder diameter > 400 mm.

I. Testing Instructions for Hull Structural Parts

For testing instructions for hull structural parts see Guidance for Marine Industry (Pt.1, Vol.AC), Sec.4.R-69.

J. Testing Instruction for Diesel Engine Parts

In the Fig. 7.3 and Fig. 7.4 the specifications for the non-destructive testings are prescribed.

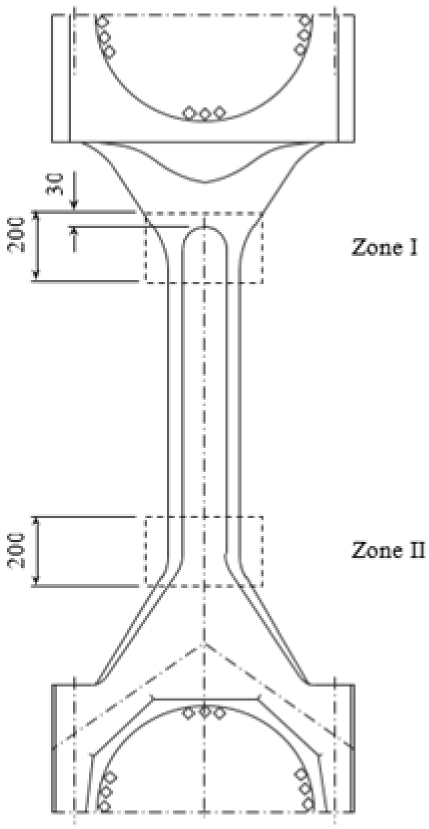


Figure 7.3: Testing instruction for connecting rods

Testing scope :	
Visual testing	entire surface
Magnetic particle testing	entire surface
Ultrasonic testing	shaft and bearing areas
Penetrant testing	machined bearing surface (◇◇◇◇◇◇)
Severity levels :	
Visual testing	V1 for zone I and II; V3 for the remaining areas
Magnetic particle testing	SM1; LM1; AM1 for zone I and II; remaining areas SM2, LM2, AM2
Ultrasonic testing	UV1 for zone I and II: UV2 for remaining areas
Penetrant testing	SP2, CP2, LP2, AP2 for areas marked with (◇◇◇◇◇◇)

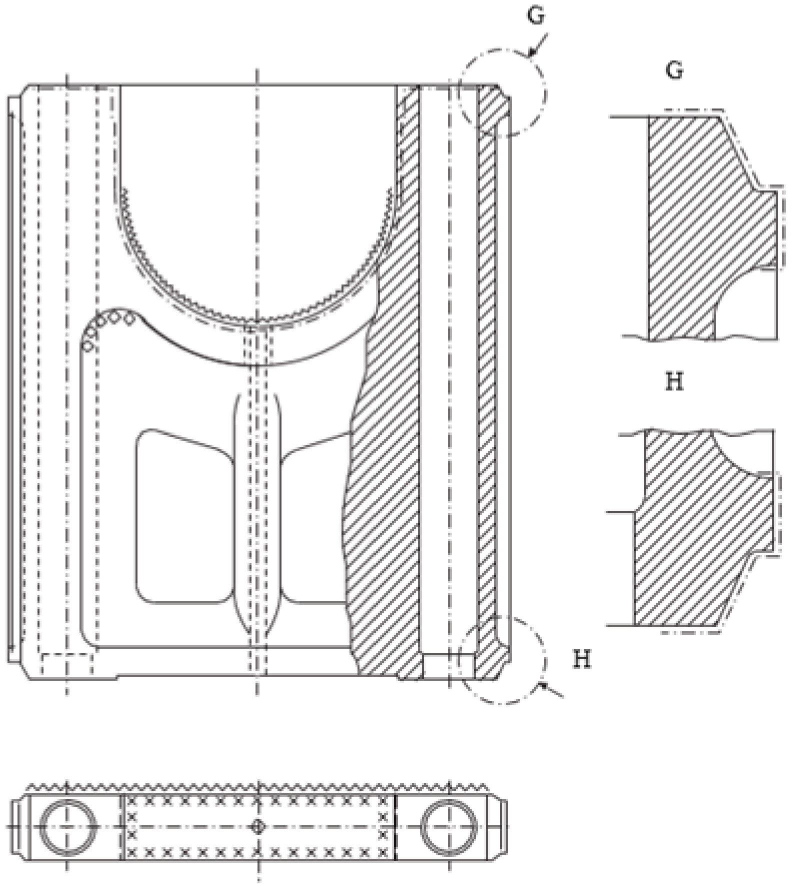


Figure 7.4: Testing instruction for main bearing support

Testing scope :	
Visual testing	entire surface
Magnetic particle testing	welding edges (-·-·-·-·-·-·), (◇◇◇◇◇◇)
Ultrasonic testing	marked areas with (vvvvvvvv)
Penetrant testing	marked areas with (××××××)
Severity levels :	
Visual testing	V1 for areas marked with (-·-·-·-·-·-·), remaining areas V2
Magnetic particle testing	SM1; LM1; AM1, for areas marked with (-·-·-·-·-·-·);
	SM2; LM2; AM2, for areas marked with (◇◇◇◇◇◇)
Ultrasonic testing	UV1 for the areas marked with (-·-·-·-·-·-·)
	UV2 for the areas marked with (vvvvvvvv)
Penetrant testing	SP2, CP2, LP2, AP2 for areas marked with (××××××)

Section 8 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 BKI 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 BKI. This is conditional upon their fulfilling the manufacturing and quality control requirements stated in Section 1, C. and furnishing proof of this to BKI 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 BKI 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.

Cast crankshaft made from nodular cast iron are to be subjected to a magnetic particle inspection. Crack like indications are not allowed.

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. BKI 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.

4.5 In the event of any casting proving defective during subsequent machining or testing it is to be rejected notwithstanding any previous certification

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. When two or more test samples are cast simultaneously in a single mould, the bars are to be at least 50 mm apart.

8.2.4 Type, quantity and location of the respective samples are to be agreed between purchaser 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. The type and location of the samples are to be selected to provide approximately the same cooling conditions as for the casting it represents. 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 BKI 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 BKI 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 BKI, 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.

8.2.10 In case nodular cast iron produced in large castings where more than one ladle of treated metal is used, additional test samples are to be provided so as to be representative of each ladle used.

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. The surfaces are not to be hammered, peened or treated in any way which may obscure defects.

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 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:

— 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.

13.3 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 iT

— application and drawing number, if necessary

— weight of products

— manufacturing process

— heat number or identifying mark

— chemical composition

— 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 requirements 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 BKI.

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 Nodular cast iron of grades EN-GJS-350-22-LT/-22U-LT to EN-GJS-400-18-LT/-18U-LT or the special qualities according to Table 8.1 with nominal strengths of 350 and 400 N/mm^2 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.

3.4 Where it is proposed to locally harden the surfaces of a casting full details of the proposed procedure and specification are to be submitted for approval by the BKI.

4. Requirements applicable to the material

4.1 Nodular cast iron conforming to EN 1563

The requirements specified in the standard and given in Table 8.2 for separately cast samples and in Table 8.3 for integrally cast samples are applicable.

In case of requirements regarding impact energy, the minimum values specified in Table 8.4 and 8.5 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 8.1 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 8.1.

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 8.1. 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 8.1: Mechanical properties and structure of nodular cast iron

Minimum tensile strength R_m [1)] [N/mm^2]		$R_{p0,2}$ [N/mm^2] min.	A [%] min.	Hardness HB 10 [2)] min.	Impact energy		Structure of metallic matrix
					Test temp. [°C]	KV [3)] [J] min.	
Ordinary qualities	370	230	17	120 – 180	—	—	Ferrite
	400	250	15	140 – 200	—	—	Ferrite
	450	310	10	160 – 210	—	—	Ferrite
	500	320	7	170 – 240	—	—	Ferrite/pearlite
	600	370	3	190 – 270	—	—	Ferrite/pearlite
	700	420	2	230 – 300	—	—	Perlite
	800	480	2	250 – 350	—	—	Perlite/sorbite
Special qualities	350	220	22 [4)]	110 – 170	– 20	17 (14)	Ferrite
	400	250	18 [4)]	140 – 200	– 20	14 (11)	Ferrite

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 8.2: Mechanical properties determined from samples of separately cast test specimens

Material designation		Tensile strength R_m [N/mm^2] min.	0,2-proof stress $R_{p0,2}$ [N/mm^2] min.	Elongation A [%] min.	Main structure of metallic matrix
Material code	Number				
EN-GJS-350-22-LT [1)]	EN-JS1015	350	220	22	Ferrite
EN-GJS-350-22-RT [2)]	EN-JS1014	350	220	22	Ferrite
EN-GJS-350-22	EN-JS1010	350	220	22	Ferrite
EN-GJS-400-18-LT [1)]	EN-JS1025	400	240	18	Ferrite
EN-GJS-400-18-RT [2)]	EN-JS1024	400	250	18	Ferrite
EN-GJS-400-18	EN-JS1020	400	250	18	Ferrite
EN-GJS-400-15	EN-JS1030	400	250	15	Ferrite
EN-GJS-450-10	EN-JS1040	450	310	10	Ferrite
EN-GJS-500-7	EN-JS1050	500	320	7	Perlite/Ferrite
EN-GJS-600-3	EN-JS1060	600	370	3	Perlite/Ferrite
EN-GJS-700-2	EN-JS1070	700	420	2	Perlite
EN-GJS-800-2	EN-JS1080	800	480	2	Perlite

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 conductibility.

Table 8.3: Mechanical properties determined from samples of integrally cast test specimens

Material designation		Determining wall thickness t [mm]	Tensile strength R_m [N/mm^2] min.	0,20% Proof stress $R_{p0,2}$ [N/mm^2] min.	Elongation A [%] min.
Material code	Number				
EN-GJS-350-22U-LT 1)	EN-JS1019	t ≤ 30	350	220	22
		30 < t ≤ 60	330	210	18
		60 < t ≤ 200	320	200	15
EN-GJS-350-22U-RT 2)	EN-JS1029	t ≤ 30	350	220	22
		30 < t ≤ 60	330	220	18
		60 < t ≤ 200	320	210	15
EN-GJS-350-22U	EN-JS1032	t ≤ 30	350	220	22
		30 < t ≤ 60	330	220	18
		60 < t ≤ 200	320	210	15
EN-GJS-400-18U-LT 1)	EN-JS1049	t ≤ 30	400	240	18
		30 < t ≤ 60	390	230	15
		60 < t ≤ 200	370	220	12
EN-GJS-400-18U-RT 2)	EN-JS1059	t ≤ 30	400	250	18
		30 < t ≤ 60	390	250	15
		60 < t ≤ 200	370	240	12
EN-GJS-400-18U	EN-JS1062	t ≤ 30	400	250	18
		30 < t ≤ 60	390	250	15
		60 < t ≤ 200	370	240	12
EN-GJS-400-15U	EN-JS1072	t ≤ 30	400	250	15
		30 < t ≤ 60	390	250	14
		60 < t ≤ 200	370	240	11
EN-GJS-450-10U	EN-JS1132	t ≤ 30	450	310	10
		30 < t ≤ 60	to be agreed		
		60 < t ≤ 200			
EN-GJS-500-7U	EN-JS1082	t ≤ 30	500	320	7
		30 < t ≤ 60	450	300	7
		60 < t ≤ 200	420	290	5
EN-GJS-600-3U	EN-JS1092	t ≤ 30	600	370	3
		30 < t ≤ 60	600	360	2
		60 < t ≤ 200	550	340	1
EN-GJS-700-2U	EN-JS1102	t ≤ 30	700	420	2
		30 < t ≤ 60	700	400	2
		60 < t ≤ 200	660	380	1
EN-GJS-800-2U	EN-JS1112	t ≤ 30	800	480	2
		30 < t ≤ 60	to be agreed		
		60 < t ≤ 200			

1) LT for low temperatures.

2) RT for room temperature.

Table 8.4: Minimum values for impact energy determined from samples with V-notch from separately cast test specimens

Material designation		Minimum value for impact energy [J]					
		at RT (23 ± 5)°C		at (-20 ± 2)°C		at (-40 ± 2)°C	
Material code	Number	Average value from 3 tests	Individual value	Average value from 3 tests	Individual value	Average value from 3 tests	Individual value
EN-GJS-350-22-LT [1)]	EN-JS1015	-	-	-	-	12	9
EN-GJS-350-22RT [2)]	EN-JS1014	17	14	-	-	-	-
EN-GJS-400-18-LT [1)]	EN-JS1025	-	-	12	9	-	-
EN-GJS-400-18-RT [2)]	EN-JS1024	14	11	-	-	-	-

[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 conductibility.

Table 8.5: Minimum values for impact energy determined from samples with V-notch from integrally cast test specimen

Material designation		Determining wall thickness t [mm]	Minimum value from inpact energy [J]					
			at RT (23 ± 5)°C		at (-20 ± 2)°C		at (-40 ± 2)°C	
Material code	Number		Average value from 3 tests	individual value	Average value from 3 tests	individual value	Average value from 3 tests	individual value
EN-GJS-350-22U-LT [1)]	EN-JS1019	t ≤ 60	–	–	–	–	12	9
		60 < t ≤ 200					10	7
EN-GJS-350-22U-RT [2)]	EN-JS1029	t ≤ 60	17	14	–	–	–	–
		60 < t ≤ 200	15	12				
EN-GJS-400-18U-LT [1)]	EN-JS1049	30 < t ≤ 60	–	–	12	9	–	–
		60 < t ≤ 200			10	7		
EN-GJS-400-18U-RT [2)]	EN-JS1059	30 < t ≤ 60	14	11	–	–	–	–
		60 < t ≤ 200	12	9				

[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. 8.1 and 8.2 respectively or from an integrally cast sample piece according to Fig. 8.3. 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.

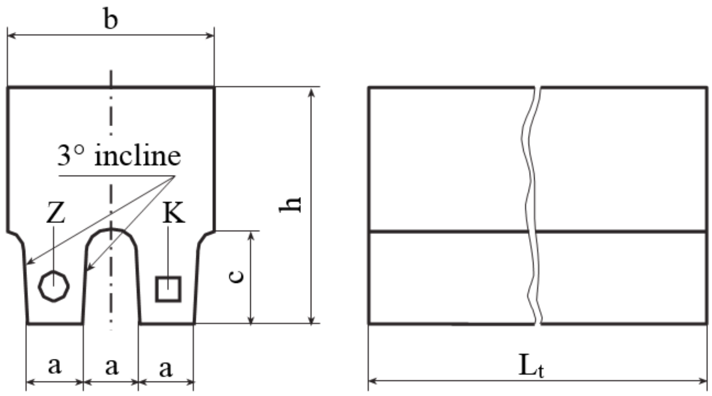
— Where heat treatments are carried out, integrally cast samples may be removed from the casting only after heat treatment. Separately cast samples shall be heat treated together with the casting.

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 Tables 8.1, 8.4 and 8.5 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.



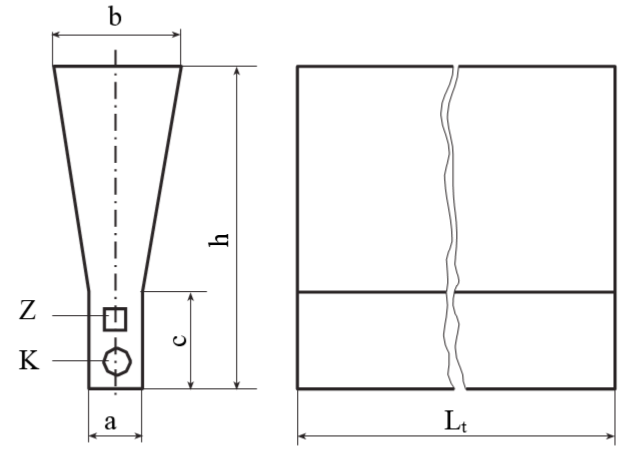
Dimensions

a	=	25	mm
b	=	90	mm
c	=	40	mm
h	=	100	mm
Lt	≥	200	mm to suit testing machine

Location of specimen

Z	=	tensile test specimen
K	=	impact test specimen

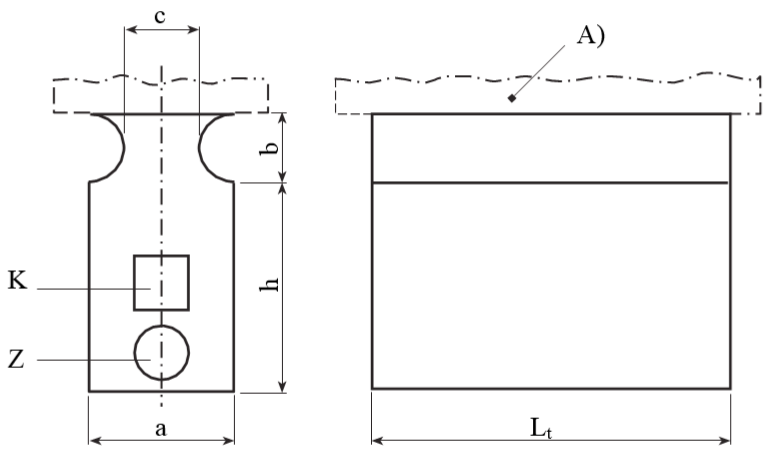
Figure 8.1: U-Type sample piece



Location of specimen
Z = tensile test specimen
K = impact test specimen

Dimension	Sizes in [mm] for samples of type			
	Y 1	Y 2	Y 3	Y 4
a	12	25	50	75
b	40	55	100	125
c	25	40	50	65
h	135	140	150	175
L_t	≥ 200			

Figure 8.2: Y-type sample piece



Location of specimen
Z = tensile test specimen
K = impact test specimen

A) Casting unit (or cast system)

Dimension in mm

Type	Determining wall thickness of casting unit t	a	b	c	h	L_t
I	30 < t ≤ 60	40	30	20	40 to 60	≥ 200
II	60 < t ≥ 200	70	52,5	35	70 to 105	≥ 200
If smaller dimensions are agreed, the following correlations apply: b = 0,75 x a and c = a/2						

Figure 8.3: Integrally cast test specimens

C. Grey Cast Iron

1. Scope

1.1 These requirements 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_m:

200 N/mm^2

250 N/mm^2

300 N/mm^2

350 N/mm^2

Castings with minimum tensile strength values of < 200 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 8.6. The requirements for specimens taken from the casting (e.g. core specimens) shall be specially agreed between manufacturer and purchaser as well as BKI.

4.2 Graphite and matrix structure

The method of manufacture shall ensure that the graphite is present in uniformly distributed flakes and 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 granular and uniform grey crystalline appearance.

Table 8.6: Tensile strength of grey cast iron

Material designation		Determining wall thickness [mm]		Tensile strength R_m values to comply with	
Material code	Number	over	Up to	In separately cast test speciments [N/mm^2]	In integrally cast test speciments [N/mm^2] min.
EN-GJL-200	EN-JL1030	2,5 [2)]	5	200 – 300 [3)]	–
		5	10		–
		10	20		–
		20	40		170
		40	80		150
		80	150		140
		150	300		130 [1)]
EN-GJL-250	EN-JL1040	5 [2)]	10	250 – 350 [3)]	–
		10	20		–
		20	40		210
		40	80		190
		80	150		170
		150	300		160 [1)]
EN-GJL-300	EN-JL1050	10 [2)]	20	300 – 400 [3)]	–
		20	40		250
		40	80		220
		80	150		210
		150	300		190 [1)]
EN-GJL-350	EN-JL1060	10 [2)]	20	350 – 450 [3)]	–
		20	40		290
		40	80		260
		80	150		230
		150	300		210 [1)]

1) These values are guidance.

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.

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. 8.4 may be used as well as integrally cast specimens of type 2 according to DIN EN 1561, see also Fig. 8.5.

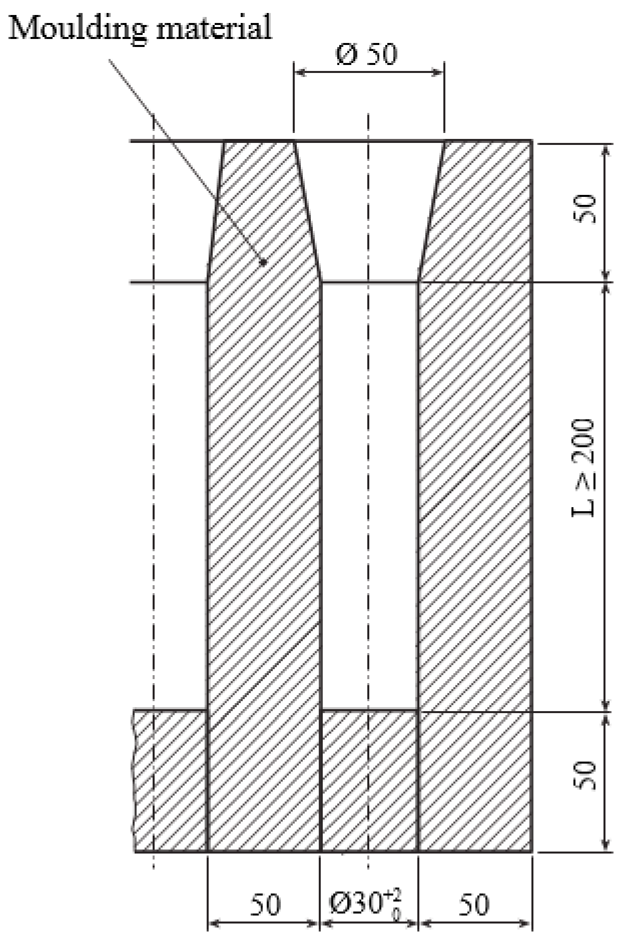


Figure 8.4: Mould for separately cast test specimen

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 Section 2, D.1.3.6.

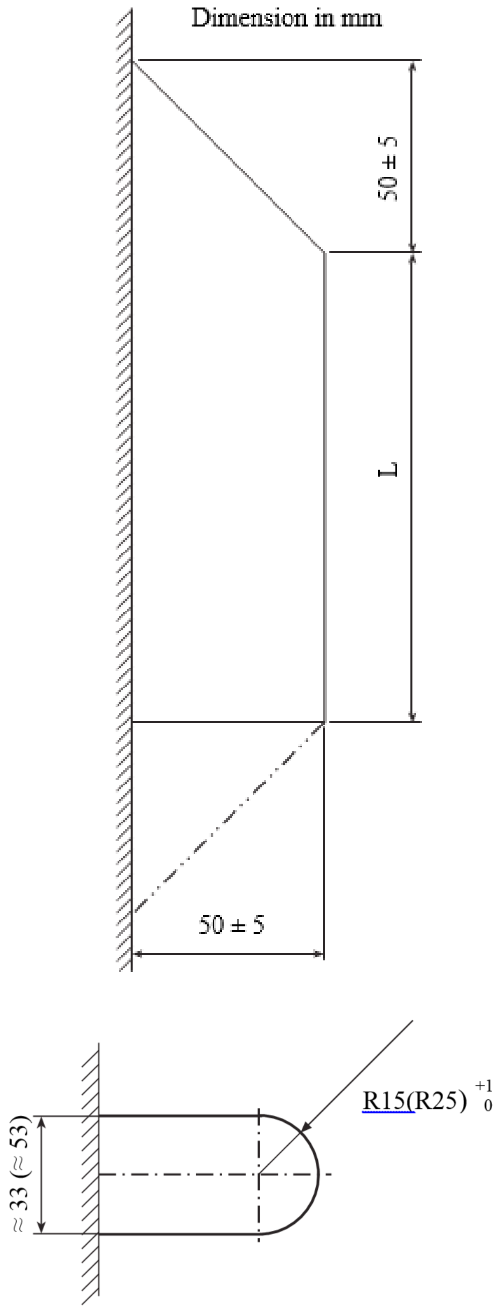
5.2.5 The following number of samples is to be provided:

- 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.

The details of 5.2.2 shall be observed in this connection.

Integrally cast sample pieces may be removed from the casting unit only after heat treatment.



The numbers in brackets apply to casting units with wall thickness larger or equal 80 mm

Figure 8.5: Integrally cast test specimen

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 9 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 BKI Rules for Welding (Pt.1, Vol.VI)

2. Requirements to be met by manufacturers

Manufacturers wishing to supply products in accordance with these Rules shall be approved by BKI. This is conditional upon their fulfilling the manufacturing and quality control requirements specified in Section 1, C. and furnishing proof of this to BKI 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 imparts 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 Ni19 and X8 Ni9), 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 BKI.

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 4. 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 $s > 0{,}05 \cdot D_m$ 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,
- if the degree of deformation exceeds 5% in the case of steel grades 12Ni14, 12Ni19, X7Ni9 and X8Ni9 conforming to EN 10028-4,

be subjected to heat treatment (normalizing or quenching and tempering) in accordance with the relevant standards or material specifications.

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 BKI 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.

7.2.2 Heat treatment of solution annealed and quenched or stabilization annealed material after cold forming may be dispensed with if:

.1 In the case of austenitic steels with required minimum elongation values A of ≥ 30% in respect of the initial material, the degree of deformation does not exceed 15% or proof is furnished that the residual elongation capacity A after cold forming is at least 15%. For size ranges in which the required minimum elongation values A are less than 30%, proof that the residual elongation capacity A is 15% is deemed to have been furnished if an elongation A of ≥ 30% is shown in the acceptance test certificate;

.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%;

.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:

— ≥ 40% for nominal wall thicknesses ≤ 15 mm at design temperatures down to −196°C,

— ≥ 45% for nominal wall thicknesses > 15 mm at design temperatures down to −196°C,

— ≥ 50% at design temperatures below −196°C;

.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 9.1, shall be taken from surplus material at the edges of the pressed parts or from cut-outs.

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 9.1 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 BKI may be dispensed with.

8.1.5 Instead of individual testing of the pressed parts, BKI may agree to testing by rolled plate (1 set of specimens per starting plate) provided that the manufacturer of the pressed parts demonstrates to BKI 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.

Table 9.1: Scope of tests on pressed parts made from plate

<table>
<tr><th colspan="2">Grade of steel</th><th>Base material according to Section 4 [1)]</th><th>Test performed on</th><th>Extend of tests on pressed parts</th></tr>
<tr><td colspan="2">All unalloyed steels with a minimum tensile strength ≤ 410 N/mm^2</td><td>C, E</td><td>starting plate</td><td>not required</td></tr>
<tr><td colspan="2">Unalloyed and fine-grained structural steels with a minimum tensile strength 410 < R_m ≤ 510 N/mm^2, and R_{eH} ≤ 355 N/mm^2, 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 colspan="2">Fine-grained structural steels, R_{eH} > 355N/mm^2</td><td>E</td><td>pressed part</td><td>1 set of specimens from each pressed part [2)]</td></tr>
<tr><td colspan="2">High-temperature CrMo alloy steels</td><td>E</td><td>pressed part</td><td>1 set of specimens from each pressed part [2)]</td></tr>
<tr><td colspan="2">Steels tough at sub-zero temperatures</td><td>F</td><td>pressed part</td><td>1 set of specimens from each pressed part [2)]</td></tr>
<tr><td colspan="5">Austenitic stainless steels:</td></tr>
<tr><td rowspan="2">Thickness [mm]</td><td>≤ 20</td><td rowspan="2">G</td><td>starting plate</td><td>not required</td></tr>
<tr><td>> 20</td><td>starting plate
pressed part</td><td>testing by batches</td></tr>
<tr><td colspan="2">Clad plates</td><td>H</td><td colspan="2">The extent of the test depends on the base material</td></tr>
<tr><td colspan="5">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.</td></tr>
</table>

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.

B. Pipe Fittings

1. Scope

1.1 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 4 or 5. Unless otherwise stipulated by BKI, the starting materials shall be ordered with inspection certificates conforming to EN 10204-3.1 from manufacturers approved by BKI.

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 BKI, 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 BKI for consideration. The nature and scope of the procedure approval inspection shall be determined by BKI 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 BKI 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 $r_m \geq 1{,}3 \cdot d_o$, subsequent heat treatment is not required if the outside diameter do is ≤ 133 mm. The same applies to all elbows manufactured with bending radii of $r_m \geq 2{,}5 \cdot d_o$.

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 9.2. A test batch in accordance with Table 9.2 consists of fittings made of the same materials and having the same dimensions, and, in the case of alloy steel fittings with a d_o > 100 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.

Table 9.2: Test batches for fittings

Size d_o (mm)	No. of fittings per test batch [1)]
< 100	≤ 200
≥ 100 up to < 225	≤ 100
≥ 225 up to < 350	≤ 50
≥ 350	≤ 25

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.

6.2.2 The scope of the mechanical tests is as shown in Table 9.3.

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 9.3: Classification into test groups and scope of tests

<table>
<tr><th rowspan="2">Test groups</th><th rowspan="2">Size
d_o
[mm]</th><th rowspan="2">Material</th><th colspan="3">Scope of tests per test batch</th></tr>
<tr><th>Hardness test 1)</th><th>Tensile test</th><th>Notched bar impact test 2)
(set of specimens = 3 specimens)</th></tr>
<tr><td>I</td><td>< 100</td><td>unalloyed</td><td rowspan="3">10 % 3)
min. on
3 fittings</td><td>1 4)</td><td rowspan="5">2 sets,
only if less than
10 fittings
1 set</td></tr>
<tr><td>II</td><td>< 100</td><td>alloyed</td><td>1 4)</td></tr>
<tr><td>III</td><td>≥ 100</td><td>unalloyed
R_m < 500 N/mm^2</td><td rowspan="3">2 specimens,
only if less than
10 fittings
1 specimen</td></tr>
<tr><td>IV</td><td>≥ 100
≤ 225
(DN ≤ 200)</td><td>unalloyed
R_m ≥ 500 N/mm^2</td><td>10 %
min on
3 fitting</td></tr>
<tr><td>V</td><td>> 225
(DN > 200)</td><td>alloyed</td><td>100% 5)</td></tr>
</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 ≥ 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.

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 Sections 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 BKI. 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 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 BKI 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 6, Table 6.2 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 6, 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 ≥ 14 %,
- Impact energy using Charpy V-notch specimen's ≥ 52 Joules for quenched and tempered steels and ≥ 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 6, Table 6.5 and Table 6.6

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 ≥ 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 9.4.

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 9.4: Batch sizes for the testing of mechanical properties

Quantity	No. of sets of specimens for mechanical testing
≤ 200	1
> 200 up to ≤ 400	2
> 400 up to ≤ 800	3
> 800 up to ≤ 1200	4
> 1200 up to ≤ 1600	5
> 1600 up to ≤ 3500	6
> 3500	7

5.3 For the tensile test, specimens may be machined from the sample material, or turned specimens of the type shown in Fig. 9.1 may be used.

5.4 Where no heat treatment is performed following 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 requires one set of test specimens to be taken from each test batch.

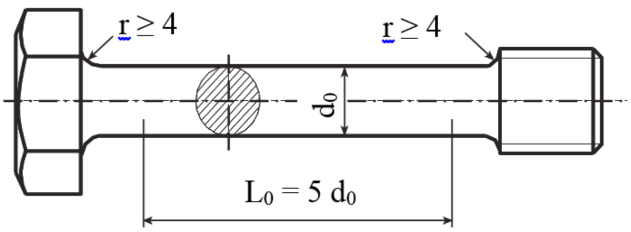


Figure 9.1: Turned specimen

5.5 Where machining is followed by heat treatment, 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 compliance 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 demonstrated by the manufacturer by means of hardness tests. For this purpose, at least 20 bolts from each test batch are to be tested and at least 10 bolts in the case of quantities ≤ 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 approximates most closely to the level of the operating temperature, rounded off to the nearest 50°C. The test may be dispensed with in the case of bolts to recognized standards, the high-temperature mechanical properties of which are regarded as proven.

6. Testing of nuts

6.1 Chemical composition

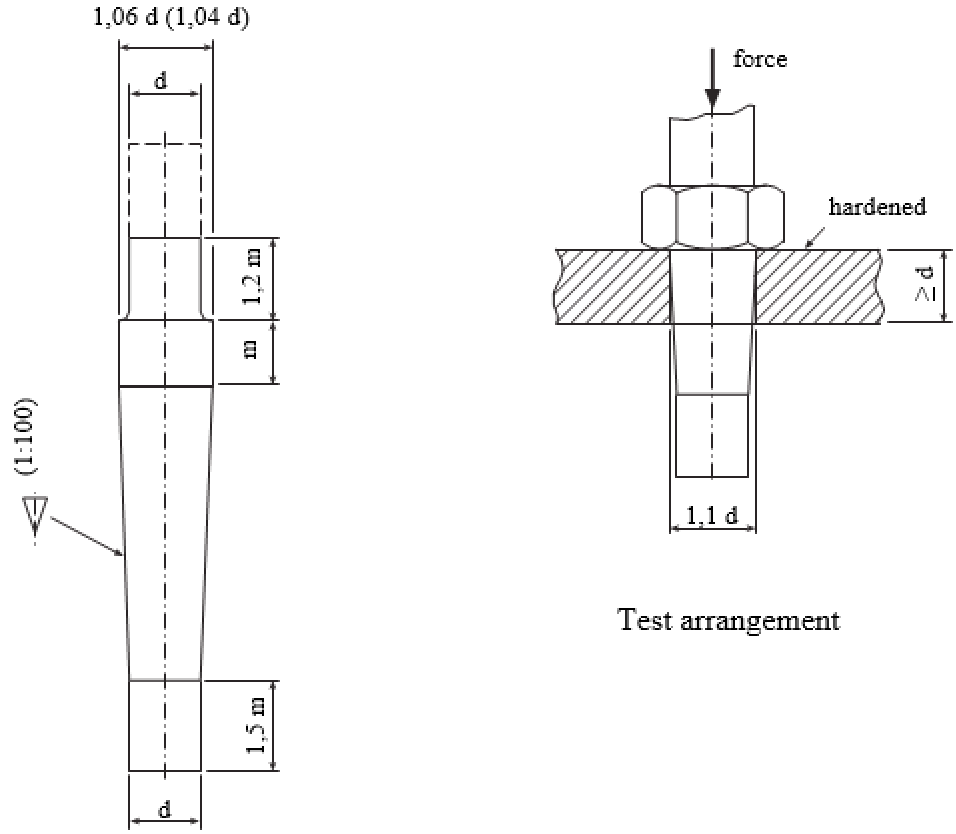
The chemical composition shall satisfy the stipulations according to Section 6, Table 6.2 and the relevant standards or specifications respectively.

6.2 Nuts with nominal thread diameters of up to and including 39 mm are to be subjected to the expansion test using a mandrel with a 1:100 taper, see Fig. 9.2. 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 9.4 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.

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.



Test mandrel for 6 % expansion (1,06 d) or

4 % expansion (1,04 d) of the nut

d = nominal threat diameter

m = nominal depth of nut

Figure 9.2: Expansion testing of nuts

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 $\leq$ 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 BKI 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 BKI 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.

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Section 10 Aluminium Alloys

A. Wrought Aluminium Alloys

1. Scope

1.1 These requirements are applicable to the wrought aluminium alloys which are described below and which are intended for the fabrication of ships' hulls, superstructures and other ship structures as well as for pipelines. They are also applicable to wrought aluminium alloys which are intended for the manufacture of systems designed to transport liquefied gases at low temperatures.

1.2 These Rules are applicable to products made from wrought aluminium alloys having a product thickness of 3 to 50 mm inclusive. Requirements applicable to products having thicknesses outside this range are to be specially agreed with BKI.

1.3 Alloys and material conditions which differ from the specified requirements given below, but which conform to national standards or the manufacturer's material specifications may be used provided that their properties and suitability for use, and also their weldability have been checked by BKI and that BKI has approved their use.

1.4 Alloy designations and material conditions which are indicated in these Rules, comply with the designations of the Aluminium Association.

1.5 With regard to the definition of the material conditions EN 515:2017 or ANSI H35.1:2017 is applicable.

2. Requirements to be met by manufacturers

Manufacturers wishing to supply products in accordance with these Rules shall be approved by BKI for the alloys and product forms in question. This is conditional upon their fulfilling the manufacturing and quality control requirements stated in Section 1, C. and furnishing proof of this to BKI prior to the commencement of supplies. BKI reserves the right to carry out performance tests on products selected for this purpose.

3. Manufacture and material condition

The starting material for rolled and pressed products is manufactured by continuous casting. Plates may be hot or cold rolled according to the characteristics (strength, dimensions, tolerances, etc.) required. Sections shall be extruded. Pipes and bars shall be extruded followed, where necessary, by drawing. Pipes may also be fabricated from longitudinally welded strips.

All products shall be delivered in the material conditions specified for the alloy concerned.

4. Suitable alloys

All alloys shall be suitable for use within seawater atmosphere or under exposure to seawater. The alloys mentioned in 4.1 and 4.2 may be used, if this precondition is satisfied. Aluminium alloys according to other standards and specifications may be used, if they are equivalent to those mentioned in 4.1 and 4.2 and if their suitability is confirmed by BKI.

4.1 Alloys for use in load bearing structures

Table 10.1 specifies aluminium alloys which are suitable as welded, bonded or mechanically joint structural members exposed to marine environment.

Depending on the product type the wrought alloys may be supplied in the material conditions given in Table 10.1.

As regards chemical composition Table 10.3 applies, Table 10.4 as regards mechanical properties of plates and strips and Table 10.5 as regards mechanical properties of extruded sections, bars and pipes.

4.2 Wrought aluminium and wrought alloys for use in non-load bearing structures and for rivets

Aluminium and aluminium alloys which are suitable as welded, bonded or mechanically joint structural members in non-load bearing structures exposed to marine environment are given in Table 10.2.

The chemical composition of these materials shall be taken from EN 573-3:2019 or equivalent standards.

The recommended product types for these alloys are also given in Table 10.2. They may be used in the material conditions specified in the relevant European or equivalent standards.

The alloys specified in Table 10.1 may also be used for non-load bearing structures applicable to all products and material conditions.

Note:

Products made from the 5000 and 6000 series of alloys shall not come into direct contact with seawater. Where necessary, they are to be protected by anodes or coatings.

5. General characteristics of products

5.1 The products shall have a smooth surface compatible with the method of manufacture and shall be free of defects liable to impair further manufacturing processes or the proposed application of the products, e.g. cracks, laps, appreciable inclusions of extraneous substances and major mechanical damage.

5.2 Surface defects may be repaired only by grinding provided that this is accomplished with a gentle transition to the adjacent surface of the product and that the dimensions remain within the tolerance limits. Repair by welding is not permitted. For repair purposes only tools are to be used which are exclusively applied for aluminium processing.

6. Dimensional and geometrical tolerances

6.1 Unless otherwise agreed with BKI, the following specified requirements are applicable in respect of permitted thickness tolerances.

- for plates and strips: Table 10.6
- for open sections: Table 10.7
- for closed sections: Table 10.8

Other product shapes and other dimensional and geometrical tolerances are subject to the applicable standards.

6.2 Compliance with tolerances and the requirements applicable to the general characteristics is the responsibility of the manufacturer. Examination of the products by the Surveyor does not release the manufacturer from this responsibility.

Where the performance of non-destructive tests is necessary, method and evaluation criteria shall be agreed with BKI.

Table 10.1: Wrought aluminium alloys: Alloys, products and material onditions, recommended for use in load bearing structures

Designation of alloy	Sheets, strips and plates	Extruded products			Drawn products		Forgings
		Bars	Pipes	Sections	Bars	Pipes	
KI AW-5059 (AlMg5,5Mn0,8ZnZr)	O/H111 H112 H116 H321	—	—	—	—	—	—
KI AW-5083 (AlMg4,5Mn0,7) and KI AW-5383 (AlMg4,5Mn0,9)	O/H111 H112 H116 H32	O/H111 H112	O/H111 H112	H112	O/H111	O/H111	H112
KI AW-5086 (AlMg4)	O/H111 H112 H116 H32/H321	O/H111 H112	O/H111 H112	H112	O/H111	O/H111	—
KI AW-5454 (AlMg3Mn)	O/H111 H112 H32/H321	O/H111 H112	O/H111 H112	H112	—	—	—
KI AW-5456 (AlMg5Mn1)	O/H111 H112 H116 H32/H321	—	—	—	—	—	—
KI AW-5754 (AlMg3)	O/H111 H112 H32	O/H111 H112	O/H111 H112	H112	O/H111	O/H111	H112
KI AW-6005A (AlSiMg(A))	—	T6 [1)]	T6 [1)]	T6 [1)]	—	—	—
KI AW-6061 (AlMg1SiCu)	—	T6 [1)]	T6 [1)]	T6 [1)]	—	—	—
KI AW-6082 (AlSiMgMn)	T6/T651	T6 [1)]	T6 [1)]	T5 T6 [1)]	T6 [1)]	T6 [1)]	T6 [1)]
KI AW-6106 (AlMgSiMn)	—	—	—	T6 [1)]	—	—	—

1) The properties may be achieved by quenching at the press.

Table 10.2: Wrought aluminium and wrought aluminium alloys: Alloys and products recommended for use in non-load bearing structures and for rivets

Designation of alloy	Sheets, strips and plates	Extruded products			Drawn products		Forgings	Electrical welded pipes	Drawn wire for rivets
		Bars	Pipes	Sections	Bars	Pipes			
EN AW-1050 A (Al99,5)	+	+	+	+	+	+	×	×	-
EN AW-1200 (Al99,0)	+	+	+	+	+	+	×	×	-
EN AW-3103 (AlMn1)	+	+	+	+	+	+	×	+	-
EN AW-5005 (AlMg1(B))	+	+	+	+	+	+	+	+	-
EN AW-5050 (AlMg1,5(C))	+	×	×	×	×	×	×	+	-
EN AW-5251 (AlMg2)	+	+	+	+	+	+	×	+	-
EN AW-5052 (AlMg2,5)	+	+	+	+	+	+	×	×	-
EN AW-6060 (AlMgSi)	×	+	+	+	+	+	×	×	-
EN AW-6063 (AlMg0,7Si)	×	+	+	+	+	+	×	×	-
EN AW-5154 (AlMg3,5)	-	-	-	-	-	-	-	-	*
EN AW-5754 (AlMg3)	-	-	-	-	-	-	-	-	*

\+ The recommended alloy is included in the relevant product standard.
× The recommended alloy is not included in the relevant product standard.
* The recommended alloy, particularly in the material condition 0 and H32, is included in the relevant standard.
– The alloy is not recommended

Table 10.3: Chemical composition of selected wrought aluminium alloys [1]

Alloy number	Chemical composition [%] [2]									Other Addition [%] [2]		Additional requirements
	Al	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Single	Total	
KI AW-5059	remainder	$\leq$ 0,45	$\leq$ 0,50	$\leq$ 0,25	0,6 – 1,2	5,0 – 6,0	$\leq$ 0,25	0,40 – 0,90	0,2	$\leq$ 0,05	$\leq$ 0,10	0,05 – 0,25 Zr
KI AW-5083	remainder	$\leq$ 0,40	$\leq$ 0,40	$\leq$ 0,10	0,4 – 1,0	4,0 – 4,90	0,05 – 0,25	$\leq$ 0,25	$\leq$ 0,15	$\leq$ 0,05	$\leq$ 0,15	
KI AW-5086	remainder	$\leq$ 0,40	$\leq$ 0,50	$\leq$ 0,10	0,2 – 0,7	3,5 – 4,50	0,05 – 0,25	$\leq$ 0,25	$\leq$ 0,15	$\leq$ 0,05	$\leq$ 0,15	
KI AW-5383	remainder	$\leq$ 0,25	$\leq$ 0,25	$\leq$ 0,20	0,7 – 1,0	4,0 – 5,20	$\leq$ 0,25	$\leq$ 0,40	$\leq$ 0,15	$\leq$ 0,05	$\leq$ 0,15	$\leq$ 0,20 Zr
KI AW-5454	remainder	$\leq$ 0,25	$\leq$ 0,40	$\leq$ 0,10	0,5 – 1,0	2,4 – 3,0	0,05 – 0,20	$\leq$ 0,25	$\leq$ 0,20	$\leq$ 0,05	$\leq$ 0,15	
KI AW-5456	remainder	$\leq$ 0,25	$\leq$ 0,40	$\leq$ 0,10	0,5 – 1,0	4,7 – 5,5	0,05 – 0,20	$\leq$ 0,25	$\leq$ 0,20	$\leq$ 0,05	$\leq$ 0,15	
KI AW-5754	remainder	$\leq$ 0,40	$\leq$ 0,40	$\leq$ 0,10	$\leq$ 0,50	2,6 – 3,6	$\leq$ 0,30	$\leq$ 0,20	$\leq$ 0,15	$\leq$ 0,05	$\leq$ 0,15	$0{,}10 \leq Mn + Cr \leq 0{,}6$
KI AW-6005-A	remainder	0,5 – 0,90	$\leq$ 0,35	$\leq$ 0,30	$\leq$ 0,50	0,4 – 0,70	$\leq$ 0,30	$\leq$ 0,20	$\leq$ 0,10	$\leq$ 0,05	$\leq$ 0,15	$0{,}12 \leq Mn + Cr \leq 0{,}5$
KI AW-6061	remainder	0,4 – 0,80	$\leq$ 0,70	0,15 – 0,40	$\leq$ 0,15	0,8 – 1,20	0,04 – 0,35	$\leq$ 0,25	$\leq$ 0,16	$\leq$ 0,05	$\leq$ 0,15	
KI AW-6082	remainder	0,7 – 1,30	$\leq$ 0,50	$\leq$ 0,10	0,4– 1,0	0,6 – 1,20	$\leq$ 0,25	$\leq$ 0,20	$\leq$ 0,10	$\leq$ 0,05	$\leq$ 0,15	
KI AW-6106	remainder	0,3 – 0,60	$\leq$ 0,35	$\leq$ 0,25	0,05 – 0,20	0,4 – 0,80	$\leq$ 0,20	$\leq$ 0,20	–	$\leq$ 0,05	$\leq$ 0,10	

1) Minor deviations of the prescribed composition may be accepted, see A.7.2.

2) Other elements are seen as permissible additions. They need not to be specified, if their limit values are not exceeded.

Table 10.4: Material condition and mechanical properties of plates and strips from wrought aluminium alloys [1] (Product thickness t = 3,0 up to 50 mm)

<table>
<tr><th rowspan="2">Alloy number</th><th rowspan="2">Material condition</th><th rowspan="2">Yield strength $R_{p0,2}$ [N/mm²] min.</th><th rowspan="2">Tensile strength R_m [N/mm²]</th><th rowspan="2">Thickness t [mm]</th><th colspan="2">Elongation [%] min.</th></tr>
<tr><th>A_{50mm}</th><th>A</th></tr>
<tr><td rowspan="6">KI AW-5083</td><td rowspan="2">0/H111/H112</td><td rowspan="2">125</td><td rowspan="2">275 - 350</td><td>t ≤ 12,5</td><td>16</td><td>–</td></tr>
<tr><td>t > 12,5</td><td>–</td><td>15</td></tr>
<tr><td rowspan="2">H116</td><td rowspan="2">215</td><td rowspan="2">≥305</td><td>t ≤ 12,5</td><td>12</td><td>–</td></tr>
<tr><td>t > 12,5</td><td>–</td><td>10</td></tr>
<tr><td rowspan="2">H32/H321</td><td rowspan="2">215</td><td rowspan="2">305 – 380</td><td>t ≤ 12,5</td><td>10</td><td>–</td></tr>
<tr><td>t > 12,5</td><td>–</td><td>9</td></tr>
<tr><td rowspan="6">KI AW-5086</td><td rowspan="2">0/H111/H112</td><td rowspan="2">100</td><td rowspan="2">240 – 310</td><td>t ≤ 12,5</td><td>17</td><td>–</td></tr>
<tr><td>t > 12,5</td><td>–</td><td>16</td></tr>
<tr><td rowspan="2">H116</td><td rowspan="2">195</td><td rowspan="2">≥ 275</td><td>t ≤ 12,5</td><td>10</td><td>–</td></tr>
<tr><td>t > 12,5</td><td>–</td><td>9</td></tr>
<tr><td rowspan="2">H32/H321</td><td rowspan="2">185</td><td rowspan="2">275 – 335</td><td>t ≤ 12,5</td><td>10</td><td>–</td></tr>
<tr><td>t > 12,5</td><td>–</td><td>9</td></tr>
<tr><td rowspan="3">KI AW-5754</td><td rowspan="2">O/H111/H112</td><td rowspan="2">80</td><td rowspan="2">190 – 240</td><td>t ≤ 12,5</td><td>18</td><td>–</td></tr>
<tr><td>t > 2,5</td><td>–</td><td>17</td></tr>
<tr><td>H32</td><td>165</td><td>≥ 240</td><td>3 ≤ t ≤ 40</td><td>–</td><td>10</td></tr>
<tr><td rowspan="8">KI AW-5456</td><td rowspan="2">O</td><td>130-205</td><td>290-365</td><td>3 ≤ t ≤ 6,3 mm</td><td>16</td><td></td></tr>
<tr><td>125-205</td><td>285-360</td><td>6,3 < t ≤ 50 mm</td><td>16</td><td>14</td></tr>
<tr><td rowspan="3">H116</td><td>230</td><td>315</td><td>3 ≤ t ≤ 30 mm</td><td>10</td><td>10</td></tr>
<tr><td>215</td><td>305</td><td>30 < t ≤ 40 mm</td><td>–</td><td>10</td></tr>
<tr><td>200</td><td>285</td><td>40 < t ≤ 50 mm</td><td>–</td><td>10</td></tr>
<tr><td rowspan="3">H321</td><td>230-315</td><td>315-405</td><td>3 ≤ t ≤ 12,5 mm</td><td>12</td><td>–</td></tr>
<tr><td>215-305</td><td>305-385</td><td>12,5 < t ≤ 40 mm</td><td>–</td><td>10</td></tr>
<tr><td>200-295</td><td>285-370</td><td>40 < t ≤ 50 mm</td><td>–</td><td>10</td></tr>
<tr><td rowspan="2">KI AW-5454</td><td>O/H111</td><td>85</td><td>≥ 215</td><td rowspan="2">3 ≤ t ≤ 40</td><td rowspan="2">–</td><td rowspan="2">10</td></tr>
<tr><td>H32</td><td>180</td><td>≥ 250</td></tr>
<tr><td rowspan="2">KI AW-5383</td><td>O/H111</td><td>145</td><td>≥ 290</td><td>3 ≤ t ≤ 40</td><td>–</td><td>17</td></tr>
<tr><td>H116/H321</td><td>220</td><td>≥ 305</td><td>3 ≤ t ≤ 40</td><td>–</td><td>10</td></tr>
<tr><td rowspan="3">KI AW-5059</td><td>O/H111</td><td>160</td><td>≥ 330</td><td>3 ≤ t ≤ 50</td><td rowspan="2">–</td><td>24</td></tr>
<tr><td rowspan="2">H116/H321</td><td>270</td><td>≥ 370</td><td>3 ≤ t ≤ 20</td><td>10</td></tr>
<tr><td>260</td><td>≥ 360</td><td>20 < t ≤ 40</td><td>–</td><td>10</td></tr>
<tr><td colspan="7">1) The mechanical properties are applicable to both longitudinal and transverse specimens.</td></tr>
</table>

Table 10.5: Material condition and mechanical properties of extruded sections, bars and pipes made of wrought aluminium alloys [1] (Product thickness t = 3,0 to 50 mm)

Alloy number	Material condition	Yield strength $R_{p0,20}$ [N/mm^2] min.	Tensile strength R_m [N/mm^2]	Thickness t [mm]	Elongation [%] min.	
					A_{50mm}	A
KI AW-5059	H112	200	$\geq$ 330	$3 \leq t \leq 50$	–	10
KI AW-5083	O/H111	110	270 – 350	$t \leq 12{,}5$	10	–
	H112	125	> 270	t > 12,5	–	12
KI AW-5086	O/H111	95	240 – 320	$t \leq 12{,}5$	15	–
	H112			t > 12,5	–	18
KI AW-5383	O/H111	145	$\geq$ 290	$3 \leq t \leq 50$	–	17
	H112	190	$\geq$ 310			13
KI AW-6005A	T5/T6	215	$\geq$ 260	$t \leq 12{,}5$	8	–
				t > 12,5	–	6
KI AW-6061	T5/T6	240	$\geq$ 260	$t \leq 12{,}5$	10	–
				t > 12,5	–	8
KI AW-6082	T5/T6	260	$\geq$ 310	$t \leq 12{,}5$	10	–
				t > 12,5	–	8

[1] The mechanical properties are applicable to both longitudinal and transverse test specimens

7. Chemical composition

7.1 The chemical composition of the alloys specified in these Rules shall correspond to the data given in Table 10.3. For wrought aluminium and wrought alloys which are not specified therein the requirements of the standards or approved specifications shall be satisfied.

7.2 The manufacturer shall determine the chemical composition on test specimens taken from each charge. Slight variations from the specified composition may be permitted by agreement of BKI provided that the suitability of the product concerned for its intended purpose is not impaired thereby.

7.3 The analysis certificate produced by the manufacturer is normally accepted, with the Surveyor reserving the right to have occasional check analyses carried out.

7.4 The material to be used for welded structural members should be made from ingots or billets with a hydrogen content of maximum 0,2 ml per 100 g aluminium, when measurement is carried out on the liquid metal during casting.

8. Mechanical properties

The required values of tensile strength, 0,2 % proof stress and elongation specified in Tables 10.4 and 10.5 shall be fulfilled under tensile test.

9. Tests

9.1 Definition of test batch

For test purposes, products are to be grouped together in test batches. A test batch is made up of products:

— Made from the same alloy and from the same charge

— Of the same product shape and with the same dimensions (for plates and strips of the same thickness)

- With the same forming process
- With the same material condition
- With the same heat treatment

9.2 Tensile test

9.2.1 Number of tensile test specimens

For rolled products, one tensile test specimen shall be taken from each test batch. Where the weight of a test batch exceeds 2000 kg, an additional tensile test specimen shall be taken from each additional 2000 kg or parts thereof.

For single plates or for coils weighting more than 2000 kg each, only one tensile test specimen per plate or coil shall be taken.

9.2.2 For extruded products with a weight per meter of less than 1 kg/m, one tensile test specimen shall be taken from each 1000 kg of a test batch or parts thereof.

For weights per meter of 1 to 5 kg/m, one tensile test specimen shall be taken from each 2000 kg of a test batch or parts thereof. Where the weight per meter exceeds 5 kg/m one tensile test specimen shall be taken from each 3000 kg of a test batch or parts thereof.

9.2.3 Location of specimens

The test samples are to be taken

- At one third of the width from a longitudinal edge of rolled products.
- In the range 1/3 to 1/2 of the distance from the edge to the centre of the thickest part of extruded products.

For plates and strips, transverse specimens are generally taken. If the width is insufficient to obtain transverse test specimen, or in the case of strain hardening alloys, tests in the longitudinal direction will be permitted.

In the case of extruded products, longitudinal specimens are normally taken.

9.2.4 Marking of specimens

Specimens shall be marked so that they can be traced back to the product from which they were taken and also so that their location in the product itself can be verified at all times.

9.2.5 Shape and arrangement of specimens

For product thicknesses up to and including 12,5 mm, flat specimens with a gauge length of 50 mm shall be prepared, the rolling skin being maintained on both sides.

For product thicknesses above 12,5 mm, round test specimens of 10 mm ⌀ and with an initial gauge length of 50 mm shall be prepared. In the case of product thicknesses up to and including 40 mm, the axis of the round test specimen shall be positioned in the centre of the product thickness and for thicknesses in excess of 40 mm it is to be positioned at a distance of one quarter of the thickness of the product, measured from the surface.

9.2.6 Tensile test procedure

Tensile testing shall be performed in accordance with Section 2, D.

9.3 Test of surface finish

Products shall be presented to the Surveyor for testing of their surface finish.

9.4 Test of press welding of closed sections

The manufacturer shall demonstrate, by means of macro sections of each test batch, that the press welds have no lack of fusion. In case of round pipes or pipes with quadratic cross section (with rounded edges) which outer diameter does not exceed 100 mm, this may be carried out alternatively by means of a drift expanding test.

9.4.1 Drift expanding test

Of every fifth section, but at minimum of one section, samples are to be taken. Sections with length of more than 6 m shall be individually tested unless otherwise agreed with BKI.

9.5 Corrosion test

9.5.1 On rolled products from alloys of the series 5XXX supplied in the condition H116, H32 or H321, a test of resistance against exfoliation corrosion and intercrystalline corrosion is to be carried out according to ASTM-G66:2018 (ASSET) and ASTM-G67:2018 (NAMLT).

9.5.2 The manufacturers shall establish the relationship between microstructure and resistance to corrosion when the above alloys are approved. A reference photomicrograph taken at 500x, under the conditions specified in ASTM B928:2015, Section 9.4.1, shall be established for each of the alloy-tempers and thickness ranges relevant. The reference photographs shall be taken from samples which have exhibited no evidence of exfoliation corrosion and a pitting rating of PB or better, when subjected to the test described in ASTM G66:2018 (ASSET). The samples shall also have exhibited resistance to intergranular corrosion at a mass loss no greater than 15 mg/cm^2, when subjected to the test described in ASTM-G67: 2018 (NAMLT). Upon satisfactory establishment of the relationship between microstructure and resistance to corrosion, the master photomicrographs and the results of the corrosion tests are to be approved by BKI. Production practices shall not be changed after approval of the reference micrographs. Other test methods may also be accepted at the discretion of BKI.

9.5.3 For batch acceptance of 5xxx-alloys in the H116 and H321 tempers, metallographic examination of one sample selected from mid width at one end of a coil or random sheet or plate is to be carried out. The microstructure of the sample is to be compared to the reference photomicrograph of acceptable material in the presence of the Surveyor. A longitudinal section perpendicular to the rolled surface shall be prepared for metallographic examination, under the conditions specified in ASTM B928:2015, Section 9.6.1. If the microstructure shows evidence of continuous grain boundary network of aluminium-magnesium precipitate in excess of the reference photomicrographs of acceptable material, the batch is either to be rejected or tested for exfoliation corrosion resistance and intergranular corrosion resistance subject to the agreement of the Surveyor. The corrosion tests are to be in accordance with ASTM-G66:2018 and ASTM-G67:2018 or equivalent standards. Acceptance criteria are that the sample shall exhibit no evidence of exfoliation corrosion and a pitting rating of PB or better when test subjected to ASTM-G66:2018 ASSET test, and the sample shall exhibit resistance to intergranular corrosion at a mass loss no greater than 15mg/cm^2 when subjected to ASTM-G67:2018 NAMLT test. If the results from testing satisfy the acceptance criteria stated in paragraph 9.5.2 the batch is accepted, else it is to be rejected.

As an alternative to metallographic examination, each batch may be tested for exfoliation-corrosion resistance and intergranular corrosion resistance, in accordance with ASTM-G66:2018 and ASTM-G67:2018 under the conditions specified in ASTM B928:2015, or equivalent standards. If this alternative is used, then the results of the test must satisfy the acceptance criteria stated in this paragraph.

For rolled plates of grade 5083, 5383, 5059, 5086 and 5456 delivered in the tempers H116 or H321, one sample is to be tested per batch.

9.6 Retests

9.6.1 If, during tensile testing, a test specimen selected in accordance with 9.2 fails to meet the standards, two additional specimens shall be taken from the same test piece. If both retest specimens satisfy the test conditions, the test piece from which the retest specimens were taken and the other test pieces included in the test batch may be accepted.

9.6.2 Where one or both of the retest specimens described in 9.6.1 fail to meet the standards, the test piece from which the specimens were taken shall be rejected. The remaining test pieces in the batch may be accepted provided that the result of tests performed on specimens from two other test pieces is satisfactory. Where these specimens also fail to meet the standards, the entire test batch shall be rejected.

9.6.3 In the case of products which fail to satisfy the test requirements but which already bear the BKI stamp, the stamp marks shall be removed to avoid confusion.

10. Marking

10.1 The manufacturer shall mark each product in at least one place with the following details:

— Manufacturer's mark

— Short designation of alloy

— Short designation of the condition of the material

— Rolled products which were corrosion tested in accordance with 9.5 are to be marked with the letter "M" additionally (e.g. KI AW-5083-H321 M).

— Number of the manufacturing batch enabling the manufacturing process to be traced back

Products shall also be marked with the BKI "batch stamp".

10.2 Where sections, bars or pipes are bundled together or packed in crates, the markings specified in 10.1 may be affixed to the products by a securely fastened tag or label.

Table 10.6: Permitted lower thickness tolerances for plates and strips

Nominal thickness t [mm]	Thickness tolerance for product widths [mm]		
	up to 1500 m	over 1500 mm up to 2000 mm	over 2000 mm up to 3500 mm
up to 4	0,10	0,15	0,15
over 4 up to 8	0,20	0,20	0,25
over 8 up to 12	0,25	0,25	0,25
over 12 up to 20	0,35	0,40	0,50
over 20 up to 50	0,45	0,50	0,65

Table 10.7: Permitted lower thickness tolerances for open sections

Nominal thickness t [mm]	Thickness tolerance for sections which section shape is enclosed by a circle of [mm] diameter		
	up to 250 mm	over 250 mm up to 400 mm	over 400 mm
from 3 up to 6	0,25	0,35	0,40
over 6	0,30	0,40	0,45

Table 10.8: Permitted lower thickness tolerances for closed sections

Nominal thickness t [mm]	Thickness tolerance for sections which section shape is enclosed by a circle of [mm] diameter	
	up to 250 mm	over 250 mm up to 400 mm
from 3 up to 6	0,15	0,25
over 6	0,2	0,3

11. Certificates issued by the supplier

11.1 For each delivery accepted, the manufacturer shall supply the Surveyor with an acceptance certificate or delivery specification containing the following details:

— customer and order number

— project number or new building number, where known

— number, dimensions and weight of the products

— designation of the alloy and material condition

— method of manufacture

— chemical composition

— manufacturing batch number or identifying mark

— results of the mechanical tests, where testing is carried out by the manufacturer

— details of heat treatment, where applicable

— corrosion Test results (if any).

11.2 Where the alloys are not cast in the same works in which they are made into semi-finished products, the Surveyor shall be given a certificate issued by the smelting plant which indicates charge numbers and chemical composition. The manufacturer of the ingots or extrusion billets shall be approved by BKI.

B. Aluminium Casting Alloys

1. Scope

1.1 These Rules are applicable to aluminium casting alloys which are intended for the fabrication of ship's hulls and also machine construction parts and other shipbuilding components.

1.2 Also applicable to the manufacture and testing of casting are Section 1 and Section 2.

2. Requirements to be met by aluminium foundries

2.1 Foundries wishing to supply castings conforming to these Rules shall be approved by BKI for the grades of castings concerned. BKI reserves the right to call for performance tests to be carried out on castings selected for the purpose.

2.2 If castings are required to be weldable, this is to be stated in the order and proof of suitability furnished to BKI.

3. Permitted grades of casting

3.1 Suitable grades of castings to international or national standards, e.g. to EN 1706:2020 shall generally be used. Where castings conforming to manufacturer's specifications are to be used, these are to be submitted to BKI for examination and approval.

3.2 Castings such as fittings, housings and fan rotors which are exposed without protection to the action of seawater or salty atmosphere should be made of alloys suitable for this kind of use. AlSi-, AlSiMg- and AlMg-alloys with a maximum copper content of 0,1 % should normally be used. AlSi- and AlSiMg-alloys shall not come into direct contact with seawater. Where necessary, they are to be protected by anodes or coatings.

3.3 For the applications mentioned in 1.1, use may be made of the casting alloys conforming to EN 1706:2020 listed in Table 10.9.

Use may be made of other alloys provided these are suitable for the intended application and their use has been approved by BKI.

4. Requirements

4.1 The chemical composition of the castings shall correspond to the standards or to recognized manufacturer's specifications and shall be demonstrated by the manufacturer of the castings for each charge.

4.2 With regard to mechanical properties, the requirements stated in the standards or the manufacturer's specifications are applicable. Specimens taken from integrally cast test pieces shall meet the requirements for separately cast sample bars.

4.3 All castings shall be free from internal and external defects which could have more than just a slight adverse effect on the application and any appropriate further manufacturing processes carried out on the castings. Where defects are to be repaired by welding, a welding specification shall be produced by the manufacturer for this purpose and the approval of the Surveyor sought.

Table 10.9: Aluminium-casting alloys

Designation of alloy	Cast procedure	Material condition	Sea water suitability
EN AC-41000 (AlSi2MgTi)	S, K	F, T6	good
EN AC-42100 (AlSi7Mg0,3)	S, K, L	T6, T64	good
EN AC-42200 (AlSi7Mg0,6)	S, K, L	T6, T64	good
EN AC-43100 (AlSi10Mg(b))	S, K, L	F, T6, T64	good / moderate
EN AC-44100 (AlSi12(b))	S, K, L, D	F	good / moderate
EN AC-51000 (AlMg3(b))	S, K, L	F	very good
EN AC-51300 (AlMg5)	S, K, L	F	very good
EN AC-51400 (AlMg5(Si))	S, K, L	F	very good

S = sand casting
K = permanent mould casting
L = investment casting
D = pressure die casting
F = cast condition
T6 = solution annealed and completely artificially aged
T64 = solution annealed and not completely artificially aged – under aged (only for permanent mould casting)

5. Tests

5.1 Castings which shall form part of the ship's hull or are designed as structural components of the propulsion system are to be presented to the Surveyor for testing. A tensile test shall be performed on the castings in his presence to establish their mechanical properties.

5.2 For the tensile test, one test specimen is to be provided from each charge or each heat treatment batch. For unfinished castings weighing 300 kg and over, a tensile test specimen is required for each casting.

5.3 Specimens for tensile testing shall normally be taken from integrally cast sample bars which may only be separated from the casting when the final heat treatment has been performed.

The use of separately cast sample pieces shall be subject to special agreement with BKI with regard to their casting and the requirements applicable to the mechanical properties of the tensile test specimens taken from them.

5.4 Where stipulated following examination of the drawings or in the order, and also where there is some doubt as to whether the castings are free from defects, the manufacturer of the castings shall perform non-destructive tests at the places specified for the purpose, and the results are to be certified by him. Critical areas of casting and repaired defects are also to be incorporated in the test.

6. Marking

As a minimum requirement, the manufacturer shall apply the following marks on the castings:

— manufacturer's mark

— short designation of the casting alloys

— short designation of the condition of the material

— charge number or some other mark to permit identification of the casting.

7. Certificates

For each delivery, the manufacturer shall present the Surveyor with a certificate or delivery specification giving the following minimum details:

— purchaser and order number

— type of casting and grade of casting

— item numbers and quantities

— method of manufacture

— heat numbers and chemical composition

— details of heat treatment

— test pressures, where applicable

— weight of the delivery.

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Section 11 Copper Alloys

A. Pipes of Copper and Wrought Copper Alloys

1. Scope

These Rules are applicable to pipes and fittings made of copper and wrought copper alloys and intended for use in pressurized lines and for condensers and heat exchangers. In the case of finned pipes, specifications shall be submitted to BKI for approval.

2. Requirements to be met by pipe manufacturers

Manufacturers wishing to supply products in accordance with these Rules shall be approved by BKI. This is conditional upon their fulfilling the requirements indicated in Section 1, C. and furnishing proof of this to BKI prior to the commencement of supplies.

3. Method of manufacture

3.1 The pipes shall generally be manufactured by seamless methods, e.g. by hot pressing followed by rolling and cold drawing.

3.2 Where welded pipes or fittings are to be used, the characteristics of these and the method of manufacture employed shall be made known to BKI. BKI reserves the right to demand a procedure approval test in these cases.

3.3 Cold-formed pipes and fittings shall be subjected to recrystallization annealing. Notwithstanding this, copper pipes which are to be supplied in the ”half hard” to ”hard” condition (e.g. conditions R250 and R290, EN 12449) may be cold formed after annealing. CuNi2Si-pipes are cold formed in the solution annealed condition or hot formed with simultaneous solution annealing and subsequent quenching. After cold forming hardening occurs.

4. Suitable grades of pipe

All pipes shall be suitable for the intended application and satisfy the requirements specified in 8. Subject to these conditions, the following grades of pipe may be used:

4.1 Copper and wrought copper alloy pipes according to EN 12449 in the grades shown in Table 11.1.

4.2 Copper and wrought copper alloy pipes for condensers and heat exchangers according to EN 12451, preferably in the grades of pipe shown in Table 11.1.

4.3 Pipes conforming to other standards or specifications, provided that they are comparable to the grades specified in 4.1 and 4.2 and their suitability have been confirmed by BKI.

Table 11.1: Suitable grades of pipe

Material designation		Composition: Weight fraction [%]															
Material Code	**Number**	**Element**	**Cu**	**Al**	**As**	**C**	**Co**	**Fe**	**Mn**	**Ni**	**P**	**Pb**	**S**	**Si**	**Sn**	**Zn**	**Other Total**
Cu-DHP	CW024A	min.	99,90 [1)]	–	–	–	–	–	–	–	0,015	–	–	–	–	–	–
		max.	–	–	–	–	–	–	–	–	0,040	–	–	–	–	–	–
CuNi2Si	CW111C	min.	remainder	–	–	–	–	–	–	1,6	–	–	–	0,4	–	–	–
		max.		–	–	–	–	0,2	0,1	2,5	–	0,02	–	0,8	–	–	0,3
CuNi10Fe1Mn	CW352H	min.	remainder	–	–	–	–	1,0 [3)]	0,5	9,0	–	–	–	–	–	–	–
		max.		–	–	0,05	0,1 [2)]	2,0 [3)]	1,0	11,0	0,02	0,02	0,05	–	0,03	0,5	0,2
CuNi30Mn1Fe	CW354H	min.	remainder	–	–	–	–	0,4	0,5	30,0	–	–	–	–	–	–	–
		max.		–	–	0,05	0,1 [2)]	1,0	1,5	32,0	0,02	0,02	0,05	–	0,03	0,5	0,2
CuZn20Al2As	CW702R	min.	76,0	1,8	0,02	–	–	–	–	–	–	–	–	–	–	residue	–
		max.	79,0	2,3	0,06	–	–	0,07	0,1	0,1	0,01	0,05	–	–	–	–	0,3

1) Including Ag up to max. 0,015%

2) Co max. 0,1 is counted as Ni.

3) For application exposed to seawater: $1,5 \le Fe \le 1,8$

5. Surface finish

5.1 Pipes shall have a smooth surface compatible with the method of manufacture. The surface shall be free from impurities, e.g. pickling residue or burnt drawing lubricants, and may not be cracked or have suffered mechanical damage. Die marks and laminations which may impair further manufacturing operations or the use of the material are not allowed.

5.2 Surface defects may be repaired by grinding provided that a gradual transition is made to the surface of the pipe and that the dimensional tolerances are not exceeded. Repairs by welding or soldering are not permitted.

6. Dimensions; dimensional and geometrical tolerances

The tolerances on wall thickness and diameter shall be those prescribed in EN 12449, see on this also Tables 11.4 to 11.9. Pipe ends shall be cut off at right angles to the pipe axis and shall be free from burrs.

7. Resistance to leakage

Pipes shall not leak when submitted to the hydraulic pressure test at the prescribed test pressures.

8. Requirements applicable to the material

8.1 Chemical composition

The chemical composition shall conform to Table 11.1.

8.2 Mechanical properties

The mechanical properties shall conform to the relevant standards. Table 11.2 gives an extract from EN 12449 for the grades of pipe specified in 4.1.

8.3 Formability

With the exception of pipes made of copper Cu-DHP in condition R290 and CuNi2Si in condition R460, all pipes shall be capable of being cold formed with the degrees of deformation customary in workshop practice, e.g. by bending and expansion.

8.4 Absence of stresses

Pipes made of copper zinc alloys shall be free from stresses liable to cause stress cracks.

8.5 Resistance to hydrogen embrittlement

Copper pipes may not become brittle due to the effect of hydrogenous gases and elevated temperatures such as occur, for example, in gas welding, soldering and hot forming.

8.6 Grain size

The average grain diameter of the materials specified in Table 11.2 in the conditions mentioned in the Table shall be between 0,01 and 0,05 mm. An exception is material Cu-DHP in condition R290.

9. Testing

9.1 For the purpose of testing, the pipes shall be grouped into test batches in accordance with Table 11.3.

A test batch shall comprise pipes which have been manufactured by the same method, are made of the same material, and are in the same condition and of the same thickness. It is not necessary for a test batch to originate from a single heat or heat treatment.

Where 2 or more test specimens are required, they shall be taken from different pipes in the test batch.

If pipes are supplied in rings, a test specimen shall be taken from every fifth ring; if there are less than five rings, however, at least one specimen shall be taken.

9.2 Test of chemical composition

The manufacturer shall determine the chemical composition of each manufacturing batch and pass this information on to the Surveyor.

Table 11.2: Condition and mechanical properties of pipes made of copper and wrought copper alloys to EN 12449

<table>
<tr><th>Material designation</th><th colspan="2">Material condition</th><th>Wall Thickness t [mm]</th><th>Yield strength $R_{p0,2}$ [N/mm^2]</th><th>Tensile strength R_m [N/mm^2]</th><th>Elongation A [%] min.</th></tr>
<tr><td rowspan="3">Cu-DHP</td><td>soft</td><td>R200</td><td>$\leq$ 20</td><td>$\leq$ 110</td><td>$\geq$ 200</td><td>40</td></tr>
<tr><td>half-hard</td><td>R250</td><td>$\leq$ 10</td><td>$\geq$ 150</td><td>$\geq$ 250</td><td>20</td></tr>
<tr><td>hard [1)]</td><td>R290</td><td>$\leq$ 5</td><td>$\geq$ 250</td><td>$\geq$ 290</td><td>5</td></tr>
<tr><td>CuZn20Al2As</td><td>annealed</td><td>R340</td><td>$\leq$ 10</td><td>$\geq$ 120</td><td>$\geq$ 340</td><td>45</td></tr>
<tr><td>CuNi10Fe1Mn</td><td>annealed</td><td>R290</td><td>$\leq$ 20</td><td>$\geq$ 90</td><td>$\geq$ 290</td><td>30</td></tr>
<tr><td>CuNi30Mn1Fe</td><td>annealed</td><td>R370</td><td>$\leq$ 10</td><td>$\geq$ 120</td><td>$\geq$ 370</td><td>35</td></tr>
<tr><td rowspan="4">CuNi2Si</td><td>solution annealed</td><td>R260</td><td rowspan="4">$\leq$ 10</td><td>$\geq$ 60</td><td>$\geq$ 260</td><td>30</td></tr>
<tr><td>solution annealed [1)] and precipitationhardened</td><td>R460</td><td>$\geq$ 300</td><td>$\geq$ 460</td><td>12</td></tr>
<tr><td>solution annealed and cold formed</td><td>R380</td><td>$\leq$ 260</td><td>$\geq$ 380</td><td>6</td></tr>
<tr><td>solution annealed, cold formed and precipitationhardened</td><td>R600</td><td>$\leq$ 480</td><td>$\geq$ 600</td><td>8</td></tr>
<tr><td colspan="7">[1)] Without former annealing, cold forming is not possible.</td></tr>
</table>

Table 11.3: Test batches

<table>
<tr><th colspan="2">Test batch [kg]</th><th rowspan="2">No. of specimens for testing according to 9.3 to 9.8</th></tr>
<tr><th>over</th><th>up to</th></tr>
<tr><td></td><td>500</td><td>1 each</td></tr>
<tr><td>500</td><td>1000</td><td>2 each</td></tr>
<tr><td>1000</td><td>2000</td><td>3 each</td></tr>
<tr><td>2000</td><td>3000</td><td>4 each</td></tr>
<tr><td colspan="2">each subsequent 1000</td><td>1 more each</td></tr>
</table>

Table 11.4: Limiting sizes for the diameter

Diameter (nominal) [mm]		Limiting size for the diameter [mm]	
over	up to	applicable to the average diameter	applicable to every diameter including ovality in case of linear lengths [1),2)]
3 [3)]	10	± 0,06	± 0,12
10	20	± 0,08	± 0,16
20	30	± 0,12	± 0,24
30	50	± 0,15	± 0,30
50	100	± 0,20	± 0,50
100	200	± 0,50	± 1,0
200	300	± 0,75	± 1,5
300	450	± 1,0	± 2,0

1) The limiting sizes in this column are not applicable for:
- coiled pipes (limiting sizes for coiled pipes, see Table 11.8)
- pipes with OD/t >50 (OD = outside diameter, t = wall thickness)
- pipes in annealed condition

2) If not otherwise agreed, the outside diameter sizes in way of the pipe ends, i.e. within a distance of 100 mm or one time the nominal outside diameter whichever is the lesser, may be increased by a factor of 3.

3) Including 3.

Table 11.5: Limiting sizes for the wall thickness

Outside diameter (nominal) [mm]		Limiting sizes for the wall thickness t (nominal) [%]				
over	up to	from 0,3 mm up to 1 mm	over 1 mm up to 3 mm	over 3 mm up to 6 mm	over 6 mm up to 10 mm	over 10 mm
3 [1)]	40	± 15	± 13	± 11	± 10	—
40	120	± 15	± 13	± 12	± 11	± 10
120	250	—	± 13	± 13	± 12	± 11
240	450	—	—	± 15	± 15	± 15

1) Including 3.

Table 11.6: Limiting sizes for fixed lengths of linear pipes

<table>
<tr><th colspan="2">Outside diameter (nominal) [mm]</th><th colspan="4">Limiting sizes for fixed lengths [mm]</th></tr>
<tr><th>over</th><th>up to</th><th>up to 250</th><th>over 250 up to 1000</th><th>over 1000 up to 4000</th><th>over 4000</th></tr>
<tr><td rowspan="2">3 [1]</td><td rowspan="2">25</td><td>+1</td><td>+3</td><td>+5</td><td rowspan="6">upon agreement</td></tr>
<tr><td>0</td><td>0</td><td>0</td></tr>
<tr><td rowspan="2">25</td><td rowspan="2">100</td><td>+2</td><td>+5</td><td>+7</td></tr>
<tr><td>0</td><td>0</td><td>0</td></tr>
<tr><td rowspan="2">100</td><td rowspan="2">450</td><td>+</td><td>+5</td><td>+10</td></tr>
<tr><td>0</td><td>0</td><td>0</td></tr>
</table>

1) Including 3.

Table 11.7: Limiting sizes for fixed lengths of coiled pipes (non-helical coiled)

Nominal length [m]	Deviation limit [%]
up to 50	+ 2
	0
over 50 up to 100	+ 3
	0
over 100	+ 2
	0

Table 11.8: Limiting sizes for the diameter including ovality of coiled pipes

Outside diameter (nominal) [mm]		Limiting sizes for the nominal diameter including ovality [mm]	Applicable for the inner ring diameter of [mm]
over	up to		
3 [1]	6	$\pm$ 0,30	400
6	10	$\pm$ 0,50	600
10	20	$\pm$ 0,70	800
20	30	$\pm$ 0,90	1000

[1] Including 3.

Table 11.9: Straightness tolerance

Ratio of outside diameter / wall thickness		Depth [1] [mm]	
over	up to	h_1 per 1000 mm length ℓ_1 max.	h_2 per 400 mm length ℓ_2 max.
—	5	2	0,8
5	10	3	1,2
10	20	4	1,6
20	40	5	2,0
40	—	6	2,5

[1] See Fig. 11.1

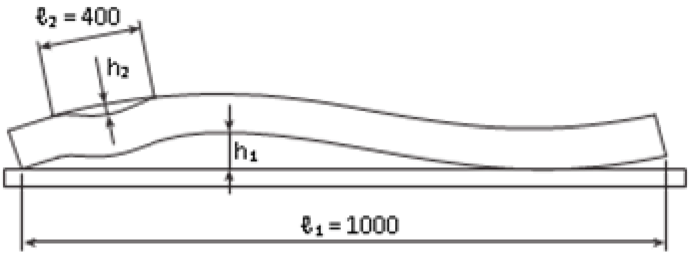

Figure 11.1: Measuring of straightness

9.3 Determination of grain size

In the case of condenser and heat exchanger tubes, the manufacturer shall determine the average grain diameter on at least one specimen from each test batch according to ISO 2624.

9.4 Tensile test

Pipes shall be subjected to tensile test to determine the tensile strength, the 0,2 % proof stress and the elongation.

9.5 Ring flattening test

Pipes shall be submitted to the ring flattening test.

The test specimens shall be flattened until the inner surfaces touch. This shall not cause cracks visible to the eye. Cu-DHP copper pipes in condition R290 are to be annealed before testing. CuNi2Si pipes are to be solution annealed beforehand.

9.6 Expanding test

Pipes with an outside diameter of up to 76 mm shall be subjected to the expanding test using a drift with a 45° taper. The expansion shall equal at least 30 % of the original inside diameter and no cracks may appear. Cu-DHP copper pipes in condition R290 are annealed before testing. CuNi2Si pipes have to be in the solution annealed condition.

9.7 Testing for absence of internal stresses (CuZn pipes)

The manufacturer shall prove that CuZn alloy pipes are free from internal stresses by carrying out the ammonia test according to ISO 6957 and shall then present the specimens to the Surveyor. At the express request of the purchaser, this test may be replaced by the mercurous nitrate test according to ISO 196.

Should a specimen reveal cracks when tested, the manufacturing batch shall be rejected. The manufacturer shall be free to submit the batch to renewed heat treatment before presenting it for retesting.

9.8 Test of resistance to hydrogen embrittlement (Cu pipes)

For this purpose, pipe specimens 10 to 20 mm in length shall be annealed for 30 minutes at 800 to 850°C in a reducing atmosphere (hydrogen or fuel gas), cooled and flattened between two parallel plates until the inner surfaces touch. In the case of thick-walled and large-diameter pipes, flattening test specimens may comprise approx. 10 mm wide strips taken from the sample pipe. The points of folding shall neither reveal cracks nor fracture.

9.9 Test of surface finish and dimensions

The manufacturer shall inspect the finish of the inner and outer surfaces of every pipe and shall also check the diameters and wall thicknesses. The pipes shall then be submitted to the Surveyor for final inspection.

9.10 Tightness test

The manufacturer shall subject all pipes to a tightness test.

Preferably, this shall be done by applying an eddy current test carried out in accordance with a recognized standard (e.g. EN 1971) or test specification. Instead of the eddy-current test, another equivalent non-destructive test method may be agreed, or a hydraulic pressure test shall be performed. Each pipe is to be subjected for at least 5 seconds to an inner water pressure, which shall be calculated according to the following formula:

$$P = \frac{2 \times S \times t}{D}$$

P	=	inner water pressure
t	=	wall thickness (nominal) of the pipe
D	=	outer diameter (nominal) of the pipe
S	=	half of the minimum value for the 0,2 % proof stress

The pipes need not to be tested with a water pressure above 6,9 MPa, if not otherwise agreed.

9.11 Retests in the event of failure

If the required values are not met in the mechanical and technological tests, then, before the manufacturing batch is rejected, the procedures for retests prescribed in Section 2, H. may be applied.

10. Marking

10.1 The following marks shall be applied by the manufacturer to each pipe with an outside diameter ≥ 25 mm using an indelible and weatherproof dye:

- Manufacturer's mark
- Designation of material or material number
- Test batch number or another mark enabling the pipe to be clearly identified

10.2 Where pipes are supplied in bundles or packed in crates, the marks specified in 10.1 may be affixed by means of securely fastened tags or labels; however, pipes with an outside diameter $\geq$ 25 mm shall be marked individually.

11. Certificates issued by the manufacturers

For each consignment the manufacturer shall supply to the Surveyor a certificate giving the following details:

- Purchaser and order number
- Number, size and weight of pipes
- Material designation
- Test batch number or identification mark
- Results of the analysis, of the mechanical and technological tests, the tightness test and, if specified for the type of pipe concerned or specially stipulated, of the tests to determine absence of internal stresses, resistance to hydrogen embrittlement and average grain size.

12. Copper and wrought copper alloy fittings

12.1 Scope

These Rules are applicable to saddles, T-shaped fittings, tapered transition pieces and pipe elbows. Fittings conforming to recognized standards shall be used.

12.2 Approval

Fitting manufacturers shall prove the suitability of their products as an initial measure by means of an approval test. The scope of testing is determined by the relevant standards, e.g. DIN 86086 to DIN 86090 for fittings manufactured from pipes by cold or hot forming. For welded fittings the testing scope will be stipulated by BKI.

12.3 Properties

The chemical composition and mechanical properties of the fittings shall correspond to those of the grades of pipe used for their manufacture.

12.4 Testing

If testing is required under BKI Rules for Construction, the procedure shall be as follows:

12.4.1 The manufacturer shall furnish proof of the chemical composition of the starting materials by means of certificates issued by the manufacturer of the starting material.

12.4.2 For testing, the fittings shall be grouped into test batches. A test batch shall comprise units of the same shape and size, made of the same grade of material in the same condition and produced in a single manufacturing cycle. Two specimens shall be taken from each test batch for the following tests:

— tensile test, where the nominal bore is 100 mm or over

— ring flattening test

— test for absence of internal stresses where fittings are made of CuZn alloys.

Where the number of units is 10 or less, one test specimen is sufficient.

The manufacturer shall inspect the fittings for their dimensional accuracy and surface finish.

12.5 Marking and certification

The marking and the certification of the characteristics of the material are subject, in analogous manner, to the provisions of 10. and 11.

B. Cast Copper Alloys

1. Scope

These Rules are applicable to cast copper alloys for the manufacture of valve and pump housings, shaft liners, bushes and similar parts.

2. Requirements to be met by foundries

Foundries wishing to supply products in accordance with these Rules shall be approved by BKI, see Section 1, C.

3. Manufacture

The method of manufacture shall be chosen to suit the shape of the casting. Sand casting, chill casting, centrifugal casting and continuous casting may be used. Castings may be supplied in the as cast or heat-treated condition at the manufacturer’s option unless this is specified in the order.

4. Suitable grades of cast alloy

The grades of cast alloy shall be suitable for the intended application. Subject to these conditions, the following grades may be used.

4.1 Grades stated in Table 11.10 for applications exposed to sea water.

4.2 Grades conforming to other standards or specifications provided that their suitability has been confirmed by BKI.

5. Characteristics of castings

5.1 All castings shall be supplied in a clean fettled condition. They shall be free from shrinkage cavities, pores, blow holes, cracks, inclusions and other defects which impair their use and the further course of manufacture.

Small surface defects may be removed by grinding provided that the dimensional tolerances are not exceeded.

5.2 Where defects are to be repaired by welding, the details of the process shall be submitted to the Surveyor for approval before the repair work begins and he shall be notified of the location, nature and extent of the defects. Bearing bushes and liners of cast CuPbSn alloys may not be welded. Welds aimed solely at improving the appearance of the casting are unacceptable.

6. Dimensional and geometrical tolerances

The dimensional and geometrical tolerances shall be those specified in the relevant standards. The standards shall be stated in the order and made known to the Surveyor.

7. Resistance to leakage

Castings subjected to internal pressure by the operating medium shall be tight at the prescribed test pressure.

8. Requirements applicable to the material

The chemical composition and mechanical properties shall conform to Tables 11.10 and Tables 11.11, the relevant standards or the approved specifications.

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.

Where castings are made of remelting ingots of starting material of the same grade without further additions to the heat, the certificate of the manufacturer of the starting material can be accepted as proof of the chemical composition. Minor additions to compensate for melting losses may be disregarded. In case of doubt the composition shall be determined by analyzing the casting.

Table 11.10: Suitable cast copper alloys

Material designation		Composition: [%]																				
KI-Material Code	**Material no./code acc. to EN 1982**	**Element**	**Al**	**B**	**Bi**	**C**	**Cd**	**Cr**	**Cu**	**Fe**	**Mg**	**Mn**	**Nb**	**Ni**	**P**	**Pb**	**S**	**Sb**	**Se**	**Si**	**Sn**	**Te**	**Zn**
G-CuAl10Ni	CC333G/	min.	8,5		–			–	76,0	4,0	–	–		4,0		–				–	–		–
	CuA110Fe5Ni5-C	max.	10,5		0,01			0,05	83,0	5,5	0,05	3,0		6,0		0,03				0,10	0,1		0,5
G-CuAl11Ni	CC334G/	min.	10,0						72,0	4,0	–	–		4,0		–				–	–		–
	CuAl11Fe6Ni6-C	max.	12,0						78,0	7,0	0,05	2,5		7,5		0,05				0,10	0,2		0,5
G-CuNi10	CC380H/	min.	–			–			84,5	1,0	–	–		4,0		–				–	–		–
	CuNi10Fe1Mn1-C	max.	0,01			0,10			–	1,80	0,05	2,5		7,5		0,05				0,10	0,2		0,5
G-CuNi30	CC383H/	min.	–	–	–	–	–			0,5	–	0,6	0,5	29,0	–	–	–		–	0,30		–	–
	CuNi30Fe1Mn1NbSi-C	max.	0,01	0,01	0,01	0,03	0,02			1,5	0,01	1.2	1,0	31,0	0,01	0,01	0,01		0,01	0,70		0,01	0,5
G-CuSn10	CC480K/	min.	–						88,0	–		–		–	–	–	–	–		–	9,0		–
	CuSn10-C	max.	0,01						90,0	0,2		0,1		0,2	0,20	1,0	0,05	0,2		0,02	11,0		0,5
G-CuSn12	CC483K/	min.	–						85,0	–		–		–	–	–	–	–		–	11,0		–
	CuSn12-C	max.	0,01						88,5	0,2		0,2		0,2	0,60	0,7	0,05	0,15		0,01	13,0		0,5
G-CuSn12Ni	CC484K/	min.	–						84,5	–		–		1,5	0,05	–	–	–		–	11,0		–
	CuSn12Ni2-C	max.	0,01						87,5	0,2		0,2		2,5	0,40	0,3	0,05	0,1		0,01	13,0		0,4
G-CuSn5ZnPb	CC491K/	min.	–						83,0	–				–	–	4,0	–	–		–	4,0		4,0
	CuSn5Zn5Pb5-C	max.	0,01						87,0	0,3				0,2	0,10	6,0	0,10	0,25		0,01	6,0		6,0
G-CuSn7ZnPb	CC491K/	min.	–						81,0	–				–	–	5,0	–	–		–	6,0		2,0
	CuSn7Zn4Pb7-C	max.	0,01						85,0	0,2				2,0	0,10	8,0	0,10	0,3		0,01	8,0		5,0

Table 11.11: Mechanical properties of cast copper alloys according to 4.1

KI-Material code	Condition of supply	Proof stress $R_{p0,2}$ [N/mm^2] min.	Tensile strength R_m [N/mm^2] min.	Elongation A [%] min.	Hardness HB 10 min.
G-CuSn10	sand cast	130	270	18	70
	permanent mould cast	160	270	10	80
	centrifugally cast	160	270	10	80
	continuously cast	170	280	10	80
G-CuSn7ZnPb	sand cast	120	240	15	65
	permanent mould cast	120	230	12	60
	centrifugally cast	130	270	13	75
	continuously cast	130	270	16	70
G-CuSn5ZnPb	sand cast	90	240	18	60
	permanent mould cast	110	220	8	65
	centrifugally cast	110	250	13	65
	continuously cast	110	250	13	65
G-CuSn12	sand cast	140	260	12	60
	permanent mould cast	150	270	5	65
	centrifugally cast	150	280	8	65
	continuously cast	150	300	6	65
G-CuSn12Ni	sand cast	160	280	14	90
	centrifugally cast	180	300	8	100
	continuously cast	180	300	10	95
G-CuAl10Ni	sand cast	270	600	13	140
	permanent mould cast	300	650	10	150
	centrifugally cast	300	700	13	160
	continuously cast	300	700	13	160
G-CuAl11Ni	sand cast	320	680	5	170
	permanent mould cast	400	750	5	200
	centrifugally cast	400	750	5	185
G-CuNi10	sand cast	150	310	20	100
	centrifugally cast	100	280	25	70
	continuously cast	100	280	25	70
G-CuNi30	sand cast	230	440	18	115

9.2 Tensile test

For this purpose a specimen shall be taken from each heat and subjected to test. If the weight of the heat exceeds 1000 kg, a second test specimen is required. The specimens shall be taken as follows:

9.2.1 In the case of sand and chill casting, the specimens shall be taken from integrally cast sample bars or from separately cast sample pieces. Separately cast sample pieces shall have the dimensions shown in

Fig.11.2, shall originate from the same heat and shall be cast using the same mould material.

9.2.2 In the case of centrifugal and continuous casting, the specimen shall be taken from the cast part.

9.2.3 Where castings are supplied in the heat-treated condition, the test specimen shall be subjected to the same heat treatment.

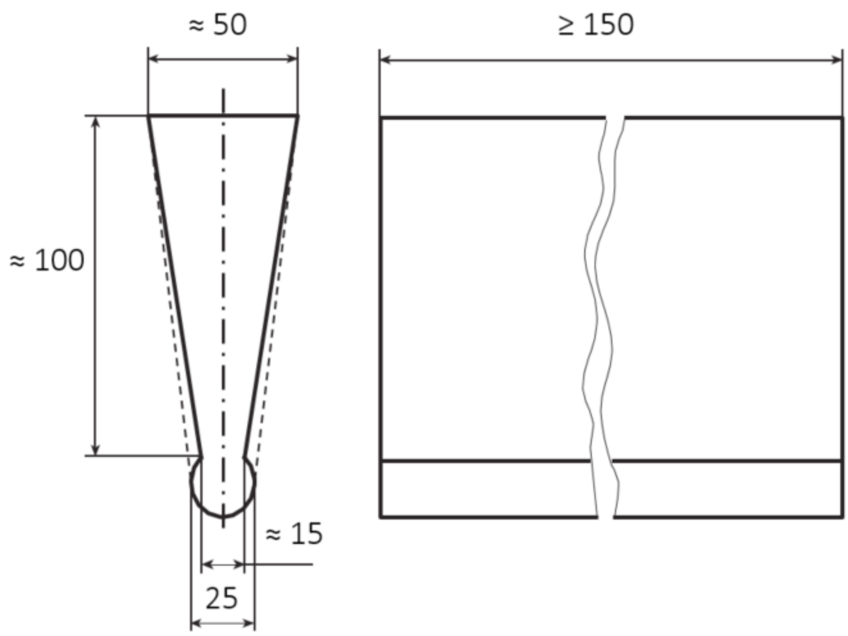

Figure 11.2: Sample piece

9.3 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, after which the casting shall be presented to the Surveyor for final inspection.

9.4 Tightness test

Where this is called for in the Rules for Construction, the castings shall be subjected to a hydraulic pressure test in the presence of the Surveyor. Shaft liners shall be tested at a pressure of at least 2 bar. For all other components the test pressure is normally 1,5 times the operating pressure.

10. Identification and marking

10.1 The manufacturer shall employ a monitoring system which enables all castings to be traced back to their heat. On request, the Surveyor shall be given proof of this.

10.2 Prior to final inspection by the Surveyor, each casting shall be marked by the manufacturer as follows:

- Manufacturer’s mark
- Short designation of the alloy
- Charge number or a code marking enabling the manufacturing process to be traced back
- Specimen number
- Date of test

— Test pressure, where applicable

At the request of the Surveyor, the test certificate number shall also be stamped on. In the case of small castings produced in series, e.g. valve housings, the marking shall be in a form which enables the casing to be matched up with the test certificate.

11. Test certificates

For each consignment the manufacturer shall supply to the Surveyor a test certificate or delivery specification containing the following details:

— purchaser and order number

— number and weight of the castings

— designation of the material and condition in which supplied

— composition of the heat (or of the starting material, where applicable)

— method of manufacture

— results of mechanical tests if performed by the manufacturer

— test pressure, where applicable.

Section 12 Anchors

A. General

1. These Rules apply to anchors made of forged or cast steel as well as to anchors made of welded components. They are also applicable to the repair of damaged anchors.

Anchor manufacturers and repair shops shall meet the requirements according to Section 1, C.

The term "anchor" also covers the connecting components which are fixed thereto, such as the anchor shanks, the swivel shackle and also the bolts.

2. Anchors conforming to these Rules are divided into three categories according to their holding power:

Category 1	:	Anchors with normal holding power
Category 2	:	Anchors with high holding power (HHP anchors)
Category 3	:	Anchors with very high holding power (VHHP)

3. The use of these Rules for the mooring anchors of floating docks and offshore equipment may be agreed.

B. Design and Tests

1. The design of the anchors shall be approved by BKI. To this end, the anchor manufacturer shall submit to BKI for approval drawings and/or data sheets containing all the details necessary for carrying out an evaluation of the anchor and its associated components (anchor shackles and swivel shackles).

2. Connecting components, such as shackles and swivel shackles shall be designed to withstand at least the test loads of the appropriate anchors.

3. Anchors with a high holding power (HHP anchors) may only be used in conjunction with KI-K2 or KI-K3 chains and those with a very high holding power (VHHP anchors) only in conjunction with KI-K3 chains, see Section 13.

4. HHP anchors and VHHP anchors and also swivel shackles which are regarded as part of the anchor shall be subjected to a type test in the presence of the Surveyor. In the case of swivel shackles, the proof and breaking loads shall also be demonstrated in accordance with Table 13.7.

The scope of the tests performed, including the tests on the HHP and VHHP anchors shall be agreed on a case by case basis between the manufacturers and BKI. This applies particularly to SHHP anchors (anchors with super high holding power).

C. Materials for Anchors and Anchor Components

1. Forged anchor components such as shanks and crowns shall be made of weldable carbon or carbon manganese steels with a carbon content not exceeding 0,22 % and shall meet the requirements set out in Section 6, B.

If swivels shall be welded directly to the anchor a welding procedure test in the presence of the Surveyor shall be carried out before hand.

2. Cast anchor components such as shanks and crowns shall be made of weldable carbon or carbon manganese cast steel and shall meet the requirements set out in Section 7, B.

3. Rolled steels for the manufacture of anchors of welded construction shall be made of weldable steel and shall meet the requirements specified in Section 4, B. or C.

4. The choice of material for shackles, swivel shackles, bolts and other connecting components is left to the manufacturer. In this case, the components shall be cast or hot-formed into a form approaching the final dimensions, with a small machining allowance. Excessive machining, such as turning a swivel body made of round steel to a smaller pin diameter is not permitted. All parts shall be produced with the maximum fillet radii possible. Threads shall be produced in such a way that they cannot cause notch effects at their run out.

D. Testing of Materials

1. For all anchor components, the anchor manufacturer shall provide the Surveyor with certificates, issued by the manufacturer of the material or fittings, indicating the chemical composition, the heat treatment condition or the condition on delivery, the heat number and the results of the mechanical tests performed on the components.

2. All cast steel parts shall be subjected, in the presence of the Surveyor, to a material test as set out in Section 7, B. Special requirements apply to SHHP anchors, for which the notched bar impact test performed on Charpy V-notch specimens is to be carried out at a test temperature of 0°C. An impact energy of at least 27 J is to be proven.

3. Contrary to Section 7, A.10.2.3 the dimensions of integrally cast specimens are to be adjusted to the determining wall thickness as described in the following.

4. On anchor shanks and palms two integrally cast specimens each are to be provided, having a width of 1/4 t, max. 100 mm and 250 mm length, where t is the anchor shank or palm root cross section.

5. If anchors are made from forged parts, these are to be subjected to a material test in the presence of the Surveyor according to Section 6, B.

E. Manufacture of anchors

1. Tolerance

If not otherwise specified on standards or on drawings demonstrated to be appropriate, the following assembly and fitting tolerance are to be applied.

The clearance either side of the shank within the shackle jaws is to be no more than 3 mm for small anchors up to 3 tonnes weight, 4 mm for anchors up to 5 tonnes weight, 6 mm for anchors up to 7 tonnes weight and is not to exceed 12 mm for larger anchors.

The shackle pin is to be a push fit in the eyes of the shackle, which are to be chamfered on the outside to ensure a good tightness when the pin is clenched over on fitting. The shackle pin to hole tolerance is to be no more than 0,5 mm for pins up to 57 mm and 1,0 mm for pins of larger diameter.

The trunnion pin is to be a snug fit within the chamber and be long enough to prevent horizontal movement. The gap is to be no more than 1% of the chamber length.

The lateral movement of the shank is not to exceed 3 degrees, see Fig. 12.1

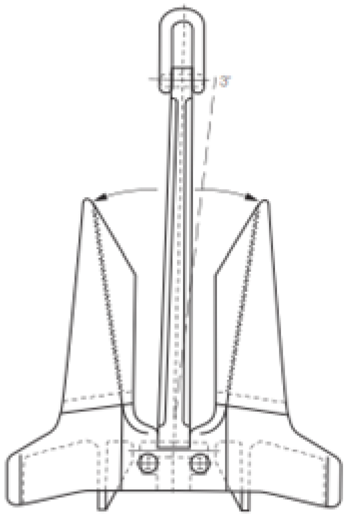

Figure 12.1: Allowable lateral movement of shank

2. Welding of anchors

Welded construction of fabricated anchors is to be done in accordance with procedures approved by BKI. Welding is to be carried out by qualified welders, following the approved welding procedures qualified in accordance with Rules for Welding (Pt.1, Vol.VI) Sec.4, using consumables manufactured in accordance with the requirements of Rules for Welding (Pt.1, Vol.VI) Sec.5. NDT is to be carried in accordance with the requirements of F.

3. Heat treatment

Components for forged or cast anchors are to properly heat treated; fully annealed; normalised or normalised and tempered in accordance with Section 6 and Section 7.

Fabricated anchors may require stress relief after welding depending upon weld thickness. Stress relief is to be carried out as indicated in the approved welding procedure. Stress relief temperatures are not to exceed the tempering temperature of the base material.

4. Freedom from defects

All parts are to have a clean surface consistent with the method of manufacture and be free from cracks, notches, inclusions and other defects that would impair the performance of the product.

After testing at the test load specified in F. anchors may not reveal any permanent deformations. In addition, in the case of anchors of composite construction, the freedom of movement of the arms over the whole angle of deflection shall be preserved following the test, and no excessive changes may be caused by deformation of the bearings.

5. Anchor assembly

Assembly and fitting are to be done in accordance with the design details. Securing of the anchor pin, shackle pin or swivel nut by welding is to be done in accordance with an approved procedure.

F. Testing of Anchors

1. Condition in which tested

Anchors are to be submitted for testing in the fully assembled condition and may not be coated with paint or preservatives.

2. Non-destructive tests

2.1 Before the load test all anchors are to be visually inspected by the manufacturer as well as tested for surface defects and cracks in highly stressed areas of the palms by means of magnetic particle test.

If no other requirements regarding quality have been agreed between the purchaser and manufacturer, quality level 2 according to DIN EN 1370 is applicable for the visual inspection and quality levels SM2, LM2 and AM2 according to EN 1369 are applicable for the magnetic particle test.

2.2 Any defects and/or cracks are to be removed by grinding or welding according to Section 7, A.13. In any case the repaired areas have to be retested prior to the load test according to 2.1.

2.3 In addition ultrasonic tests have to be carried out with HHP and VHHP anchors in way of cut risers and gating systems and in way of repair welding. On this quality requirements according to EN 12680-1 have to be agreed between purchaser and manufacturer considering geometric conditions. If not otherwise agreed, quality level 2 applies.

2.4 Weld seams of anchors of welded construction have to be tested according to Rules for Welding (Pt.1, Vol.VI), if not otherwise agreed between purchaser and manufacturer.

Highly stressed weld seams of HHP and VHHP anchors have to be tested according to the requirements for weld seam grade 1, those of other anchor types according to weld seam grade 2.

3. Load test

3.1 Anchors with a total weight (including the stock) of 75 kg and over are to be subjected in the presence of a Surveyor to a load test at the appropriate loads shown in Table 12.1 using a calibrated testing machine approved by BKI.

3.2 In the case of large anchors weighing 15000 kg and over, other tests may be substituted for the load tests, if the available testing machine is incapable of producing the specified test load. The nature of these tests is to be agreed with BKI.

3.3 The test load shall be applied at a point on the arm or palm which, measured from the point of the palm, is located at one third of the distance from the point of the palm to the centre of the anchor crown. With stockless anchors, both arms are to be tested simultaneously in both end positions. In the case of stocked anchors, the test load is to be applied alternately to each arm.

3.4 The following anchor weights are to be applied in establishing the test loads in accordance with Table 12.1:

— Stockless anchors: the total weight

— Stocked anchors: the weight without the stock

— Anchors with high holding power (HHP): a weight equal to 1,33 times the actual weight

— Anchors with very high holding power (VHHP): a weight equal to 2,0 times the actual weight of the anchor

— Mooring anchors: a weight equal to 1,33 times the actual weight, unless specified otherwise.

3.5 After the load test, anchors are to be submitted to the Surveyor for verification of their delivery condition. Verification comprises visual inspection according to 4. as well as surface crack testing. In case of anchors of composite construction the freedom of movement of the arms is to be demonstrated.

Table 12.1: Test loads for anchor [1]

Weight [2] [kg]	Test load [kN]	Weight [2] [kg]	Test load [kN]	Weight [2] [kg]	Test load [kN]
50	23,2	2200	376	7800	861
55	25,2	2300	388	8000	877
60	27,1	2400	401	8200	892
65	28,9	2500	414	8400	908
70	30,7	2600	427	8600	922
75	32,4	2700	438	8800	936
80	33,9	2800	450	9000	949
90	36,3	2900	462	9200	961
100	39,1	3000	474	9400	975
120	44,3	3100	484	9600	987
140	49	3200	495	9800	998
160	53,3	3300	506	10000	1010
180	57,4	3400	517	10500	1040
200	61,3	3500	528	11000	1070
225	65,8	3600	537	11500	1090
250	70,4	3700	547	12000	1110
275	74,9	3800	557	12500	1130
300	79,5	3900	567	13000	1160
325	84,1	4000	577	13500	1180
350	88,8	4100	586	14000	1210
375	93,4	4200	595	14500	1230
400	97,9	4300	604	15000	1260
425	103	4400	613	15500	1280
450	107	4500	622	16000	1300
475	112	4600	631	16500	1330
500	116	4700	638	17000	1360
550	124	4800	645	17500	1390
600	132	4900	653	18000	1410
650	140	5000	661	18500	1440
700	149	5100	669	19000	1470
750	158	5200	677	19500	1490
800	166	5300	685	20000	1520
850	175	5400	691	21000	1570
900	182	5500	699	22000	1620
950	191	5600	706	23000	1670
1000	199	5700	713	24000	1720
1050	208	5800	721	25000	1770
1100	216	5900	728	26000	1800
1150	224	6000	735	27000	1850
1200	231	6100	740	28000	1900
1250	239	6200	747	29000	1940
1300	247	6300	754	30000	1990
1350	255	6400	760	31000	2030
1400	262	6500	767	32000	2070
1450	270	6600	773	34000	2160
1500	278	6700	779	36000	2250
1600	292	6800	786	38000	2330
1700	307	6900	794	40000	2410
1800	321	7000	804	42000	2490
1900	335	7200	818	44000	2570
2000	349	7400	832	46000	2650
2100	362	7600	845	48000	2730

[1] Intermediate values can be determined by linear interpolation.

[2] In order to establish the test load of HHP anchors, VHHP anchors and mooring anchors, the weight stated in the table is to be multiplied by the factors given in F.3.4.

4. Extended non-destructive test

After proof loading general NDT is to be carried out as indicated in the following Table 12.2.

Table 12.2: Extended NDT for Normal Holding Power, HHP and VHHP anchors

Location	Method of NDT
Feeders of castings	PT or MT and UT
Risers of castings	PT or MT and UT
All surfaces of castings	PT or MT
Random areas of castings	UT
Weld repairs	PT or MT
Forged components	Not required
Fabrication welds	PT or MT
Guidance for Marine Industry (Pt.1, Vol.AC) Sec.4, R-69 "Guidelines for non-destructive examination of marine steel castings" is regarded as an example of an acceptable standard for surface and volumetric examination.	

5. Repair criteria

If defects are detected by NDT, repairs are to be carried out in accordance with H.

6. Mass and dimensional inspection

Unless otherwise agreed, the verification of mass and dimensions is the responsibility of the manufacturer. The Surveyor is only required to monitor this inspection. The mass of the anchor is to exclude the mass of the swivel, unless this is an integral component.

G. Marking

1. Anchors which have fulfilled the test conditions are to be marked by the manufacturer as follows:

- Manufacturer's symbol
- Number of the BKI test certificate
- Month and year of test
- Total weight
- Weight of stock (in the case of stocked anchors)
- The letters HHP in the case of anchors with high holding power
- The letters VHHP in the case of anchors with very high holding power

2. The marks are to be impressed with punches on the anchor shank and on the right palm (line of sight anchor base to shackle) as shown in Fig. 12.2.

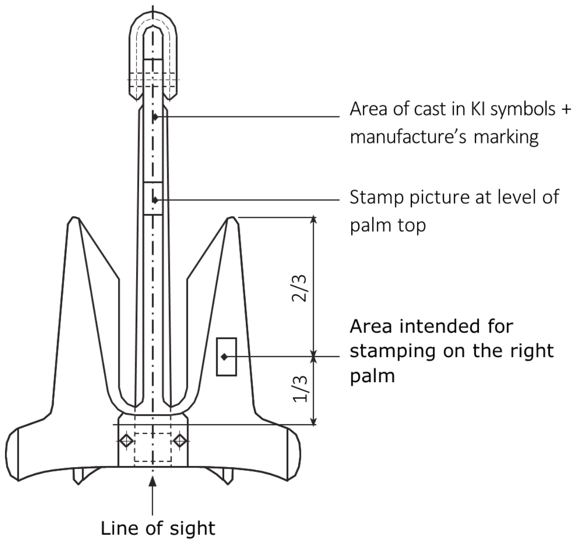

Figure 12.2: Marking of anchor

3. For anchors which have met the requirements according to F. an acceptance test certificate will be issued.

This shall specify at least the following:

- Manufacturer
- Type of anchor
- Total weight
- Material
- Anchor shank number
- Anchor shackle number, where necessary palm marking
- Test load
- Anchor stamping
- Heat treatment

H. Repair and Testing of Damaged Anchors

1. Damaged anchors may be repaired by straightening and/or welding, provided that the Surveyor approves the method used. Straightening shall be performed hot.

2. Welds are to be executed, preferably in the horizontal position and with the welding area pre-heated accordingly, by certified welders using approved electrodes. After welding, the anchor component concerned is to be stress-relieved. Welds shall be free from defects liable to impair the function of the anchor, e.g. cracks, slag inclusions, serious undercutting and lack of fusion.

3. Where welds are performed on steel castings, the requirements specified in Section 7, A.13 are also to be complied with.

4. Repaired anchors are to be retested in accordance with F.

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Section 13 Chain Cables and Accessories

A. Anchor Chain Cables and Accessories Chain

1. General rules

1.1 Scope

These Rules are applicable to the materials, design, manufacture and testing of stud link chain cables and accessories for ships. Where short-linked studless chain cables are used in exceptional cases with BKI's approval, they shall comply with a recognized standard. For connecting components fixed to the anchor Section 12 is applicable.

1.2 Chain cable grades

Depending on the nominal strength of the steel used to manufacture the chain cable, stud link chain cables are classified into the grades KI-K1, KI-K2 and KI-K3.

Regarding chain cable grades KI-R3, KI-R3S and KI-R4 the Rules for Mobile Offshore Unit (Pt.5, Vol.VI) are to be observed and applied.

1.3 Approval of chain cable manufacturers

1.3.1 Anchor chain cables and accessories may only be manufactured by works approved by BKI.

1.3.2 For non-standard accessories, the drawings shall be submitted to BKI for approval.

2. Chain cable materials

2.1 Scope

These Rules are applicable to rolled steels, forgings and cast steels for the manufacture of anchor chain cables and accessories.

2.2 Requirements to be met by material manufacturers

2.2.1 All materials for the manufacture of anchor chain cables and accessories may only be supplied by manufacturers approved by BKI. Approval tests shall be conducted for this purpose.

2.2.2 The manufacturers of the materials or the anchor chain cables shall submit to BKI specifications of the materials to be used.

2.2.3 The material specification shall contain all the information required for its evaluation, such as the method of manufacture, method of deoxidation, nominal chemical composition, method of heat treatment and mechanical properties.

2.2.4 Rolled products, forgings and castings intended for the manufacture of anchor chain cables and accessories shall meet the required values for the mechanical properties according to Table 13.2.

2.3 Rolled steel bars

2.3.1 Manufacturing process

The steels shall be manufactured by the basic oxygen, electric furnace or open-hearth process. Grade KI-K1 chain cable steel shall be killed before pouring, while all other grades shall be killed and fine grain treated.

2.3.2 Condition of supply

Unless otherwise specified, the steels shall be supplied in rolled condition.

2.3.3 Chemical composition

Rolled steel bars are to be supplied with a certificate of the manufacturer about the chemical composition of each heat. The chemical composition of the steels shall conform to the data in Table 13.1.

Table 13.1: Chemical composition of rolled steel bars

Grade	Chemical composition (heat) [%]					
	C max.	Si	Mn	P max.	S max.	Al_{tot} [1) min.
KI-K1	0,2	0,15 – 0,35	min. 0,40	0,04	0,04	–
KI-K2 [2)	0,24	0,15 – 0,55	max. 1,60	0,035	0,035	0,02
KI-K3 [3)	0,33	0,15 – 0,35	max. 1,90	0,04	0,04	0,065

1) Aluminium may be partly replaced by other grain refining elements.
2) With BKI approval, additional alloying constituents may be added.
3) Nb = max. 0,05; V = max. 0,10; N = max. 0,015; Cr = max. 0,25; Cu = max. 0,35; Ni = max. 0,4; Mo = max. 0,08.

2.3.4 Testing of mechanical properties

The mechanical tests shall be performed at the chain cable manufacturer's premises. At the request of the chain cable manufacturer, the mechanical testing of the steel bars may be carried out at the rolling mill; the test sections shall be in a heat treated condition corresponding to that of the finished chain cable. In this case, the requirements specified in Table 13.2 shall be met.

2.3.5 Dimensional tolerances of rolled steels

The diameter and oval shape of rolled steels shall lie within the permitted dimensional tolerances shown in Table 13.3.

Table 13.2: Mechanical properties of chain cable materials

Grade	Yield strength R_{eH} [N/mm^2] min	Tensile strength R_m [N/mm^2]	Elongation A [%] min.	Reduction in area Z [%] min.	Impact energy	
					Test temperature [°C]	KV [1) [J] min
KI-K1	—	370 – 490	25	—	—	—
KI-K2	295	490 – 690	22	—	0	27 [2)
KI-K3	410	min. 690	17	40	0	60
					(– 20)	(35) [3)

1) Average value obtained with 3 specimens. One individual value may be below, but not less than 70 % of, the average value.
2) The notched bar impact test may be dispensed with for KI-K2 material if the chain cable is supplied in heat-treated condition.
3) Alternatively, the notched bar impact test may be performed at – 20°C.

Table 13.3: Permitted tolerances applicable to the diameter and oval shapes of rolled chain cable steel

Nominal diameter [mm]	Diameter tolerance [mm]	Oval shape (d_{max} – d_{min}) [mm]
Below 25	– 0 + 1,0	0,6
25 – 35	– 0 + 1,2	0,8
36 – 50	– 0 + 1,6	1,1
51 – 80	– 0 + 2,0	1,5
81 – 100	– 0 + 2,6	1,95
101 – 120	– 0 + 3,0	2,25
121 – 160	– 0 + 4,0	3

2.3.6 External and internal condition

The material shall be free from internal and surface defects which have more than an insignificant adverse effect on their proper working and use. Surface defects may be removed by grinding provided that the permitted tolerances are not exceeded.

2.3.7 Identification of the material

The manufacturer shall have an identification system which enables the material to be traced back to its manufacture.

2.3.8 Testing

For the mechanical tests, the steel bars shall be sorted into heats and sizes and grouped into test batches weighing 50 t max. One test section shall be taken from each test batch for the tests stated in 2.3.8.3 and 2.3.8.4.

Before the test specimens are prepared, the test sections shall be subjected to the heat treatment intended for the finished chain cable, see Table 13.4. The details of the heat treatment shall be established by the manufacturer.

Tensile and notched bar impact test specimens shall be taken from the test section in the longitudinal direction in such a way that the longitudinal axis is located at a distance of 1/6 of the diameter from the surface, see Fig. 13.1.

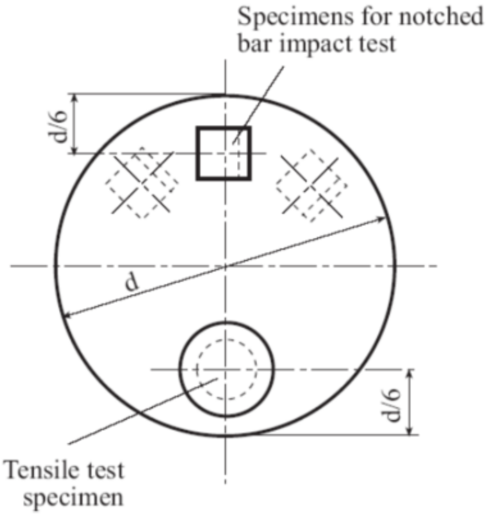


Figure 13.1: Location of specimens in chain cable steel

For tensile testing, one specimen shall be taken from each test batch and tested in accordance with Section 2, D.

The notched bar impact test on steel bars of grade KI-K3 and, if necessary, grade KI-K2 shall be performed in accordance with Section 2, E. For this purpose, one set of 3 Charpy V-notch specimens is to be taken from each test batch and tested at the temperature specified in Table 13.2. The notch shall be located radially in the bar.

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

If specimens subjected to tensile or impact testing fail to meet the requirements, two new specimens or sets of specimens shall be tested for each unsatisfactory test. The specimens for the retests shall be taken from other samples of the same unit test quantity which were not the source of the test sections used for the first test. The unit test quantity is deemed to be accepted if both new specimens or sets of specimens have satisfied the requirements in the retest.

If the unsatisfactory test result is attributable to inadequate heat treatment, a fresh test section may be taken from the same sample and heat-treated again. In this case the entire testing (tensile and impact tests) shall be repeated, the first result being disregarded.

2.3.9 Marking

The steels shall be marked, as a minimum requirement, with the manufacturer's symbol, the grade and an abbreviated designation for the heat. Steel bars up to 40 mm in diameter which are collected into bundles may be marked by means of a permanently attached tag.

2.3.10 Works acceptance certificate

For each delivery, the manufacturer shall give the Surveyor a certificate containing, as a minimum requirement, the following data:

— Job and/or order no.

— Quantity, dimensions and weight of delivery

— Grade of steel

— Heat number

— Method of manufacture

— Chemical analysis

— Details of heat treatment of test section (where applicable)

— Results of mechanical testing (where applicable)

— Test specimen numbers (where applicable)

2.4 Forged steel

2.4.1 General requirements

Forgings intended for the manufacture of chain cables and accessories shall satisfy the requirements specified in Section 6, B., unless otherwise prescribed below.

2.4.2 Chemical composition

The chemical composition shall correspond to a specification approved by BKI. The steel manufacturer shall determine and certify the composition of every heat.

2.4.3 Condition of supply

The starting material may be supplied in either rolled or forged condition. Finished forgings shall be properly heat-treated, i.e. normalized, normalized and tempered or quenched and tempered.

2.4.4 Mechanical properties

Unless other requirements are prescribed according to the specification, the requirements shown in Table 13.2 shall, as a minimum requirement, be met after heat treatment has been carried out.

2.4.5 Mechanical tests

For the preparation of test specimens, forgings of approximately the same size which originate from the same heat and heat treatment batch shall be grouped into a test batch. One tensile test specimen and one set of 3 Charpy V-notch specimens shall be taken from every test batch and tested. For the location of the specimens, please refer to 2.3.8.2 and Fig. 13.1.

2.5 Steel castings

2.5.1 General requirements

Steel castings intended for the manufacture of chain cables and accessories shall satisfy the requirements specified in Section 7, B., unless otherwise prescribed below.

2.5.2 Chemical composition

The chemical composition shall correspond to a specification approved by BKI. The steel manufacturer shall determine and certify the composition of every heat.

2.5.3 Heat treatment

All steel castings shall be properly heat treated, i.e. normalized or quenched and tempered.

2.5.4 Mechanical properties

Unless other requirements are prescribed according to the specification, the requirements shown in Table 13.2 shall be met as a minimum requirement.

2.5.5 Mechanical tests

For the preparation of test specimens, castings of approximately the same size which originate from the same heat and heat treatment batch shall be grouped into a test batch. One tensile test specimen and one set of 3 Charpy V-notch specimens shall be taken from every test batch and tested.

2.6 Material for the studs of chain links

The studs of chain links shall be made of a type of steel which corresponds to the chain cable or of unalloyed rolled, forged or cast low-carbon steels. The use of other materials such as grey or nodular cast iron is not permitted.

3. Construction and manufacture

3.1 Method of manufacture

3.1.1 Stud link chain cables should preferably be manufactured by flash butt welding using rolled steel bars of grades KI-K1, KI-K2 or KI-K3, see 2. Manufacture of the links by drop forging or steel casting is also permitted. On request, pressure butt-welding may also be approved for studless chain cables made of grades KI-K1 and KI-K2, provided that the nominal diameter of the chain cable does not exceed 26 mm.

3.1.2 Accessories such as shackles, swivels and swivel shackles shall be forged or cast in steel of at least grade KI-K2. Welded constructions are subject to BKI approval.

3.2 Construction

Anchor chain cables shall be manufactured according to a standard recognized by BKI, e.g. ISO 1704:2008. Conventional constructions of chain cable links are shown in Fig. 13.4, 13.5 and 13.6. A length of chain cable shall comprise an odd number of links.

If the construction does not comply with this provision or if accessories are to be of welded construction, drawings giving full details of the manufacturing process and the method of heat treatment shall be submitted to BKI for approval.

3.3 Heat treatment

Depending on the grade of steel, chain cables shall be supplied in one of the conditions specified in Table 13.4. Heat treatments shall always be performed before the tests at proof and breaking loads.

Table 13.4: Heat treatment of chain cables and accessories

Grade	Condition of supply	Accessories
KI-K1	Untreated or normalized after welding	NA [2)]
(KI-K2) [1)]	Untreated or normalized after welding	Normalized
KI-K3	Normalized, normalized and tempered or quenched and tempered	Normalized, normalized and tempered or quenched and tempered

1) Chain cables made of grade KI-K2 steel shall generally be normalized. BKI may waive this stipulation if it is proved by means of an approval test that the chain cables meet the requirements. An extended scope of testing may be prescribed for such chain cables.

2) NA = Not Applicable

3.4 Mechanical properties

The mechanical properties of the finished chain cable and accessories, i.e. tensile strength, elongation, reduction in area and impact energy, shall meet the requirements shown in Table 13.2.

3.5 Requirements applicable to proof and breaking loads

Chain cables and accessories shall be manufactured in such a way that they withstand the proof and breaking loads specified for the respective grade of steel in Table 13.7.

3.6 Freedom from defects

3.6.1 Insignificant surface defects may be leveled by grinding so as to leave a gentle transition to the surrounding surface. Outside the bends of the links, localized grinding up to a depth of 5 % of the nominal diameter is permitted.

3.6.2 All individual parts shall have a high-quality surface consistent with the method of manufacture and free from cracks, notches, inclusions and other defects which restrict the use of the product. The flashes produced by upsetting and forging shall be properly removed, see 3.7.2.

3.7 Dimensions and dimensional tolerances

3.7.1 The dimensions of shackles and swivels shall conform to a recognized standard. Conventional constructions are shown in Fig. 13.7 to 13.10.

3.7.2 The following tolerances are acceptable for links:

— Diameter in the area of the link bend (crown)

- Up to 40 mm nominal diameter: – 1 mm
- Over 40 up to 84 mm nominal diameter: – 2 mm
- Over 84 up to 122 mm nominal diameter: – 3 mm
- Over 122 mm nominal diameter: – 4 mm

The plus tolerance may be up to 5 % of the nominal diameter. The link bend cross section may not have any negative tolerance.

— Diameter, measured at points outside the link bend (crown):

The diameter may not have a negative tolerance. The plus tolerance may be up to 5 % of the nominal diameter. The plus tolerance in the area of the reinforcement is subject to the chain cable manufacturer's production specification which shall be approved by BKI. (The plus tolerance shall not be more than 8 % of the nominal diameter).

— The maximum tolerance for the chain cable measured over a length of 5 links may be up to $+$ 2,5 % but shall not assume a negative value. This applies to chain cables under 10 % initial load after proof loading.

— All other dimensions are subject to a manufacturing tolerance of up to $\pm$ 2,5 %, provided that all parts of the chain cable fit together properly.

— Studs shall be located in the links centrally and at right angles to the sides of the link. The studs of end links may be located off-centre to facilitate the insertion of the shackles. The following tolerances are regarded as being inherent in the method of manufacture and will not be objected to provided that the stud fits snugly and its ends lie practically flush against the inside of the link:

- maximum off-centre distance "X" = 10 % of nominal diameter d
- maximum deviation "α" from the 90° position: 4°

The deviations shall be measured in accordance with Fig. 13.2.

3.7.3 The following dimensional tolerances are applicable to chain cable accessories:

— Nominal diameter: + 5 %, – 0 %

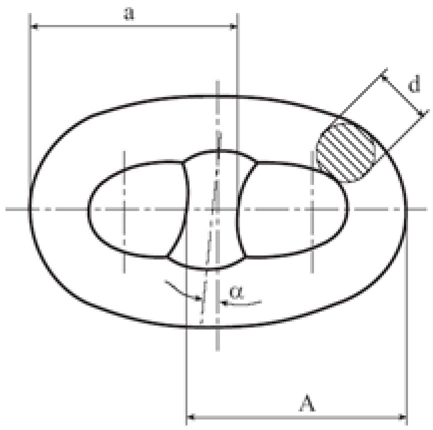
— Other dimensions: $\pm$ 2,5 %

3.8 Welding of studs

Welding of studs shall be carried out according to an approved process, subject to the following conditions:

— The studs shall be made of weldable steel, see 2.6.

— The studs may be welded at one end only, i.e. opposite the butt weld of the link. They shall lie against the sides of the links with no appreciable gap.



Off-centre distance: $X = \frac{A - a}{2}$

Figure 13.2: Tolerances for stud position

— The welds, preferably in the horizontal position, shall be executed by certified welders using suitable welding consumables.

— All welds shall be executed before the final heat treatment of the chain cable.

— The welds shall be free from defects liable to impair the use of the chain cable for its intended purpose. Undercuts, end craters and similar defects shall be ground off.

BKI reserve the right to call for a procedure test for the welding of the studs.

4. Testing of finished chain cables

4.1 Tests at proof and breaking loads

4.1.1 All chain cables are to be subjected to the following tests in the presence of the Surveyor. For this purpose, the chain cables shall be free from paint and anti-corrosion media. The test pieces shall not break and shall be free from cracks after testing.

4.1.2 Each chain cable length (27,5 m) is to be subjected to a loading test at the proof load appropriate to the particular chain cable as shown in Table 13.7, using an approved testing machine.

4.1.3 Sample links comprising three links in the quantity specified in Table 13.5 are to be taken from the chain cables. These are to be tested for at least 30 seconds at the breaking loads shown in Table 13.7. The links concerned shall be made in a single manufacturing cycle together with the chain cable and shall be welded and heat treated together with it. Only then may they be separated from the chain cable in the presence of the Surveyor.

4.1.4 If the tensile loading capacity of the testing machine is insufficient to apply the breaking load for chain cables of large diameter, another equivalent testing method shall be agreed with BKI.

4.2 Retests

4.2.1 Should a breaking load test fail, a further test specimen may be taken from the same length of chain cable and tested. The test shall be considered successful if the requirements are then satisfied.

4.2.2 If the retest fails, the length of chain cable concerned shall be rejected. If the manufacturer so wishes, the remaining three lengths belonging to the test batch may then be individually subjected to test at the breaking load. If one such test fails to meet the requirements, the entire test batch of 4 lengths shall be rejected.

4.2.3 If a proof load test fails, the defective links are to be replaced; localized heat treatment of the new links shall then be carried out and the proof load test repeated. In addition, the causes of the failure are to be determined.

4.3 Testing of mechanical and technological properties of KI-K2 and KI-K3 chain cables

4.3.1 For KI-K3 and, where necessary, for KI-K2 chain cables, one tensile test specimen and one set of 3 Charpy V-notch specimens shall be taken from every fourth length of chain cable and tested. The specimens are to be taken from the parent metal on the side of the link opposite the weld, see also Table 13.5.

In addition, one set of Charpy V-notch specimens with the notch located in the weld shall be taken from KI-K3 chains and non-heat-treated KI-K2 chains and tested.

Table 13.5: Scope of mechanical and technological testing of finished chain cables

Grade	Method of manufacture	Heat treatment [1]	No. of test specimens from every 4th length of chain cable			
			Breaking load test [2]	Tensile test parent metal	Notched bar impact test parent metal	Notched bar impact test weld
KI-K1	welding	none	1	–	–	–
KI-K2	welding	N	1	–	–	–
KI-K2	welding	none	1	1 [2]	3	3
KI-K3	welding	N, QT	1	1 [2]	3	3
KI-K2	casting or forging	N	1	1	3	–
KI-K3	casting or forging	N, QT	1	1	3	–

[1] Heat treatments: N = normalizing, QT = quenching and tempering

[2] BKI may additionally require a tensile test of the weld if there are doubts as to the characteristics of the chain cable.

4.3.2 For preparing the test specimens, an additional link (or, where the chains are small, several additional links) shall be provided in a length of chain cable which is not used to supply a specimen for the breaking load test. The sample shall be manufactured and heat-treated together with the length of chain cable.

4.3.3 The mechanical properties and the impact energy shall meet the requirements shown in Table 13.6.

Table 13.6: Mechanical properties of finished chain cables

Grade	Parent metal	Weld area		
		Elongation [1] A [%]	Notched bar impact energy: Test temperature [°C]	Notched bar impact energy: Impact energy KV [J] [2] min.
KI-K1	The requirements specified in Table 13.2 are to be met.	25	–	–
KI-K2		18	0	27
KI-K3		14	0	50
			(– 20)	(27) [3]

[1] The tensile strength and the yield strength shall conform to the requirements specified in Table 13.2. No value for the reduction in area is specified for grade KI-K3.

[2] Average value obtained with 3 test specimens. One individual value may be lower than, but not less than 70 % of, this required average value.

[3] Alternatively, the notched bar impact test may be performed at – 20°C, see Table 13.2.

5. Marking and Certification

5.1 Marking

Chain cables which have met the requirements shall be stamped on both end links of each length of chain cable with the following identifying marks, see Fig. 13.3:

- Grade of chain cable
- Test certificate number and branch office initial
- BKI's stamp

5.2 Certification

Chain cables which meet the requirements are to be certified by BKI at least with the following items:

- Manufacturer's name
- Grade
- Chemical composition (including total aluminum content)
- Nominal diameter/weight
- Proof/break loads
- Heat treatment
- Marks applied to chain
- Length
- Mechanical properties, where applicable

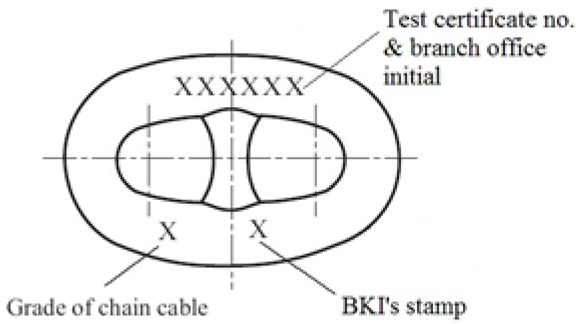


Figure 13.3: Stamping of chain cables

6. Testing of accessories

6.1 Proof load test

All accessories are to be subjected to the proof load test at the proof load specified for the corresponding chain in Table 13.7.

6.2 Breaking load test

6.2.1 From each manufacturing batch (same heat, size and heat treatment charge, but not necessarily representative of each heat of steel or individual purchase order) of 25 units or less of shackles, swivels, swivel shackles, enlarged links and end links, and from each manufacturing batch of 50 units or less of kenter shackles, one unit is to be subjected to the breaking load test at the break load specified for the corresponding chain given by Table 13.7 and in accordance with the or visions of 4.1, as appropriate. Parts tested in this way may not be put to further use. Enlarged links and end links need not be tested provided that they are manufactured and heat treated together with the chain cable.

6.2.2 In the case of swivels and swivel and anchor shackles, BKI may waive the breaking load test if:

— The breaking load has been demonstrated on the occasion of the approval testing of parts of the same design;

— The mechanical properties of each manufacturing batch are proved, and

— The parts are subjected to suitable non- destructive testing.

6.2.3 Notwithstanding the above, the accessories, which have been successfully tested at the prescribed breaking load appropriate to the chain, may be used in service at the discretion of BKI where the accessories are manufactured with the following:

a) The material having higher strength characteristics than those specified for the part in question (e.g. KI-K3 materials instead of KI-K2 materials),

b) Or alternatively, the same grade material as the chain but with increased dimensions subject to the successful procedure tests that such accessories are so designed that the breaking strength is not less than 1,4 times the prescribed breaking load of the chain for which they are intended.

Table 13.7: Proof and breaking loads for stud link chain cables

Chain diameter [mm]	Grade KI-K1		Grade KI-K2		Grade KI-K3		Weight [kg/m] 1)
	proof load [kN]	breaking load [kN]	proof load [kN]	breaking load [kN]	proof load [kN]	breaking load [kN]	
1	2	3	4	5	6	7	8
12,5	46	66	66	92	92	132	3,4
14	58	82	82	116	116	165	4,3
16	76	107	107	150	150	216	5,6
17,5	89	127	127	179	179	256	6,7
19	105	150	150	211	211	301	7,9
20,5	123	175	175	244	244	349	9,2
22	140	200	200	280	280	401	10,6
24	167	237	237	332	332	476	12,6
26	194	278	278	389	389	556	14,8
28	225	321	321	449	449	642	17,2
30	257	368	368	514	514	735	19,7
32	291	417	417	583	583	833	22,4
34	328	468	468	655	655	937	25,3
36	366	523	523	732	732	1050	28,4
38	406	581	581	812	812	1160	31,6
40	448	640	640	896	896	1280	35,0
42	492	703	703	981	981	1400	38,6

1) For footnotes, see end of table.

Table 13.7: Proof and breaking loads for stud link chain cables *(continued)*

Chain diameter [mm]	Grade KI-K1		Grade KI-K2		Grade KI-K3		Weight [kg/m] [1)]
	proof load [kN]	breaking load [kN]	proof load [kN]	breaking load [kN]	proof load [kN]	breaking load [kN]	
1	2	3	4	5	6	7	8
44	538	769	769	1080	1080	1540	42,2
46	585	837	837	1170	1170	1680	46,3
48	635	908	908	1270	1270	1810	50,4
50	696	981	981	1370	1370	1960	54,8
52	739	1060	1060	1480	1480	2110	59,2
54	794	1140	1140	1590	1590	2270	63,8
56	851	1220	1220	1710	1710	2430	68,7
58	909	1290	1290	1810	1810	2600	73,6
60	969	1380	1380	1940	1940	2770	78,8
62	1030	1470	1470	2060	2060	2940	84,2
64	1100	1560	1560	2190	2190	3130	89,7
66	1160	1660	1660	2310	2310	3300	95,4
68	1230	1750	1750	2450	2450	3500	101,3
70	1290	1840	1840	2580	2580	3690	107,3
73	1390	1990	1990	2790	2790	3990	116,7
76	1500	2150	2150	3010	3010	4300	126,5
78	1580	2260	2260	3160	3160	4500	133,2
81	1690	2410	2410	3380	3380	4820	143,7
84	1800	2580	2580	3610	3610	5160	154,5
87	1920	2750	2750	3850	3850	5500	165,8
90	2050	2920	2920	4090	4090	5840	177,4
92	2130	3040	3040	4260	4260	6080	185,4
95	2260	3280	3280	4510	4510	6440	197,6
97	2340	3340	3340	4680	4680	6690	206,1
100	2470	3530	3530	4940	4940	7060	219
102	2560	3660	3660	5120	5120	7320	227,8
105	2700	3850	3850	5390	5390	7700	241,4
107	2790	3980	3980	5570	5570	7960	250,7
111	2970	4250	4250	5940	5940	8480	269,8
114	3110	4440	4440	6230	6230	8890	284,6
117	3260	4650	4650	6510	6510	9300	299,8
120	3400	4850	4850	6810	6810	9720	315,4
122	3500	5000	5000	7000	7000	9990	326
124	3600	5140	5140	7200	7200	10280	336,7
127	3750	5350	5350	7490	7490	10710	353,2
130	3900	5570	5570	7800	7800	11140	370,1
132	4000	5720	5720	8000	8000	11420	381,6
137	4260	6080	6080	8510	8510	12160	411
142	4520	6450	6450	9030	9030	12910	441,6
147	4790	6840	6840	9560	9560	13660	473,2
152	5050	7220	7220	10100	10100	14430	506
157	5320	7600	7600	10640	10640	15200	539,8
162	5590	7990	7990	11170	11170	15970	574,7

[1)] Approximate weight data calculated according to the formula kg/m = 0,0219 × d^2 (d in mm).

6.3 Mechanical tests

The parts shall be subjected to mechanical tests in accordance with 2.4.5 and 2.5.5 in the Surveyor's presence, depending on the nature and grade of the material.

6.4 Marking

Accessories which meet the requirements shall be stamped as follows:

- Chain cable grade
- Test certificate number and branch office initial
- BKI's stamp

6.4.1 Dimensions for chain links, swivels and shackles (Fig. 13.4 to 13.10)

> ***Note:***
>
> *All dimensions are given as a factor of the nominal diameter d of the standard link:*

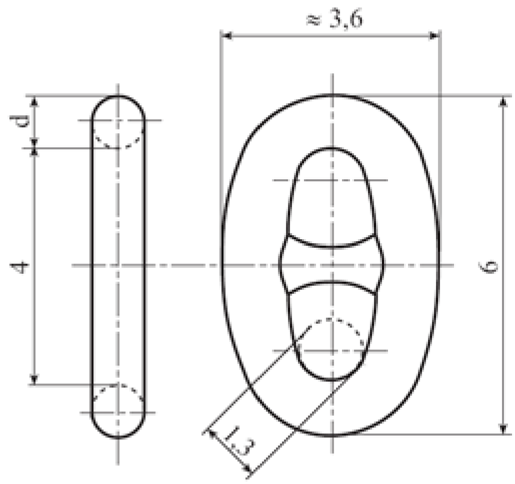


Figure 13.4: Standard link

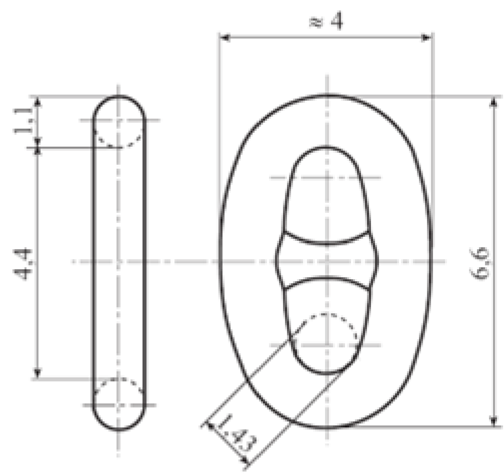


Figure 13.5: Large link

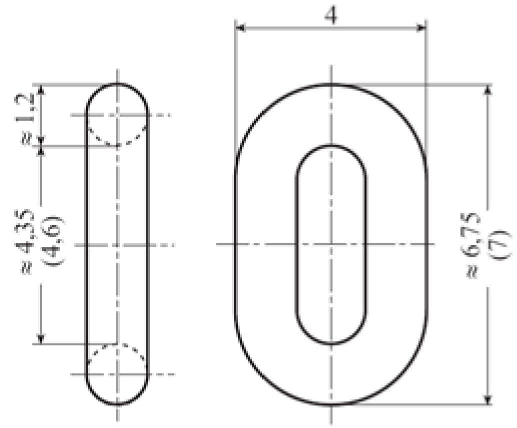


Figure 13.6: Studless link

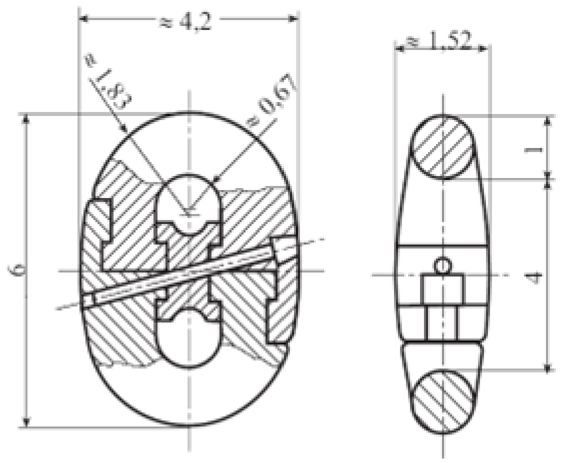


Figure 13.7: Kenter shackle

Note:

The dimensions in brackets may be chosen for studless links in fore runners.

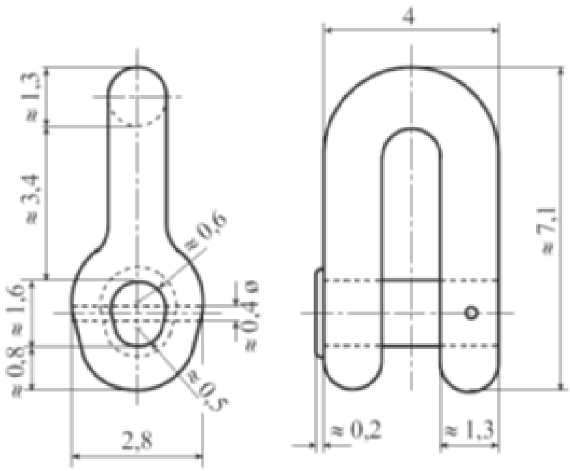


Figure 13.8: Connecting shackle

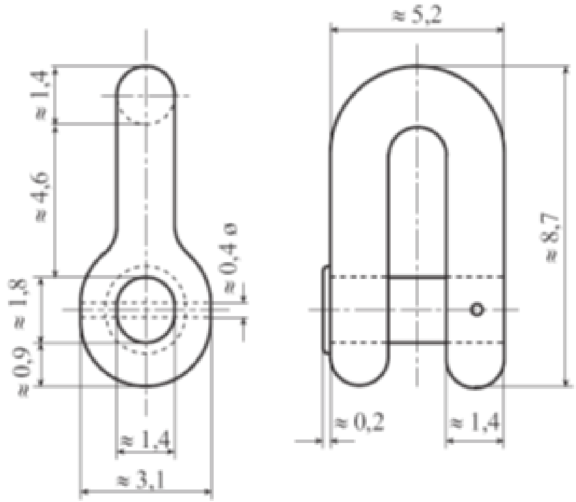


Figure 13.9: End shackle

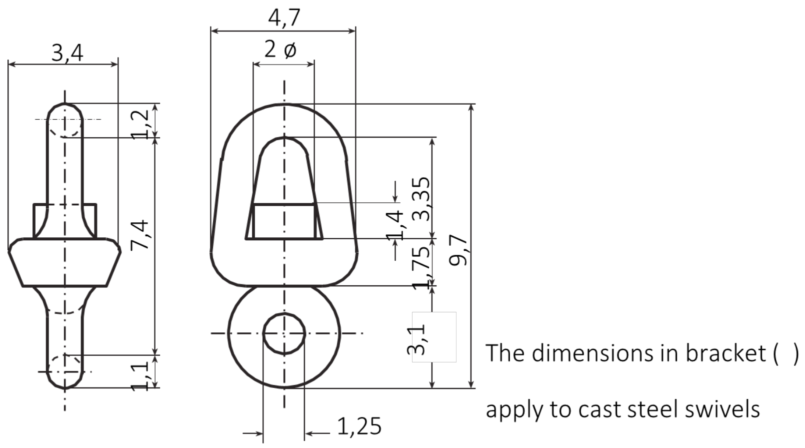


Figure 13.10: Swivel

Note:

All dimensions are given as a factor of the nominal diameter d of the standard link.

6.5 Certification

Chain accessories which meet the requirements are to be certified by BKI at least with the following items:

- Manufacturer's name
- Grade
- Heat Number
- Chemical composition (including total aluminum content)
- Nominal diameter/weight
- Proof/break loads
- Heat treatment
- Marks applied to accessory
- Mechanical properties, where applicable

B. Chafing Chains for Emergency Towing Arrangements

1. Scope

These requirements apply to the chafing chains for chafing gear of two types of emergency towing arrangements with specified working load of 1000 kN (ETA 1000) and 2000 kN (ETA 2000).

Chafing chains other than those specified here can be used subject to special agreement with BKI.

2. Approval of manufacturing

The chafing chain is to be manufactured by works approved by BKI.

3. Materials

The materials used for the manufacture of the chafing chain are to satisfy the requirements according to A.

4. Design, manufacture, testing and certification of chafing chain

4.1 The chafing chain is to be designed, manufactured, tested and certified in accordance with the requirements A.3. to A.6.

4.2 The arrangement at the end connected to the strongpoint and the dimensions of the chafing chain are determined by the type of emergency towing arrangement. The other end of the chafing chain is to be fitted with a pear-shaped open link allowing connection to a shackle corresponding to the type of emergency towing arrangement and chain cable grade. A typical arrangement of this chain end is shown in Fig. 13.11.

The common link is to be of stud link type grade KI- K2 or KI-K3.

The chafing chain is to be able to withstand a breaking load not less than twice the working load. For each type of emergency towing arrangement, the nominal diameter of common link for chafing chains is to comply with the value indicated in Table 13.8

Table 13.8: Nominal diameter of common link

Type of ETA	Nominal diameter of common link, d min.	
	grade 2	grade 3
ETA 1000	62 mm	52 mm
ETA 2000	90 mm	76 mm

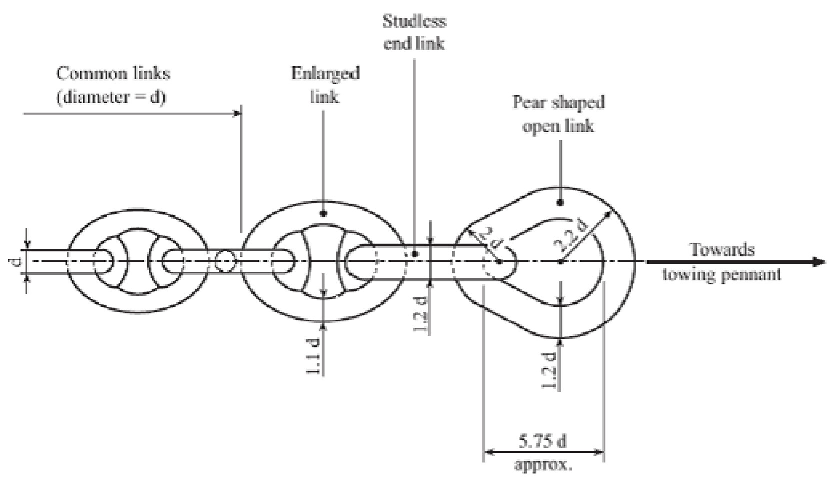


Figure 13.11: Typical outboard chafing chain end

C. Offshore Mooring Chain

1. General Requirement

1.1 Scope

1.1.1 These requirements apply to the materials, design, manufacture and testing of offshore mooring chain and accessories intended to be used for applications such as:

- Mooring of mobile offshore units,
- Mooring of floating production units,
- Mooring of offshore loading systems and
- Mooring of gravity based structures during fabrication.

1.1.2 Mooring equipment covered are common stud and studless links, connecting common links (splice links), enlarged links, end links, detachable connecting links (shackles), end shackles, subsea connectors, swivels and swivel shackles.

1.1.3 Studless link chain is normally deployed only once, being intended for long-term permanent mooring systems with pre-determined design life.

1.1.4 Requirements for chafing chain for single point mooring arrangements are given in B.

1.2 Chain grades

1.2.1 Depending on the nominal tensile strength of the steels used for manufacture, chains are to be subdivided into five grades, i.e.: KI-R3, KI-R3S, KI-R4, R4S and KI-R5.

1.2.2 Manufacturers propriety specifications for KI-R4S and KI-R5 may vary subject to design conditions and the acceptance of BKI.

1.2.3 Each Grade is to be individually approved. Approval for a higher grade does not constitute approval of a lower grade. If it is demonstrated to the satisfaction of BKI that the higher and lower grades are produced to the same manufacturing procedure using the same chemistry and heat treatment, consideration will be given to qualification of a lower grade by a higher. The parameters applied during qualification are not to be modified during production.

1.3 Approval

1.3.1 Offshore mooring chains are to be manufactured only by works approved by BKI. For this purpose approval tests are to be carried out, the scope of which is to include proof and breaking load tests, measurements and mechanical tests including fracture mechanics tests.

1.3.2 Manufacturers are to submit for review and approval the sequence of operations from receiving inspection to shipment and details of the following manufacturing processes:

A) Bar heating and bending including method, temperatures, temperature control and recording,

   a) Flash welding including current, force, time and dimensional variables as well as control and recording of parameters, maintenance procedure and programme for welding machine,
   b) Flash removal including method and inspection,
   c) Stud insertion method, for stud link chain,
   d) Heat treatment including furnace types, means of specifying, controlling and recording of temperature and chain speed and allowable limits, quenching bath and agitation, cooling method after exit,

e) Proof and break loading including method/machine, means of horizontal support (if applicable), method of measurement and recording,

f) Non-destructive examination procedures,

g) The manufacturer's surface quality requirement of mooring components is to be submitted.

h) The manufacturer's procedure for removing and replacing defective links without heat treatment of the entire chain.

1.3.3 For initial approval CTOD tests are to be carried out on the particular IACS mooring grade of material. CTOD tests are to be tested in accordance with a recognized standard such as ISO 12135:2021 and ISO 15653:2018. The CTOD test piece is to be a standard 2 x 1 single edge notched bend piece, test location as shown in Fig. 13.12.

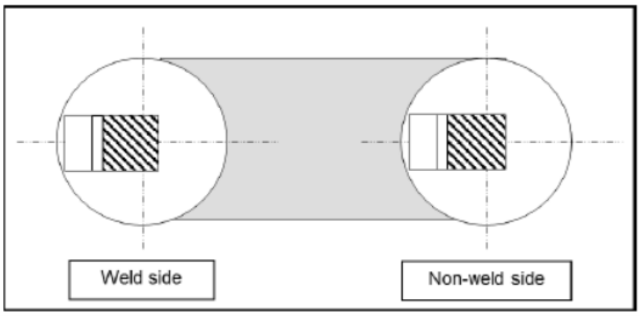


Figure 13.12: Location of CTOD test specimens for chain

The notch of the CTOD specimen is to be located as close to the surface as practicable. The minimum cross section of the test piece shall be 50 x 25 mm for chain diameters less than 120 mm, and 80 x 40 mm for diameters 120 mm and above.

CTOD specimens are to be taken from both the side of the link containing the weld and from the opposite side. Three links are to be selected for testing, a total of six CTOD specimens. The tests are to be taken at minus 20° C and the lowest CTOD of each set of 3 specimens shall meet the minimum values indicated below in Table 13.9.

Table 13.9: Minimum CTOD test values for chain type

Chain type	R3 in mm		R3S in mm		R4 in mm		R4S & R5 in mm	
	BM	*WM*	*BM*	*WM*	*BM*	*WM*	*BM*	*WM*
Stud link	0.20	0.10	0.22	0.11	0.24	0.12	0.26	0.13
Studless	0.20	0.14	0.22	0.15	0.24	0.16	0.26	0.17

1.3.4 Calibration of furnaces shall be verified by measurement and recording of a calibration test piece with dimensions equivalent to the maximum size of link manufactured. The manufacturer shall submit a procedure for furnace temperature surveys which shall include the following requirements: The temperature uniformity of furnaces is to be surveyed whenever approval of manufacturer is requested and at least annually during normal operating conditions. Furnaces are to be checked by conveying a monitoring link instrumented with two thermocouples through the furnaces at representative travel speed.

One thermocouple shall be attached to the surface of the straight part and one thermocouple shall be imbedded in a drilled hole located at the mid thickness position of the straight part of the calibration block. The time-temperature curves shall show that the temperatures throughout the cross section and the soaking times are within specified limits as given in the heat treatment procedure.

1.3.5 For R4S and R5 chain and accessories, prior to approval, the manufacturer is to have undertaken experimental tests or have relevant supporting data to develop the chain and accessory material. The tests and data may include: fatigue tests, hot ductility tests (no internal flaws are to develop whilst bending in the link forming temperature range), welding parameter research, heat treatment study, strain age resistance, temper embrittlement study, stress corrosion cracking (SCC) data and hydrogen embrittlement (HE) study, using slow strain test pieces in hydrated environments. Reports indicating the results of experimental tests are to be submitted.

1.4 Approval of quality system at chain and accessory manufacturers

Chain and accessory manufacturers are to have a documented and effective quality system approved by BKI. The provision of such a quality system is required in addition to, and not in lieu of, the witnessing of tests by a Surveyor as specified in paragraph 2 to 5 of this Sub-Section.

1.5 Approval of steel mills; Rolled bar

1.5.1 Bar materials intended for chain and accessories are to be manufactured only by works approved by BKI. The approval is limited to a nominated supplier of bar material. If a chain manufacturer wishes to use material from a number of suppliers, separate approval tests must be carried out for each supplier.

1.5.2 Approval will be given only after successful testing of the completed chain. Each Grade is to be individually approved. Approval for a higher grade does not constitute approval of a lower grade. If it is demonstrated to the satisfaction of BKI that the higher and lower grades are produced to the same manufacturing procedure using the same chemistry and heat treatment, consideration will be given to qualification of a lower grade by a higher. The parameters applied during qualification are not to be modified during production. The approval will normally be limited up to the maximum diameter equal to that of the chain diameter tested. The rolling reduction ratio is to be recorded and is to be at least 5:1 for KI-R3, KI-R3S, KI-R4, KI-R4S and KI-R5. The rolling reduction ratio used in production can be higher, but should not be lower than that qualified.

1.5.3 The steelmaker is to submit a specification of the chemical composition of the bar material, which must be approved by BKI and by the chain manufacturer. The steel maker is to confirm by analysis and testing that the specification is met. For Grade KI-R4, KI-R4S and KI-R5 chain the steel shall contain a minimum of 0.20 per cent molybdenum.

1.5.4 A heat treatment sensitivity study simulating chain production conditions shall be applied in order to verify mechanical properties and establish limits for temperature and time combinations. All test details and results are to be submitted to BKI.

1.5.5 The bar manufacturer is to provide evidence that the manufacturing process produces material that is resistant to strain ageing, temper embrittlement and for KI-R3S, KI-R4, KI-R4S and KI-R5, hydrogen embrittlement. All test details and results are to be submitted to BKI.

1.6 Approval of forges and foundries for accessories

1.6.1 Forges and foundries intending to supply finished or semi-finished accessories are to be approved by BKI. A description of manufacturing processes and process controls is to be submitted to BKI. The scope of approval is to be agreed with BKI. The approval is to be limited to a nominated supplier of forged or cast material. If an accessory manufacturer wishes to use material from a number of suppliers, a separate approval must be carried out for each supplier.

1.6.2 Approval will be given only after successful testing of the completed accessory. Approval for a higher grade does not constitute approval of a lower grade. If it is demonstrated to the satisfaction of BKI that the higher and lower grades are produced to the same manufacturing procedure using the same steel specification, supplier and heat treatment, consideration will be given to qualification of a lower grade by a higher. The approval will normally be limited to the type of accessory and the IACS designated mooring grade of material up to the maximum diameter or thickness equal to that of the completed accessory used for qualification unless otherwise agreed by BKI. However for the different accessories that have the same geometry, the tests for initial approval are to be carried out on the one having the lowest reduction ratio.

Qualification of accessory pins to maximum diameters is also required. Individual accessories of complex geometries will be subject to BKI requirements.

1.6.3 For forgings – Forgings are to have wrought microstructure and the minimum reduction ratio is to be 3 to 1. The forging reduction ratio, used in the qualification tests, from cast ingot/slab to forged component is to be recorded. The forging reduction ratio used in production can be higher, but should not be lower than that qualified. The degree of upsetting during qualification is to be recorded and maintained during production. Heat cycling during forging and reheating is to be monitored by the manufacturer and recorded in the forging documentation. The manufacturer is to have a maintenance procedure and schedule for dies and tooling which shall be submitted to BKI.

1.6.4 The forge or foundry is to submit a specification of the chemical composition of the forged or cast material, which must be approved by BKI. For Grade KI-R4, KI-R4S and KI-R5 chain the steel should contain a minimum of 0,20 per cent molybdenum.

1.6.5 Forges and foundries are to provide evidence that the manufacturing process produces material that is resistant to strain ageing, temper embrittlement and for KI-R4S and KI-R5 grades, hydrogen embrittlement. A heat treatment sensitivity study simulating accessory production conditions shall be applied in order to verify mechanical properties and establish limits for temperature and time combinations. (Cooling after tempering shall be appropriate to avoid temper embrittlement). All test details and results are to be submitted to BKI.

1.6.6 For initial approval CTOD tests are to be carried out on the particular IACS mooring grade of material. Three CTOD tests are to be tested in accordance with a recognized standard such as ISO 12135:2021 and ISO 15653:2018. For rectangular accessories, the CTOD test piece is to be a standard 2 x 1 single edge notched bend specimen of thickness equal to full thickness of material to be tested. Subsized specimens can be used subject to approval of BKI. For circular geometries, the minimum cross section of the test piece shall be 50 x 25mm for accessory diameters less than 120mm, and 80 x 40mm for diameters 120 mm and above. The notch of the CTOD specimen is to be located as close to the surface as practicable. The tests are to be taken at minus 20°C and the results submitted for review.

The minimum values of each set of three specimens are to at least meet the requirements as indicated in Table 13.10 (same as that of the studless chain material shown in Table 13.9).

Table 13.10: Minimum CTOD test values for accessories

Grade of accessories	R3 in mm	R3S in mm	R4 in mm	R4S & R5 in mm
CTOD	0,2	0,22	0,24	0,26

The geometry of accessories can vary. Fig. 13.13 shows the CTOD location for circular and rectangular cross sections such as those of the D-shackle and accessories fabricated from rectangular sections. The orientation of the specimen shall consider the direction of the grain flow. Fig. 13.13(b) shows two possible sampling positions for CTOD test specimens with notch orientation for rectangular type accessories.

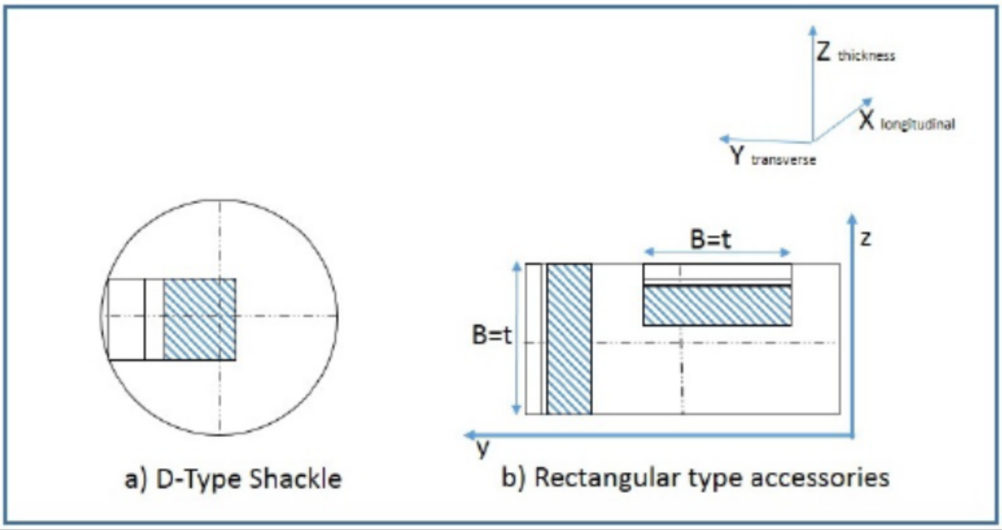


Figure 13.13: Location of CTOD test specimens: a) Circular type accessory and b) rectangular type accessory, B corresponds to the thickness of material, the grain flow is considered in the longitudinal direction X

1.6.7 Calibration of furnaces shall be verified by measurement and recording of a calibration test piece with dimensions equivalent to the maximum size of link manufactured.

Thermocouples are to be placed both on the surface and in a drilled hole located to the mid thickness position of the calibration block. The furnace dimensions shall be such as to allow the whole furnace charge to be uniformly heated to the necessary temperature. Temperature uniformity surveys of heat treatment furnaces for forged and cast components shall be carried out according to API Spec 6A/ISO 10423:2009 Annex M or ASTM A991-17. The initial survey shall be carried out with maximum charge (load) in the furnace. Subsequent surveys shall be carried out annually and may be carried out with no furnace charge.

The quench bath maximum temperature and the maximum heat treatment transfer times from furnace to quench are to be established and documented. During production the established quenching parameters are to be followed and records are to be maintained of bath temperatures and transfer times.

1.6.8 For KI-R4S and KI-R5 refer to additional requirements in 1.3.5.

1.7 Approval of quality system at accessory manufacturers

For approval of quality system at accessory manufacturers, refer to 1.4.

2. Materials

2.1 Scope

2.1.1 These requirements apply to rolled steels, forgings and castings used for the manufacture of offshore mooring chain and accessories.

2.2 Rolled steel bars

2.2.1 Steel manufacture

.1 The steels are to be manufactured by basic oxygen, electric furnace or such other process as may be specially approved. All steels are to be killed and fine grain treated. The austenitic grain size for KI-R3, KI-R3S and KI-R4 is to be 6 or finer in accordance with ASTM E112-13(2021) or equivalent grain size index in accordance to ISO 643:2019. Measurements for circular sections are to be taken at 1/3 radius.

.2 Steel for bars intended for KI-R4S and KI-R5 chain is to be vacuum degassed. The austenitic grain size is to be 6 or finer in accordance with ASTM E112-13(2021) or equivalent grain size index in accordance to ISO 643:2019. Measurements for circular sections are to be taken at 1/3 radius.

.3 For KI-R4S and KI-R5 the following information is to be supplied by the bar manufacturer to the mooring chain manufacturer and the results included in the chain documentation:

a) Each heat is to be examined for non-metallic inclusions. The level of micro inclusions is to be quantified and assessed in accordance to the national/international standards; to be sure inclusion levels are acceptable for the final product.

b) A sample from each heat is to be macro etched according to ASTM E381-20 or equivalent, to be sure there is no injurious segregation or porosity.

c) Hardenability data, according to ASTM A255-20a(2020), or equivalent, is to be supplied with each heat.

2.2.2 Chemical Composition

.1 For acceptance tests, the chemical composition of ladle samples of each heat is to be determined by the steel maker and is to comply with the approved specification.

2.2.3 Mechanical tests

Bars of the same nominal diameter are to be presented for test in batches of 50 tonnes or fraction thereof from the same heat. Test specimens are to be taken from material heat treated in the same manner as intended for the finished chain.

Each heat of Grade KI-R3S, KI-R4, KI-R4S and KI-R5 is to be tested for hydrogen embrittlement. In case of continuous casting, test samples representing both the beginning and the end of the charge shall be taken. In case of ingot casting, test samples representing two different ingots shall be taken.

1) Two (2) tensile test specimens shall be taken from the central region of bar material which has been subjected to the heat treatment cycle intended to be used in production. A specimen with a diameter of 20 mm is preferred (consideration will be given to a diameter of 14 mm).

2) One of the specimens is to be tested within a maximum of 3 hours after machining (for a 14 mm diameter specimen, the time limit is $1\frac{1}{2}$ hours). Where this is not possible, the specimen is to be immediately cooled to -60°C after machining and kept at that temperature for a maximum period of 5 days.

3) The second specimen is to be tested after baking at 250°C for 4 hours, alternatively 2 hours for 14 mm diameter specimen.

4) A slow strain rate < 0,0003 s^{-1} must be used during the entire test, until fracture occurs (This is approximately 10 minutes for the 20 mm diameter specimen). Tensile strength, elongation and reduction of area are to be reported.

5) The acceptance requirement for the test is:

$$Z_1 / Z_2 \geq 0,85$$

where:

Z_1 = Reduction of area without baking

Z_2 = Reduction of area after baking

If the requirement $Z_1/Z_2 \geq 0,85$ is not achieved, the bar material may be subjected to a hydrogen degassing treatment after agreement with BKI. New tests shall be performed after degassing.

For all grades, one tensile and three Charpy V-notch specimens are to be taken from each sample selected. The test specimens are to be taken at approx. one-third radius below the surface, as shown in Fig. 13.14 and prepared in accordance with Section 2, E. The results of all tests are to be in accordance with the appropriate requirements of Table 13.11.

Re-test requirements for tensile and Charpy impact tests are detailed in Section 2, H.

Failure to meet the requirements will result in rejection of the batch represented unless it can be clearly attributable to improper simulated heat treatment.

Table 13.11: Mechanical properties of offshore mooring chain and accessories

Grade	Yield stress [N/mm²] min. 1)	Tensile strength [N/mm²] min. 1)	Elongation [%] min.	Reduction of area 3) [%] min.	Charpy V-notch impact tests		
					Test temperature [°C]	Average energy [J] min.	Avg. energy flash weld [J] min.
KI-R3 2)	410	690	17	50	0	60	50
					-20	40	30
KI-R3S 2)	490	770	15	50	0	65	53
					-20	45	33
KI-R4	580	860	12	50	-20	50	36
KI-R4S 4)	700	960	12	50	-20	56	40
KI-R5 4)	760	1000	12	50	-20	58	42

Notes:

1) Aim value of yield to tensile ratio: 0,92 max.

2) At the option of BKI the impact test of Grade KI-R3 and KI-R3S may be carried out at either 0°C or minus 20°C (See Table 13.11).

3) Reduction of area of cast steel is to be for Grades KI-R3 and KI-R3S: min. 40 %, for R4, R4S and R5: min. 35 %, cf. item 2.4.4.

4) Aim maximum hardness for KI-R4S is HB330 and KI-R5 is HB340.

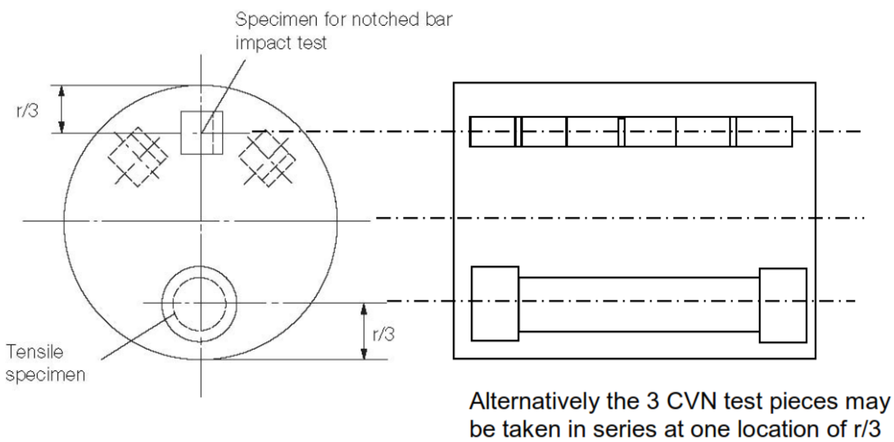


Figure 13.14: Sampling of steel bars, forgings and castings

2.2.4 Dimensional tolerances

The diameter and roundness shall be within the tolerances specified in Table 13.12, unless otherwise agreed.

Table 13.12: Dimensional tolerance of bar stock

Nominal diameter [mm]	Tolerance on diameter [mm]	Tolerance on roundness (d_{max} - d_{min}) [mm]
Less than 25	- 0 + 1,0	0,6
25 - 35	- 0 + 1,2	0,8
36 - 50	- 0 + 1,6	1,1
51 - 80	- 0 + 2,0	1,5
81 - 100	- 0 + 2,6	1,95
101 - 120	- 0 + 3,0	2,25
121 - 160	- 0 + 4,0	3,00
161 - 222	- 0 + 5,0	4,00

2.2.5 Non-destructive examination and repair

Non-destructive examination is to be performed in accordance with recognized Standards such as those indicated below or equivalent. Non-destructive examination procedures, together with rejection/acceptance criteria are to be submitted to BKI.

Magnetic particle testing (MT) of bars:

- ASTM E1444:2021 and ISO 9934:2015

Magnetic Leakage Flux Testing (MLFT)-JIS Z2319:2018

Eddy current testing (ET) of bars:

- ISO 15549:2019

Manufacturers shall prepare written procedures for NDE. NDE personnel shall be qualified and certified according to ISO 9712:2021, ACCP or equivalent. Personnel qualification to an employer or responsible agency based qualification scheme as SNT-TC-1A may be accepted if the employer's written practice is reviewed and found acceptable and the Level III is ASNT Level III, ISO 9712:2021 Level III or ACCP Professional Level III and certified in the applicable method. NDE operators shall be qualified to at least level II.

The manufacturer shall ensure that 100 percent of bar material intended for either chain or fittings is subjected to ultrasonic examination at an appropriate stage of the manufacture to procedures approved by BKI and to the acceptance criteria required. The bars shall be free of pipe, cracks and flakes. If the end length of the delivered bars is not subjected to UT then it must be agreed between the bar supplier and the chain manufacturer of what length of bar is to be removed from the ends. The details are to be documented in the approval of each bar supplier. Phased array UT procedures may be applied, subject to approval by BKI.

100 percent of the bar material is to be examined by magnetic particle (MT) or eddy current (ET) or Magnetic Leakage Flux Testing (MLFT) methods. The bars shall be free of injurious surface imperfections such as seams, laps and rolled-in mill scale. Provided that their depth is not greater than 1% of the bar diameter, longitudinal discontinuities may be removed by grinding and blending to a smooth contour.

All bars supplied in a machined (peeled) condition shall be 100% visually inspected. BKI may also require: 10% inspected with magnetic particle testing (MT) or eddy current testing (ET) or Magnetic Leakage Flux Testing (MLFT), for longitudinal imperfections. The maximum depth of peeling is to be agreed and documented in the approval of each supplier.

The frequency of NDE may be reduced at the discretion of BKI provided it is verified by statistical means that the required quality is consistently achieved.

Weld repair of bar is not permitted.

2.2.6 Marking

Each bar is to be stamped with the steel grade designation and the charge number (or a code indicating the charge number) on one of the end surfaces. Other marking methods may be accepted subject to agreement.

2.3 Forged steel

2.3.1 Manufacture

Forged steels used for the manufacture of accessories must be in compliance with approved specifications and the submitted test reports approved by BKI.

Steel is to be manufactured by basic oxygen, electric furnace or such other process as may be specially approved. All steel is to be killed and fine grain treated. The austenitic grain size for KI-R3, KI-R3S and KI-R4 is to be 6 or finer in accordance with ASTM E112-13(2021) or equivalent grain size index in accordance to ISO 643:2019. Measurements for circular sections are to be taken at 1/3 radius. Measurements for non-circular sections are to be taken at 1/4t.

Steel for forgings intended for KI-R4S and KI-R5 chain is to be vacuum degassed. The austenitic grain size is to be 6 or finer in accordance with ASTM E112-13(2021) or equivalent grain size index in accordance to ISO 643:2019. Measurements for circular sections are to be taken at 1/3 radius. Measurements for non-circular sections are to be taken at 1/4t.

For steel intended for KI-R4S and KI-R5 accessories the following information is to be supplied by the steel manufacturer to the mooring accessory manufacturer and the results included in the accessory documentation:

a) Each heat is to be examined for non-metallic inclusions. The level of micro inclusions is to be quantified and assessed in accordance with the national/international standards; to be sure inclusion levels are acceptable for the final product.

b) A sample from each heat is to be macro-etched according to ASTM E381-20 or equivalent, to be sure there is no injurious segregation or porosity.

c) Hardenability data, according to ASTM A255-20a(2020), or equivalent, is to be supplied with each heat.

2.3.2 Chemical composition

For chemical composition, see 2.2.2.

2.3.3 Heat treatment

Finished forgings are to be properly heat treated in compliance with specifications submitted and approved.

2.3.4 Mechanical properties

The forgings must comply with the mechanical properties given in Table 13.11, when properly heat treated.

2.3.5 Mechanical tests

For test sampling, forgings of similar dimensions (diameters do not differ by more than 25 mm) originating from the same heat treatment charge and the same heat of steel are to be combined into one test unit. From each test unit one tensile and three impact test specimens are to be taken and tested in accordance with Section 2. For the location of the test specimens, see Fig. 13.14.

Each heat of Grade KI-R3S, KI-R4, KI-R4S and KI-R5 is to be tested for hydrogen embrittlement.

In case of continuous casting, test samples representing both the beginning and the end of the charge shall be taken. In case of ingot casting, test samples representing two different ingots shall be taken.

1) Two (2) tensile test specimens shall be taken from the central region of bar material which has been subjected to the heat treatment cycle intended to be used in production. A specimen with a diameter of 20 mm is preferred (consideration will be given to a diameter of 14 mm).

2) One of the specimens is to be tested within a maximum of 3 hours after machining (for a 14 mm diameter specimen, the time limit is 1½ hours). Where this is not possible, the specimen is to be immediately cooled to -60°C after machining and kept at that temperature for a maximum period of 5 days.

3) The second specimen is to be tested after baking at 250°C for 4 hours, alternatively 2 hours for 14 mm diameter specimen.

4) A slow strain rate < 0,0003 s^{-1} must be used during the entire test, until fracture occurs (This is approximately 10 minutes for the 20 mm diameter specimen). Tensile strength, elongation and reduction of area are to be reported.

5) The acceptance requirement for the test is:

$$Z_1 / Z_2 \geq 0,85$$

where:

Z_1 = Reduction of area without baking

Z_2 = Reduction of area after baking

If the requirement $Z_1/Z_2 \geq 0,85$ is not achieved, the bar material may be subjected to a hydrogen degassing treatment after agreement with BKI. New tests shall be performed after degassing.

2.3.6 Non-destructive examination and repair

Non-destructive examination is to be performed in accordance with recognized Standards, such as those indicated below, or equivalent. The non-destructive examination procedures, together with rejection/acceptance criteria are to be submitted to BKI.

Magnetic particle testing (MT) of forgings:

- EN 10228-1:2016, ASTM A275-18, using wet continuous magnetization technique

Ultrasonic testing (UT) of forgings:

- EN 10228-3:2016, ASTM A388-19, ISO 13588:2019

Manufacturers shall prepare written procedures for NDE. NDE personnel shall be qualified and certified according to ISO 9712:2021, ACCP or equivalent. Personnel qualification to an employer or responsible agency based qualification scheme as SNT-TC-1A may be accepted if the employer's written practice is reviewed and found acceptable and the Level III is ASNT Level III, ISO 9712:2021 Level III or ACCP Professional Level III and certified in the applicable method. NDE operators shall be qualified to at least level II.

The forgings are to be subjected to one hundred percent ultrasonic examination at an appropriate stage of manufacture and in compliance with the standard submitted and approved.

Defects on non-machined surfaces may be removed by grinding to a depth of 5% of the nominal diameter. Grinding is not permitted on machined surfaces, except for slight inspection grinding on plane surfaces to a maximum depth of 0.8 mm in order to investigate spurious indications. Welding repairs are not permitted.

2.3.7 Marking

Marking is to be similar to that specified in 2.2.6.

2.4 Cast steel

2.4.1 Manufacture

Cast steel used for the manufacture of accessories must be in compliance with approved specifications and the submitted test reports approved by BKI.

Steel is to be manufactured by basic oxygen, electric furnace or such other process as may be specially approved. All steel is to be killed and fine grain treated. The austenitic grain size for KI-R3, KI-R3S and KI-R4 is to be 6 or finer in accordance with ASTM E112-13(2021) or equivalent grain size index in accordance to ISO 643:2019. Measurements for circular sections are to be taken at 1/3 radius. Measurements for non-circular sections are to be taken at 1/4t.

Steel for castings intended for KI-R4S and KI-R5 accessories is to be vacuum degassed.

The austenitic grain size is to be 6 or finer in accordance with ASTM E112-13(2021) or equivalent grain size index in accordance to ISO 643:2019. Measurements for circular sections are to be taken at 1/3 radius. Measurements for non-circular sections are to be taken at 1/4t.

For steel intended for KI-R4S and KI-R5 accessories the following information is to be obtained and the results included in the accessory documentation:

a) Each heat is to be examined for non-metallic inclusions. The level of micro inclusions is to be quantified and assessed in accordance to the national/international standards; to be sure inclusion levels are acceptable for the final product.

b) A sample from each heat is to be macro etched according to ASTM E381-20 or equivalent, to be sure there is no injurious segregation or porosity.

c) Hardenability data, according to ASTM A255-20a(2020), or equivalent, is to be supplied with each heat.

2.4.2 Chemical composition (See 2.2.2)

For chemical composition, see 2.2.2.

2.4.3 Heat treatment

All castings are to be properly heat treated in compliance with specifications submitted and approved.

2.4.4 Mechanical properties

.1 The castings must comply with the mechanical properties given in Table 13.11. The acceptance requirement for reduction of area is, however, reduced to 40 percent for grades KI-R3 and KI-R3S and 35 percent for grades KI-R4, KI-R4S and KI-R5.

2.4.5 Mechanical tests

For test sampling, castings of similar dimensions originating from the same heat treatment charge and the same heat of steel are to be combined into one test unit. From each test unit one tensile and three impact test specimens are to be taken and tested. For the location of the test specimens see Fig.13.14.

2.4.6 Non-destructive examination and repair

Non-destructive examination is to be performed in accordance with recognized standards, such as those indicated below, or equivalent. The non-destructive examination procedures, together with rejection/acceptance criteria are to be submitted to BKI.

Magnetic particle testing (MT) of castings:

- ASTM E709-21, using wet continuous magnetisation technique

Ultrasonic testing (UT) of castings:

- ASTM A609/A609M-12(2018), ISO 13588:2019

Manufacturers shall prepare written procedures for NDE. NDE personnel shall be qualified and certified according to ISO 9712:2021, ACCP or equivalent. Personnel qualification to an employer or responsible agency based qualification scheme as SNT-TC-1A may be accepted if the employer's written practice is reviewed and found acceptable and the Level III is ASNT Level III, ISO 9712:2021 Level III or ACCP Professional Level III and certified in the applicable method. NDE operators shall be qualified to at least level II.

The castings are to be subjected to one hundred percent ultrasonic examination in compliance with the standard submitted and approved.

Defects on non-machined surfaces may be removed by grinding to a depth of 5% of the nominal diameter. Grinding is not permitted on machined surfaces, except for slight inspection grinding on plane surfaces to a maximum depth of 0,8 mm in order to investigate spurious indications.

Where the repair entails removal of more than 5% of the diameter or thickness, the defective area shall be repaired by welding. The excavations shall be suitably shaped to allow good access for welding. The resulting grooves shall be subsequently ground smooth and complete elimination of the defective material shall be verified by NDE.

Weld repairs are classified as major or minor. A weld repair is considered major when the depth of the groove prepared for welding exceeds 25% of the diameter/thickness or 25 mm, whichever is smaller. All other weld repairs are considered minor.

Major weld repairs require approval before the repair is commenced. Proposals for major repairs shall be accompanied by sketches or photographs showing the extent and positions of the repairs. A grain refining heat treatment shall be given to the whole casting prior to major repairs. A post weld heat treatment or repeat of original heat treatment of castings shall be carried out.

Minor and major weld repairs must be recorded on sketches or photographs showing the extent and positions of the repairs.

All weld repairs shall be done by qualified welders using qualified procedures. Welders shall be qualified according to ISO 9606, ASME IX, ASTM A488 or equivalent.

Procedures shall be qualified according to ISO 15614, ASME IX, ASTM A488 or equivalent with the following additional requirements: Charpy V notch impact tests with notch locations in weld metal, fusion line and heat affected zone +2 mm and +5 mm from fusion line, respectively. Test results shall meet the requirements specified for the parent metal.

2.4.7 Marking

See 2.3.7.

2.5 Materials for studs

2.5.1 Studs intended for stud link chain cable are to be made of steel corresponding to that of the chain or in compliance with specifications submitted and approved. In general, the carbon content should not exceed 0,25 percent if the studs are to be welded in place.

3. Design and Manufacture

3.1 Design

3.1.1 Drawings accompanied by design calculations, giving detailed design of chain and accessories made by or supplied through the chain manufacturer are to be submitted for approval. Typical designs are given in ISO 1704:2008. For studless chain the shape and proportions are to comply with the requirements of this Sub-Section. Other studless proportions are to be specially approved. It should be considered that new or non-Standard designs of chain, shackles or fittings, may require a fatigue analysis and possible performance, fatigue or corrosion fatigue testing.

3.1.2 In addition, for stud link chain, drawings showing the detailed design of the stud shall be submitted for information. The stud shall give an impression in the chain link which is sufficiently deep to secure the position of the stud, but the combined effect of shape and depth of the impression shall not cause any harmful notch effect or stress concentration in the chain link.

3.1.3 Machining of Kenter shackles shall result in fillet radius min. 3 percent of nominal diameter.

3.2 Chain cable manufacturing process

3.2.1 General

Offshore mooring chains shall be manufactured in continuous lengths by flash butt welding and are to be heat treated in a continuous furnace; batch heat treatment is not permitted, except in special circumstances where short lengths of chain are delivered, such as chafing chain. Refer to D.

The use of joining shackles to replace defective links is subject to the written approval of the end purchaser in terms of the number and type permitted. The use of connecting common links is restricted to 3 links in each 100 m of chain.

3.2.2 Chain cable manufacturing process records

Records of bar heating, flash welding and heat treatment shall be made available for inspection by the Surveyor.

3.2.3 Bar heating

Bars for links shall be heated by electric resistance, induction or in a furnace.

For electric resistance heating or induction heating, the heating phase shall be controlled by an optical heat sensor. The controller shall be checked at least once every 8 hours and records made.

For furnace heating, the heat shall be controlled and the temperature continuously recorded using thermocouples in close proximity to the bars. The controls shall be checked at least once every 8 hours and records made.

3.2.4 Flash welding of chain cable

The following welding parameters shall be controlled during welding of each link:

a) Platen motion

b) Current as a function of time

c) Hydraulic pressure

The controls shall be checked at least every 4 hours and records made.

3.2.5 Heat treatment of chain cable

Chain shall be austenitized, above the upper transformation temperature, at a combination of temperature and time within the limits established.

When applicable, chain shall be tempered at a combination of temperature and time within the limits established. Cooling after tempering shall be appropriate to avoid temper embrittlement.

Temperature and time or temperature and chain speed shall be controlled and continuously recorded.

Grain determination shall be made for the final product. The austenitic grain size for KI-R3, KI-R3S, KI-R4, KI-R4S and KI-R5 is to be 6 or finer in accordance with ASTM E112-13(2021) or equivalent grain size index in accordance to ISO 643:2019. Measurements for circular sections are to be taken at surface, 1/3 radius and centre for the base material, HAZ and weld.

3.2.6 Mechanical properties

The mechanical properties of finished chain and accessories are to be in accordance with Table 13.11. For the location of test specimens see Fig. 13.14 and 13.15.

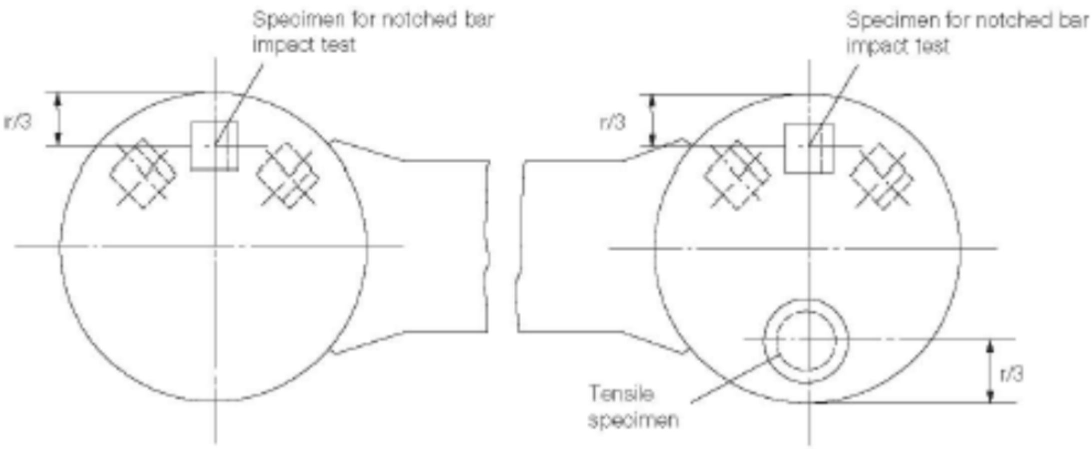


Figure 13.15: Sampling of chain links

3.2.7 Proof and breaking test loads

Chains and accessories are to withstand the proof and break test loads given in Table 13.13.

3.2.8 Freedom from defects

All chains are to have a workmanlike finish consistent with the method of manufacture and be free from defects. Each link is to be examined in accordance with sub-section 4.5 using approved procedures.

Table 13.13: Formulas for proof and break test loads, weight and length over 5 links

Test Load, in kN	**Grade KI-R3 Stud Link**	**Grade KI-R3S Stud Link**	**Grade KI-R4 Stud Link**	**Grade KI-R4S Stud Link**	**Grade KI-R5 Stud Link**
Proof	0,0148 d^2 (44 – 0,08d)	0,0180 d^2 (44 – 0,08d)	0,0216 d^2 (44 – 0,08d)	0,0240 d^2 (44 – 0,08d)	0,0251 d^2 (44 – 0,08d)
Break	0,0223 d^2 (44 – 0,08d)	0,0249 d^2 (44 – 0,08d)	0.0274 d^2 (44 – 0.08d)	0.0304 d^2 (44 – 0.08d)	0,0320 d^2 (44 – 0,08d)
Test Load, in kN	**Grade KI-R3 Studless**	**Grade KI-R3S Studless**	**Grade KI-R4 Studless**	**Grade KI-R4S Studless**	**Grade KI-R5 Studless**
Proof	0,0148 d^2 (44 – 0,08d)	0,0174 d^2 (44 – 0,08d)	0,0192 d^2 (44 – 0,08d)	0,0213 d^2 (44 – 0,08d)	0,0223 d^2 (44 – 0,08d)
Break	0,0223 d^2 (44 – 0,08d)	0.0249 d^2 (44 – 0,08d)	0,0274 d^2 (44 – 0,08d)	0,0304 d^2 (44 – 0,08d)	0,0320 d^2 (44 – 0,08d)
Chain Weight, in kg/m	Stud link = 0,0219 d^2				
Chain Weight, in kg/m	Studless chain Weight calculations for each design are to be submitted.				
Pitch Length	Five Link Measure				
Minimum	22d				
Maximum	22,55d				

Table 13.13-1: Proof and breaking loads for offshore mooring stud link chain

Chain diameter [mm] 1)	Grade KI-R3		Grade KI-R3S		Grade KI-R4		Grade KI-R4S		Grade KI-R5		Weight [kg/m] 2)	Pitch Length 3)	
	proof load [kN]	breaking load [kN]	proof load [kN]	breaking load [kN]	proof load [kN]	breaking load [kN]	proof load [kN]	breaking load [kN]	proof load [kN]	breaking load [kN]		Min	Max
1	2	3	4	5	6	7	8	9	10	11	12	13	14
12,5	99	150	121	167	145	184	161	204	169	215	3	275	282
14	124	187	151	209	182	230	202	255	211	269	4	308	316
16	162	244	197	272	236	300	262	332	275	350	6	352	361
17,5	193	291	235	325	282	357	313	397	327	417	7	385	395
19	227	342	276	382	331	420	368	466	385	491	8	418	428
20,5	263	397	320	443	385	488	427	541	447	570	9	451	462
22	303	456	368	509	442	560	491	622	513	654	11	484	496
24	359	541	436	604	524	664	582	737	608	776	13	528	541
26	419	632	510	706	612	776	680	861	711	907	15	572	586
28	485	730	589	815	707	897	786	995	822	1048	17	616	631
30	554	835	674	932	809	1026	899	1138	940	1198	20	660	677
32	628	946	764	1057	917	1163	1018	1290	1065	1358	22	704	722
34	706	1064	859	1188	1031	1308	1145	1451	1198	1527	25	748	767
36	789	1188	959	1327	1151	1460	1279	1620	1338	1705	28	792	812
38	875	1319	1065	1473	1278	1621	1420	1798	1485	1893	32	836	857
40	966	1456	1175	1625	1410	1789	1567	1985	1639	2089	35	880	902
42	1061	1599	1290	1785	1548	1964	1721	2179	1799	2294	39	924	947
44	1160	1748	1411	1951	1693	2147	1881	2382	1967	2508	42	968	992
46	1263	1903	1536	2124	1843	2338	2048	2594	2141	2730	46	1012	1037
48	1369	2063	1666	2304	1999	2535	2221	2813	2322	2961	50	1056	1082
50	1480	2230	1800	2490	2160	2740	2400	3040	2510	3200	55	1100	1128
52	1594	2402	1939	2682	2327	2952	2585	3275	2704	3447	59	1144	1173

1) For footnotes, see end of table
2) For footnotes, see end of table
3) For footnotes, see end of table

Table 13.13-1: Proof and breaking loads for offshore mooring stud link chain *(continued)*

Chain diameter [mm] [1]	Grade KI-R3		Grade KI-R3S		Grade KI-R4		Grade KI-R4S		Grade KI-R5		Weight [kg/m] [2]	Pitch Length [3]	
	proof load [kN]	breaking load [kN]	proof load [kN]	breaking load [kN]	proof load [kN]	breaking load [kN]	proof load [kN]	breaking load [kN]	proof load [kN]	breaking load [kN]		Min	Max
1	2	3	4	5	6	7	8	9	10	11	12	13	14
54	1712	2580	2083	2881	2499	3170	2777	3517	2904	3703	64	1188	1218
56	1834	2764	2231	3086	2677	3396	2974	3768	3111	3966	69	1232	1263
58	1960	2953	2383	3297	2860	3628	3178	4025	3323	4237	74	1276	1308
60	2089	3147	2540	3514	3048	3867	3387	4290	3542	4516	79	1320	1353
62	2221	3347	2701	3737	3242	4112	3602	4562	3767	4802	84	1364	1398
64	2357	3551	2867	3965	3440	4364	3822	4841	3997	5096	90	1408	1443
66	2496	3761	3036	4200	3643	4621	4048	5127	4233	5397	95	1452	1488
68	2639	3976	3209	4440	3851	4885	4279	5420	4475	5706	101	1496	1533
70	2785	4196	3387	4685	4064	5156	4516	5720	4723	6021	107	1540	1579
73	3010	4535	3660	5064	4392	5572	4881	6182	5104	6507	117	1606	1646
76	3242	4884	3942	5454	4731	6001	5257	6658	5498	7009	126	1672	1714
78	3400	5123	4135	5720	4962	6295	5514	6984	5766	7351	133	1716	1759
81	3643	5490	4431	6130	5317	6745	5908	7484	6179	7877	144	1782	1827
84	3893	5866	4735	6550	5682	7208	6313	7997	6602	8418	155	1848	1894
87	4149	6252	5046	6981	6056	7682	6729	8523	7037	8971	166	1914	1962
90	4412	6647	5365	7422	6439	8167	7154	9062	7482	9539	177	1980	2030
92	4590	6916	5582	7722	6699	8497	7443	9428	7784	9924	185	2024	2075
95	4862	7326	5913	8180	7096	9001	7884	9987	8246	10512	198	2090	2142
97	5047	7604	6138	8490	7365	9343	8184	10366	8559	10911	206	2134	2187
100	5328	8028	6480	8964	7776	9864	8640	10944	9036	11520	219	2200	2255
102	5519	8315	6712	9285	8054	10217	8949	11336	9359	11932	228	2244	2300
105	5809	8753	7065	9773	8478	10754	9420	11932	9851	12560	241	2310	2368

1) For footnotes, see end of table
2) For footnotes, see end of table
3) For footnotes, see end of table

Table 13.13-1: Proof and breaking loads for offshore mooring stud link chain *(continued)*

Chain diameter [mm] 1)	Grade KI-R3		Grade KI-R3S		Grade KI-R4		Grade KI-R4S		Grade KI-R5		Weight [kg/m] 2)	Pitch Length 3)	
	proof load [kN]	breaking load [kN]	proof load [kN]	breaking load [kN]	proof load [kN]	breaking load [kN]	proof load [kN]	breaking load [kN]	proof load [kN]	breaking load [kN]		Min	Max
1	2	3	4	5	6	7	8	9	10	11	12	13	14
107	6005	9048	7304	10103	8764	11118	9738	12335	10184	12984	251	2354	2413
111	6404	9650	7789	10775	9347	11856	10385	13154	10861	13847	270	2442	2503
114	6709	10109	8159	11287	9791	12420	10879	13780	11378	14506	285	2508	2571
117	7018	10574	8535	11807	10242	12993	11380	14415	11902	15174	300	2574	2638
120	7331	11047	8916	12334	10700	13573	11889	15059	12434	15852	315	2640	2706
122	7542	11365	9173	12690	11008	13964	12231	15493	12792	16308	326	2684	2751
124	7755	11686	9432	13048	11319	14358	12576	15930	13153	16768	337	2728	2796
127	8078	12171	9824	13591	11789	14955	13099	16592	13700	17466	353	2794	2864
130	8404	12663	10221	14139	12265	15559	13628	17262	14253	18171	370	2860	2932
132	8623	12993	10488	14508	12585	15965	13984	17713	14625	18645	382	2904	2977
137	9178	13829	11162	15441	13395	16992	14883	18852	15565	19844	411	3014	3089
142	9741	14677	11847	16388	14216	18033	15796	20008	16520	21061	442	3124	3202
147	10311	15536	12540	17347	15048	19089	16720	21179	17487	22294	473	3234	3315
152	10887	16405	13241	18317	15890	20156	17655	22363	18464	23540	506	3344	3428
157	11469	17282	13949	19297	16739	21234	18599	23559	19452	24799	540	3454	3540
162	12056	18166	14663	20284	17596	22320	19551	24764	20447	26068	575	3564	3653

1) For chain diameter other than mentioned in this table, see Table 13 for calculation

2) Approximate weight data calculated according to the formula kg/m = $0{,}0219 \times d^2$ (d in mm).

3) Five link measure

Table 13.13-2: Proof and breaking loads for offshore mooring stud less chain

Chain diameter [mm] [1]	Grade KI-R3		Grade KI-R3S		Grade KI-R4		Grade KI-R4S		Grade KI-R5		Weight [kg/m] [2]	Pitch Length [3]	
	proof load [kN]	breaking load [kN]	proof load [kN]	breaking load [kN]	proof load [kN]	breaking load [kN]	proof load [kN]	breaking load [kN]	proof load [kN]	breaking load [kN]		Min	Max
1	2	3	4	5	6	7	8	9	10	11	12	13	14
12,5	99	150	121	167	145	184	161	204	169	215	3	275	282
14	124	187	151	209	182	230	202	255	211	269	4	308	316
16	162	244	197	272	236	300	262	332	275	350	6	352	361
17,5	193	291	235	325	282	357	313	397	327	417	7	385	395
19	227	342	276	382	331	420	368	466	385	491	8	418	428
20,5	263	397	320	443	385	488	427	541	447	570	9	451	462
22	303	456	368	509	442	560	491	622	513	654	11	484	496
24	359	541	436	604	524	664	582	737	608	776	13	528	541
26	419	632	510	706	612	776	680	861	711	907	15	572	586
28	485	730	589	815	707	897	786	995	822	1048	17	616	631
30	554	835	674	932	809	1026	899	1138	940	1198	20	660	677
32	628	946	764	1057	917	1163	1018	1290	1065	1358	22	704	722
34	706	1064	859	1188	1031	1308	1145	1451	1198	1527	25	748	767
36	789	1188	959	1327	1151	1460	1279	1620	1338	1705	28	792	812
38	875	1319	1065	1473	1278	1621	1420	1798	1485	1893	32	836	857
40	966	1456	1175	1625	1410	1789	1567	1985	1639	2089	35	880	902
42	1061	1599	1290	1785	1548	1964	1721	2179	1799	2294	39	924	947
44	1160	1748	1411	1951	1693	2147	1881	2382	1967	2508	42	968	992
46	1263	1903	1536	2124	1843	2338	2048	2594	2141	2730	46	1012	1037
48	1369	2063	1666	2304	1999	2535	2221	2813	2322	2961	50	1056	1082
50	1480	2230	1800	2490	2160	2740	2400	3040	2510	3200	55	1100	1128
52	1594	2402	1939	2682	2327	2952	2585	3275	2704	3447	59	1144	1173

[1] For footnotes, see end of table
[2] For footnotes, see end of table
[3] For footnotes, see end of table

Table 13.13-2: Proof and breaking loads for offshore mooring stud less chain *(continued)*

Chain diameter [mm] 1)	Grade KI-R3		Grade KI-R3S		Grade KI-R4		Grade KI-R4S		Grade KI-R5		Weight [kg/m] 2)	Pitch Length 3)	
	proof load [kN]	breaking load [kN]	proof load [kN]	breaking load [kN]	proof load [kN]	breaking load [kN]	proof load [kN]	breaking load [kN]	proof load [kN]	breaking load [kN]		Min	Max
1	2	3	4	5	6	7	8	9	10	11	12	13	14
54	1712	2580	2013	2881	2222	3170	2465	3517	2580	3703	-	1188	1218
56	1834	2764	2156	3086	2380	3396	2640	3768	2764	3966	-	1232	1263
58	1960	2953	2304	3297	2542	3628	2820	4025	2953	4237	-	1276	1308
60	2089	3147	2455	3514	2710	3867	3006	4290	3147	4516	-	1320	1353
62	2221	3347	2611	3737	2881	4112	3196	4562	3347	4802	-	1364	1398
64	2357	3551	2771	3965	3058	4364	3392	4841	3551	5096	-	1408	1443
66	2496	3761	2935	4200	3238	4621	3593	5127	3761	5397	-	1452	1488
68	2639	3976	3102	4440	3423	4885	3798	5420	3976	5706	-	1496	1533
70	2785	4196	3274	4685	3613	5156	4008	5720	4196	6021	-	1540	1579
73	3010	4535	3538	5064	3904	5572	4331	6182	4535	6507	-	1606	1646
76	3242	4884	3811	5454	4205	6001	4665	6658	4884	7009	-	1672	1714
78	3400	5123	3997	5720	4411	6295	4893	6984	5123	7351	-	1716	1759
81	3643	5490	4283	6130	4726	6745	5243	7484	5490	7877	-	1782	1827
84	3893	5866	4577	6550	5051	7208	5603	7997	5866	8418	-	1848	1894
87	4149	6252	4878	6981	5383	7682	5972	8523	6252	8971	-	1914	1962
90	4412	6647	5187	7422	5723	8167	6349	9062	6647	9539	-	1980	2030
92	4590	6916	5396	7722	5954	8497	6606	9428	6916	9924	-	2024	2075
95	4862	7326	5716	8180	6307	9001	6997	9987	7326	10512	-	2090	2142
97	5047	7604	5933	8490	6547	9343	7263	10366	7604	10911	-	2134	2187
100	5328	8028	6264	8964	6912	9864	7668	10944	8028	11520	-	2200	2255
102	5519	8315	6488	9285	7159	10217	7942	11336	8315	11932	-	2244	2300
105	5809	8753	6829	9773	7536	10754	8360	11932	8753	12560	-	2310	2368

1) For footnotes, see end of table
2) For footnotes, see end of table
3) For footnotes, see end of table

Table 13.13-2: Proof and breaking loads for offshore mooring stud less chain *(continued)*

Chain diameter [mm] [1]	Grade KI-R3		Grade KI-R3S		Grade KI-R4		Grade KI-R4S		Grade KI-R5		Weight [kg/m] [2]	Pitch Length [3]	
	proof load [kN]	breaking load [kN]	proof load [kN]	breaking load [kN]	proof load [kN]	breaking load [kN]	proof load [kN]	breaking load [kN]	proof load [kN]	breaking load [kN]		Min	Max
1	2	3	4	5	6	7	8	9	10	11	12	13	14
107	6005	9048	7060	10103	7790	11118	8643	12335	9048	12984	-	2354	2413
111	6404	9650	7529	10775	8308	11856	9217	13154	9650	13847	-	2442	2503
114	6709	10109	7887	11287	8703	12420	9655	13780	10109	14506	-	2508	2571
117	7018	10574	8251	11807	9104	12993	10100	14415	10574	15174	-	2574	2638
120	7331	11047	8619	12334	9511	13573	10551	15059	11047	15852	-	2640	2706
122	7542	11365	8868	12690	9785	13964	10855	15493	11365	16308	-	2684	2751
124	7755	11686	9118	13048	10061	14358	11161	15930	11686	16768	-	2728	2796
127	8078	12171	9497	13591	10479	14955	11626	16592	12171	17466	-	2794	2864
130	8404	12663	9880	14139	10903	15559	12095	17262	12663	18171	-	2860	2932
132	8623	12993	10138	14508	11187	15965	12411	17713	12993	18645	-	2904	2977
137	9178	13829	10790	15441	11906	16992	13209	18852	13829	19844	-	3014	3089
142	9741	14677	11452	16388	12637	18033	14019	20008	14677	21061	-	3124	3202
147	10311	15536	12122	17347	13376	19089	14839	21179	15536	22294	-	3234	3315
152	10887	16405	12800	18317	14124	20156	15669	22363	16405	23540	-	3344	3428
157	11469	17282	13484	19297	14879	21234	16507	23559	17282	24799	-	3454	3540
162	12056	18166	14174	20284	15641	22320	17351	24764	18166	26068	-	3564	3653

[1] For chain diameter other than mentioned in this table, see Table 13 for calculation
[2] Weight calculations for each design are to be submitted
[3] Five link measure

3.2.9 Dimensions and dimensional tolerances

.1 The shape and proportion of links and accessories shall conform to ISO 1704:2008 or to the designs specially approved.

.2 The following tolerances are applicable to links:

a) Nominal diameter measured at the crown:

- up to 40 mm nominal diameter : – 1 mm
- over 40 up to 84 mm nominal diameter : – 2 mm
- over 84 up to 122 mm nominal diameter : – 3 mm
- over 122 up to 152 mm nominal diameter : – 4 mm
- over 152 up to 184 mm nominal diameter : – 6 mm
- over 184 up to 222 mm nominal diameter : – 7,5 mm

Note 1:

The cross sectional area at the crown must have no negative tolerance. For diameters of 20 mm or greater, the plus tolerance may be up to 5 percent of the nominal diameter. For diameters less than 20 mm the plus tolerance is to be agreed with BKI at the time of approval.

Note 2:

The cross sectional area at the crown is to be calculated using the average of the diameters with negative tolerance and plus tolerance, measurements are to be taken from at least 2 locations approximately 90 degrees apart.

b) Diameters measured at locations other than the crown:

The diameter is to have no negative tolerance. The plus tolerance may be up to 5% of the nominal diameter except at the butt weld where it is to be in accordance to manufacturer's specification, which is to be agreed with BKI. For diameters less than 20 mm, the plus tolerance is to be agreed with BKI at the time of approval.

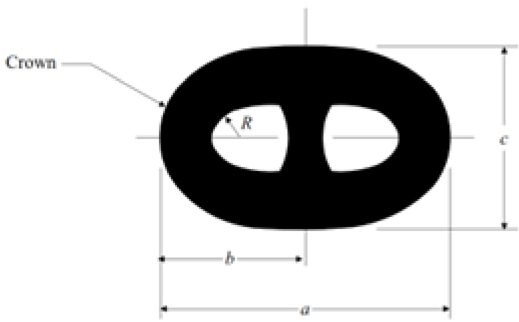
c) The allowable manufacturing tolerance on a length of five links is + 2,5%, but may not be negative.

d) All other dimensions are subject to a manufacturing tolerance of $\pm$ 2,5%, provided always that all parts fit together properly.

e) The tolerances for stud link and studless common links are to be measured in accordance with Fig. 13.16.

f) For stud link chains studs must be located in the links centrally and at right angles to the sides of the link. The following tolerances in Fig. 13.16 are acceptable provided that the stud fits snugly and its ends lie flush against the inside of the link:

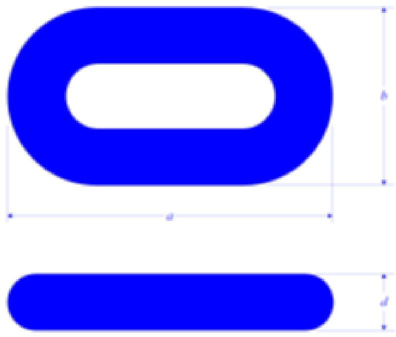
a) **Stud link** - The internal link radii (R) and external radii should be uniform



Designation 1)	Description	Nominal Dimensional of the Link	Minus Tolerance	Plus Tolerance
a	Link Length	6d	0,15d	0,15d
b	Link Half Length	a*/2	0,1d	0,1d
c	Link Width	3,6d	0,09d	0,09d
e	Stud Angular Misalignment	0 degrees	4 degrees	4 degrees
R	Inner Radius	0,65d	0	—–

1) Dimensional designation is shown in above figure
d = nominal diameter of chain, a* = actual link length

b) **Studless** - The internal link radii (R) and external radii should be uniform.



Designation 1)	Description	Nominal Dimension of the Link	Minus Tolerance	Plus Tolerance
a	Link Length	6d	0,15d	0,15d
b	Link Width	3,35d	0,09d	0,09d
R	Inner Radius	0,60d	0	—-

1) Dimensional designation is shown in above figure
d = nominal diameter of chain, a* = actual link length
2) Other dimension ratios are subject to special approval

Figure 13.16: (a) Stud link and (b) studless common link, proportions dimensions and tolerances

3.2.10 Stud link chain - Welding of studs

.1 A welded stud may be accepted for grade KI-R3 and KI-R3S chains. Welding of studs in grade KI-R4, KI-R4S and KI-R5 chains is not permitted unless specially approved.

.2 Where studs are welded into the links this is to be completed before the chain is heat treated.

.3 The stud ends shall have a good fit inside the link and the weld is to be confined to the stud end opposite to the flash butt weld. The full periphery of the stud end is to be welded unless otherwise approved.

.4 Welding of studs at both ends is not permitted unless specially approved.

.5 The welds are to be made by qualified welders using an approved procedure and low hydrogen approved consumables.

.6 The size of the fillet weld shall as a minimum be as per API specification 2F.

.7 The welds are to be of good quality and free from defects such as cracks, lack of fusion, gross porosity and undercuts exceeding 1 mm.

.8 All stud welds shall be visually examined. At least 10 per cent of all stud welds within each length of chain shall be examined by dye penetrant or magnetic particle after proof load testing. If cracks or lack of fusion are found, all stud welds in that length are to be examined.

3.2.11 Connecting common links (Splice links)

.1 Single links to substitute for test links or defective links without the necessity for re-heat treatment of the whole length are to be made in accordance with an approved procedure. Separate approvals are required for each grade of chain cables and the tests are to be made on the maximum size of chain cables for which approval is sought.

.2 Manufacture and heat treatment of connecting common links is not to affect the properties of the adjoining links. The temperature reached by these links is nowhere to exceed 250 °C.

.3 Each link is to be subjected to the appropriate proof load and non-destructive examination as detailed in Table 13.13 and 4.5. A second link shall be made identical to the connecting common link; the link shall be tested and inspected according to 4.4. and 4.5.

.4 Each connecting common link is to be marked either; on the stud for stud link chain or, on the outer straight length on the side opposite the flash butt weld for studless chain. This marking is to be in accordance with 4.7 plus an unique number for the link. The adjoining links are also to be marked on the studs or straight length as above.

4. Testing and inspection of finished chain

4.1 General

4.1.1 This section applies to but is not limited to finished chain cable such as common stud and studless links, end links, enlarged end links and connecting common links (splice links).

4.1.2 All chain is to be subjected to proof load tests, breaking load tests and mechanical tests after final heat treatment in the presence of the BKI Surveyor. Where the manufacturer has a procedure to record proof loads and the Surveyor is satisfied with the adequacy of the recording system, he needs not witness all proof load tests. The Surveyor is to satisfy himself that the testing machines are calibrated and maintained in a satisfactory condition. Prior to test and inspection the chain cable is to be free from scale, paint or other coating. The chain cable shall be sand or shot blasted to meet this requirement.

4.2 Proof and break load tests

4.2.1 The entire length of chain cable shall withstand the proof load specified in Table 13.13 without fracture and shall not crack in the flash weld. The load applied shall not exceed the proof load by more than 10% when stretching the chain cable. Where plastic straining is used to set studs, the applied load is not to be greater than that qualified in approval tests.

4.2.2 A break-test specimen consisting of at least 3 links is to be either taken from the chain or produced at the same time and in the same manner as the chain. The test frequency is to be based on tests at sampling intervals according to Table 13.14 provided that every cast is represented. Each specimen shall be capable of withstanding the break load specified without fracture and shall not crack in the flash weld. It shall be considered acceptable if the specimen is loaded to the specified value and maintained at that load for 30 seconds.

4.2.3 For chain diameters over 100 mm, alternative break-test proposals to the above break test will be considered whereby a one link specimen is used. Alternatives are to be approved by BKI, every heat is to be represented, the test frequency is to be in accordance with Table 13.14, and it is to be demonstrated and proven that the alternative test represents an equivalent load application to the three link test.

4.2.4 If the loading capacity of the testing machine is insufficient, an alternative load testing machine is to be used that does have sufficient capacity (e.g. two loading machines in parallel) provided the testing and calibration procedure are agreed with BKI.

Table 13.14: Frequency of break and mechanical tests

Nominal chain diameter (mm)	Maximum sampling interval (m)
min - 48	91
49 - 60	110
61 - 73	131
74 - 85	152
86 - 98	175
99 - 111	198
112 - 124	222
125 - 137	250
138 - 149	274
150 - 162	297
163 - 175	322
176 - 186	346
187 - 198	370
199 - 210	395
211 - 222	420

4.3 Dimensions and dimensional tolerances

4.3.1 After proof load testing measurements are to be taken on at least 5 per cent of the links in accordance with 3.7.

4.3.2 The entire chain cable is to be checked for the length, five links at a time. By the five link check the first five links shall be measured. From the next set of five links, at least two links from the previous five links set shall be included. This procedure is to be followed for the entire chain cable length. The measurements are to be taken preferably while the chain cable is loaded to 5 - 10 % of the minimum proof load. The tolerances for the 5 link measurements are indicated in Table 13.13, any deviations from the 5 link tolerances are to be agreed by BKI. The links held in the end blocks may be excluded from this measurement.

4.3.3 Chain dimensions are to be recorded and the information retained on file.

4.4 Mechanical tests

4.4.1 Links of samples detached from finished, heat treated chain shall be sectioned for determination of mechanical properties. A test unit shall consist of one tensile and nine impact specimens. The tensile specimen shall be taken at the side opposite the flash weld. Three impact specimens shall be taken across the flash weld with the notch centred in the middle. Three impact specimens shall be taken across the unwelded side and three impact specimens shall be taken from the bend region.

4.4.2 The test frequency is to be based on tests at sampling intervals according to Table 13.14 provided that every cast is represented. Mechanical properties shall be as specified in Table 13.11.

4.4.3 The frequency of impact testing in the bend may be reduced at the discretion of BKI provided it is verified by statistical means that the required toughness is consistently achieved.

4.4.4 Hardness tests are to be carried out on finished chain. The frequency and locations are to be agreed with the BKI. The recorded values are for information only and used as an additional check to verify that the heat treatment process has been stable during the chain production.

4.5 Non-destructive examination after proof load testing

4.5.1 All surfaces of every link shall be visually examined. Burrs, irregularities and rough edges shall be contour ground. Links shall be free from mill defects, surface cracks, dents and cuts, especially in the vicinity where gripped by clamping dies during flash welding. Studs shall be securely fastened. In order to allow optimal access to the surface area it is recommended that chain be hung in the vertical position, however access to inspect the interlink area may only be possible with the chain in the horizontal position.

4.5.2 Testing is to be performed in accordance with a recognized Standard and the procedures, together with acceptance/rejection criteria are to be submitted to BKI for review. Manufacturers shall prepare written procedures for NDE. NDE personnel shall be qualified and certified according to ISO 9712:2021, ACCP or equivalent. Personnel qualification to an employer or responsible agency based qualification scheme as SNT-TC-1A may be accepted if the employer's written practice is reviewed and found acceptable and the Level III is ASNT Level III, ISO 9712:2021 Level III or ACCP Professional Level III and certified in the applicable method. NDE operators shall be qualified to at least level II.

4.5.3 Magnetic particle procedures shall be employed to examine the flash welded area including the area gripped by the clamping dies. Procedures are to be submitted to BKI for approval. Procedures and equipment in accordance with those approved shall be used. The frequency of examination shall be every link. Link surface at the flash weld shall be free from cracks, lack of fusion and gross porosity. Testing shall be performed in accordance with ASTM E709-21 or another recognized standard (e.g. ISO 9934:2015) using wet continuous fluorescent magnetization technique. Non fluorescent techniques can be accepted in special cases where the standard inspection procedures are impractical.

Links shall be free from:

— Relevant linear indications exceeding 1,6 mm in transverse direction

— Relevant linear indications exceeding 3,2 mm in longitudinal direction

— Relevant non-linear indications exceeding 4,8 mm.

4.5.4 Ultrasonic procedures shall be employed to examine the flash weld fusion. Procedures are to be submitted to BKI for approval. Procedures and equipment in accordance with those approved shall be used. On-site calibration standards for chain cable configurations shall be approved. The frequency of examination shall be every link. The flash weld shall be free from defects causing ultrasonic back reflections equal to or greater than the calibration standard. The flash butt welds shall be ultrasonic tested (UT) in accordance with ASTM E587-15(2020) or another recognized standard using single probe, angle-beam shear waves in the range from 45 to 70°.

Single probe technique has limitations as far as testing of the central region is concerned and the flash weld imperfections such as flat spots may have poor reflectivity. Where it is deemed necessary, detectability of imperfections may need to be carried out by using a tandem technique, TOFD or phased array.

4.5.5 Stud welds, if used, shall be visually inspected. The toes of the fillets shall have a smooth transition to the link with no undercuts exceeding 1,0 mm. Additionally, at least 10% of the stud welds distributed through the length shall be dye penetrant tested according to ASTM E1417/E1417M-21e1 or magnetic particle tested according to ASTM E1444:2021 or equivalent. Cracks, lack of fusion or gross porosity are not acceptable. If defects are found, testing shall be extended to all stud welds in that length.

4.6 Retest, rejection and repair criteria

4.6.1 If the length over 5 links is short, the chain cable may be stretched by loading above the proof test load specified provided that the applied load is not greater than that approved and that only random lengths of the chain cable need stretching. If the length exceeds the specified tolerance, the over length chain cable links shall be cut out and 4.6.2 shall apply.

4.6.2 If single links are found to be defective or do not meet other applicable requirements, defective links may be cut out and a connecting common link inserted in their place. The individual heat treatment and inspection procedure of connecting common links is subjected to the BKI Surveyor's approval. Other methods for repair are subject to the written approval of BKI and the end purchaser. Weld repair of chain is not permitted.

4.6.3 If a crack, cut or defect in the flash weld is found by visual or magnetic particle examination, it shall be ground down no more than 5 % of the link diameter in depth and streamlined to provide smooth contours. The final dimensions shall still conform to the agreed standard.

4.6.4 If indications of interior flash weld defects in reference to the accepted calibration standards are detected during ultrasonic examination, 4.6.2 shall apply.

4.6.5 If link diameter, length, width and stud alignment do not conform to the required dimensions, these shall be compared to the dimensions of 40 more links, 20 on each side of the affected links. If a single particular dimension fails to meet the required dimensional tolerance in more than 2 of the sample links, all links shall be examined, 4.6.2 shall apply.

4.6.6 If a break load test fails a thorough examination, with the Surveyor informed in a timely manner, is to be carried out to identify the cause of failure. Two additional breaking test specimens representing the same sampling length of chain cable are to be subjected to the breaking load test. Based upon satisfactory results of the additional tests and the results of the failure investigation, it will be decided what lengths of chain cable can be accepted. Failure of either or both of the additional tests will result in-rejection of the sampling length of chain represented, and 4.6.2 shall apply.

4.6.7 If a link fails during proof load testing, a thorough examination, with the Surveyor informed in a timely manner, is to be carried out to identify the probable cause of failure of the proof load test. In the event that two or more links in the proof loaded length fail, that section of proof loaded length is to be rejected. The above failure investigation is to be carried out, especially with regard to the presence in other lengths, of factors or conditions thought to be causal to failure.

4.6.8 In addition to the above failure investigation, a breaking load test specimen is to be taken from each side of the one failed link, and subjected to the breaking load test. Where multiple chains are produced simultaneously it is recognised that the preceding flash butt welded link and subsequent flash butt welded link will be on an alternative chain length or the other end of the chain length. In such cases BKI may require that two additional break tests are to be taken from the lengths of chain that include the preceding and subsequent welded links. Based upon satisfactory results of both breaking load tests and the results of the failure investigation, it will be decided what length of chain can be considered for acceptance. Failure of either or both of the breaking load tests will result in rejection of the proof loaded length. Replacement of defective links is to be in accordance with 4.6.2.

If the investigation identifies defects in the flash butt weld or a lower strength flash weld "a glue-weld" is found, additional NDT such as phased array UT is to be carried out to identify if other links are affected. A full assessment of the flash butt welding machine is to be carried out, together with assessment of the condition of the bar ends prior to welding.

4.6.9 Re-test requirements for tensile tests are to be in accordance with Section 2. Failure to meet the specified requirements of either or both of the additional tests will result in rejection of the sampling length of chain cable represented, and 4.6.2 shall apply.

4.6.10 Re-test requirements for Charpy impact tests are to be in accordance with Section 2. Failure to meet the requirements will result in rejection of the sampling length represented, and 4.6.2 shall apply.

4.7 Marking

4.7.1 The chain cable shall be marked at the following places:

— At each end

— At intervals not exceeding 100 m

— On connecting common links.

— On links next to shackles or connecting common links

4.7.2 All marked links shall be stated on the Certificate, and the marking shall make it possible to recognize leading and tail end of the chain. In addition to the above required marking, the first and last common link of each individual charge used in the continuous length shall be adequately and traceably marked.

The marking shall be permanent and legible throughout the expected lifetime of the chain.

4.7.3 The chain shall be marked on the studs as follows:

— Chain grade

— Certificate No.

— BKI Stamp

4.7.4 The Certificate number may be exchanged against an abbreviation or equivalent. If so, this shall be stated in the Certificate.

4.7.5 The chain Certificate shall contain information on number and location of connecting common links. The Certificate number and replacement link number may be exchanged against an abbreviation or equivalent. If so, this shall be stated in the Certificate.

4.8 Documentation

4.8.1 A complete Chain Inspection and Testing Report in booklet form shall be provided by the chain manufacturer for each continuous chain cable length. This booklet shall include all dimensional checks, test and inspection reports, NDT reports, process records, photographs as well as details of any non-conformity, corrective action and repair work.

4.8.2 Individual Certificates are to be issued for each continuous single length of chain cable.

4.8.3 All accompanying documents, appendices and reports shall carry reference to the original Certificate number.

4.8.4 The manufacturer will be responsible for storing, in a safe and retrievable manner, all documentation established for a period of at least 10 years.

5. Testing and Inspection of Accessories

5.1 General

5.1.1 These requirements applies to but is not limited to mooring equipment accessories such as detachable connecting links (shackles), detachable connecting plates (triplates), end shackles, swivels and swivel shackles, and subsea connectors.

5.1.2 All accessories are to be subjected to proof load tests, breaking load tests and mechanical tests after final heat treatment in the presence of a Surveyor. Where the manufacturer has a procedure to record proof loads and the Surveyor is satisfied with the adequacy of the recording system, he need not witness all proof load tests. The Surveyor is to satisfy himself that the testing machines are calibrated and maintained in a satisfactory condition.

Prior to test and inspection the chain accessories are to be free from scale, paint or other coating.

5.1.3 For accessory production a Manufacturing Procedure Specification (MPS) is to be submitted to BKI that details all critical aspects of accessory production, casting, forging, heat treating (including arrangement and spacing of components in the heat treatment furnaces), quenching, mechanical testing, proof and break loading and NDE.

5.2 Proof and break load tests

5.2.1 All accessories are to be subjected to the proof load specified for the corresponding stud link chain.

5.2.2 Chain cable accessories are to be tested to the breaking test loads prescribed for the grade and size of chain cable for which they are intended. At least one accessory out of every batch or every 25 accessories, whichever is less, is to be tested.

5.2.3 For individually produced accessories, individually heat treated, accessories produced in small batches, alternative testing will be subject to special consideration. Alternative testing is to be approved by BKI and the following additional conditions may apply.

a) Alternative testing is described in a written procedure and manufacturing procedure specification (MPS).

b) A finite element analysis is provided at the break load and demonstrates that the accessory has a safety margin over and above the break load of the chain.

c) Strain age testing (as per approved procedure by BKI) is carried out on the material grade produced to the same parameters at the time of qualification.

d) If an accessory is of a large size that will make heat treating in batches unfeasible or has a unique design, strain gauges are to be applied during the proof and break load tests during initial qualification and during production. The strain gauge results from production are to be comparable with the results from qualification.

5.3 Dimensions and dimensional tolerances

5.3.1 At least one accessory (of the same type, size and nominal strength) out of 25 is to be checked for dimensions after proof load testing. The manufacturer is to provide a statement indicating compliance with the purchaser's requirements.

5.3.2 The following tolerances are applicable to accessories:
a) Nominal diameter : + 5,0%, – 0%
b) Other diameters : ± 2,5%

These tolerances do not apply to machined surfaces.

5.4 Mechanical tests

5.4.1 Accessories are to be subjected to mechanical testing as described in 2.3 and 2.4. Mechanical tests are to be taken from proof loaded full size accessories that have been heat treated with the production accessories they represent. At least one accessory out of every batch or every 25 accessories, whichever is less, is to be tested. Hardness tests are to be carried out on finished accessories. The frequency and locations are to be agreed with BKI. The recorded values are for information only and used as an additional check to verify that the heat treatment process has been stable during the accessory production.

The use of separate representative coupons is not permitted except as indicated in 5.4.5 below.

5.4.2 Test location of forged shackles. Forged shackle bodies and forged Kenter shackles are to have a set of three impact tests and a tensile test taken from the crown of the shackle. Tensile tests on smaller diameter shackles can be taken from the straight part of the shackle, where the geometry does not permit a tensile specimen from the crown. The tensile properties and impact values are to meet the requirements of Table 13.11 in the locations specified in Fig. 13.14, with the Charpy pieces on the outside radius.

5.4.3 The locations of mechanical tests of cast shackles and cast Kenter shackles can be taken from the straight part of the accessory. The tensile properties and impact values are to meet the requirements of Table 13.11 in the locations specified in Fig. 13.14.

5.4.4 The locations of mechanical tests of other accessories with complex geometries are to be agreed with the BKI.

For non-circular sections, 1/4t (thickness) from the surface is considered appropriate.

Rolled plates are to be tested to the Standard to which they are produced.

5.4.5 For individually produced (heat treated) accessories or accessories produced in small batches, (less than 5), alternative testing can be proposed to BKI. Each proposal for alternative testing is to be detailed by the manufacturer in a written procedure and submitted to BKI, and the following additional conditions may apply:

a) If separately forged or cast coupons are used, they are to have a cross-section and, for forged coupon, a reduction ratio similar to that of the accessories represented, and are to be heat treated in the same furnace and quenched in the same tank at the same time, as the actual forgings or castings. Thermocouples are to be attached to the coupon and to the accessories.

b) If separately forged or cast coupons are agreed, it is to be verified by procedure test that coupon properties are representative of accessory properties.

5.4.6 A batch is defined as accessories that originate from the same heat treatment charge and the same heat of steel. Reference see 2.3 and 2.4.

5.4.7 Mechanical tests of pins are to be taken as per Fig. 13.14 from the mid length of a sacrificial pin of the same diameter as the final pin. For oval pins the diameter taken is to represent the smaller dimension. Mechanical tests may be taken from an extended pin of the same diameter as the final pin that incorporates a test prolongation and a heat treatment buffer prolongation, where equivalence with mid length test values have been established. The length of the buffer is to be at least equal to 1 pin diameter dimension which is removed after the heat treatment cycle is finished. The test coupon can then be removed from the pin. The buffer and test are to come from the same end of the pin as per Fig. 13.17.

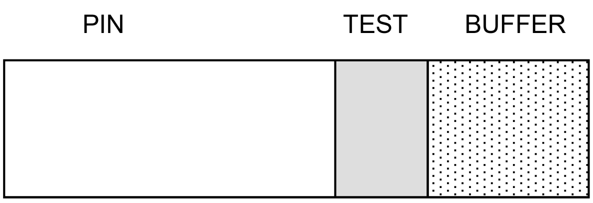


Figure 13.17: Buffer and test piece location

5.5 Non-destructive examination after proof load testing

5.5.1 All chain accessories are to be subjected to a close visual examination. Special attention is to be paid to machined surfaces and high stress regions. Prior to inspection, chain accessories are to have a suitably prepared surface as per the applied NDE testing standard. All non-machined surfaces are to be sand or shot blasted to permit a thorough examination. Where applicable, accessories shall be dismantled for inspection of internal surfaces. All accessories are to be checked by magnetic particles or dye penetrant. UT of accessories may be required by BKI. The acceptance/rejection criteria of UT established for the design is to be met.

5.5.2 Testing is to be performed in accordance with a recognized Standard, such as those indicated below, or equivalent. The procedures, together with acceptance/rejection criteria are to be submitted to BKI for review. Manufacturers shall prepare written procedures for NDE. NDE personnel shall be qualified and certified according to ISO 9712:2021, ACCP or equivalent. Personnel qualification to an employer or responsible agency based qualification scheme as SNT-TC-1A may be accepted if the employer's written practice is reviewed and found acceptable and the Level III is ASNT Level III, ISO 9712:2021 Level III or ACCP Professional Level III and certified in the applicable method. NDE operators shall be qualified to at least level II.

Magnetic particle testing (MT) of forgings:

— EN 10228-1:2016, ASTM A275/A275M-18, using wet continuous magnetization technique or equivalent standards such as ISO 4986, Guidance for Marine Industry (Pt.1, Vol.AC) Sec.4, R-69

Ultrasonic testing (UT) of forgings:

— EN 10228-3:2016, ASTM A388/A388M-19, ISO 13588:2019

Magnetic particle testing (MT) of castings:

— ASTM E709-21, using wet continuous magnetization technique

Ultrasonic testing (UT) of castings:

— ASTM A609/A609M-12(2018), ISO 13588:2019

All surfaces shall be magnetic particle tested (MT). Testing shall be performed in accordance with standards referenced using the fluorescent technique. As a minimum surfaces shall be free from:

— Relevant linear indications exceeding 1,6 mm in transverse direction

— Relevant linear indications exceeding 3,2 mm in longitudinal direction

— Relevant non-linear indications exceeding 4,8 mm.

When required by BKI, ultrasonic testing is to be carried out on 100% of cast or forged accessories. The acceptance/rejection criteria established for the design is to be met.

5.5.3 The manufacturer is to provide a statement that non-destructive examination has been carried out with satisfactory results. This statement should include a brief reference to the techniques and to the operator's qualification.

5.5.4 Weld repairs of finished accessories are not permitted.

5.6 Test failures

In the event of a failure of any test the entire batch represented is to be rejected unless the cause of failure has been determined and it can be demonstrated to the Surveyor's satisfaction that the condition causing the failure is not present in any of the remaining accessories.

5.7 Marking

5.7.1 Each accessory is to be marked as follows:

— Chain grade

— Test certificate no.

— BKI stamp

5.7.2 The Certificate number may be exchanged against an abbreviation or equivalent. If so, this shall be stated in the Certificate.

5.8 Documentation

5.8.1 A complete Inspection and Testing Report in booklet form shall be provided by the manufacturer for each order. This booklet shall include all dimensional checks, test and inspection reports, NDT reports, process records and example photographs of components positioned in furnaces, as well as any non-conformity, corrective action and repair work.

5.8.2 Each type of accessory shall be covered by separate certificates.

5.8.3 All accompanying documents, appendices and reports shall carry reference to the original Certificate number.

5.8.4 The manufacturer will be responsible for storing, in a safe and retrievable manner, all documentation established for a period of at least 10 years.

D. Chafing Chain for Single Point Mooring arrangements

1. Scope

These requirements apply to short lengths (approximately 8 m) of 76 mm diameter chain to be connected to hawsers for the tethering of oil carriers to single point moorings, FPSO's and similar uses.

2. Approval of Manufacturing

The chafing chain is to be manufactured by works approved by BKI according to C.1.3.

3. Materials

The materials used for the manufacture of the chafing chain are to satisfy the requirements of C.2.

4. Design, manufacturing, testing and certification

4.1 The chafing chain is to be designed, manufactured, tested and certified in accordance with C.3, C.4 and C.5, except that batch heat treatment is permitted.

4.2 The arrangement of the end connections is to be of an approved type.

4.3 The common link is to be of the stud link type – Grade KI-R3 or KI-R4.

4.4 The chafing chain is to be capable of withstanding the breaking test loads of 4884 kN (Grade KI-R3) and 6001 kN (Grade KI-R4). See Note 1.

4.5 The chain lengths shall be proof load tested in accordance with 4.2. The test load for Grade KI-R3 is 3242 kN and for Grade KI-R4 is 4731 kN.

Note 1:

Documented evidence of satisfactory testing of similar diameter mooring chain in the prior 6 month period may be used in lieu of break testing subject to agreement with BKI.

Note 2:

The requirements herein are also applicable to other diameter chafing chains, such as 84 mm and 96 mm, subject to compliance with the proof and break load requirements specified for the chain grade and diameters in Table 13.13.

Section 14 Wire Ropes

A. Scope

These Rules apply to wire ropes for use as hawsers (towlines, mooring lines) and as standing and running rigging for cargo handling gear and other lifting tackle on board sea-going vessels.

B. Requirements to be Met by the Manufacturers of Wire Ropes

1. With regard to their production and quality control, wire rope manufacturers shall meet the requirements stated in Section 1, C. and shall be approved by BKI.

2. Applications for approval are to be submitted to BKI in writing with a description containing at least the following details:

— type, composition and strengths of the ropes concerned

— manufacturing facilities

— testing equipment: copies of the last calibration reports on the testing machines are to be attached.

By a works inspection, the manufacturer shall demonstrate the availability of the equipment necessary for the proper manufacture and testing of wire ropes. BKI reserve the right to call for a preliminary test of suitability to be carried out on samples of the rope.

3. If the wire rope manufacturer wishes to be approved by BKI for the independent testing of wire ropes, this shall also be applied for. BKI will allocate to the manufacturer a special identification number if the conditions for approval stated in 1. and 2. are satisfied.

C. Manufacture

1. The ropes shall conform to recognized national or international standards[1)], and should, wherever possible, comply with Table 14.1. Ropes of a different construction and ropes with high nominal breaking strengths, e.g. 1960 N/mm^2, or containing austenitic stainless steel wires may be approved on application provided that they are suitable for the proposed application.

2. With the exception of wire ropes made of austenitic stainless steel wires, wire ropes shall normally be manufactured from individually galvanized wires. The use of ungalvanized wires requires the special consent of BKI.

[1)] See EN 12385-4 and ISO 2408

D. Requirements Applied to Wire Ropes

1. Nominal breaking strength

Wire ropes shall have the nominal breaking strengths of 1570 and 1770 N/mm^2 specified in Table 14.1. These values shall not be exceeded by more than the values shown in Table 14.2.

Table 14.1: Usual types of wire ropes approved by BKI

Use	Structure of rope			Construction of strands	Nominal breaking strength [N/mm^2]	Galvanizing method
	Number of strands	Number of wires per strand	Type of rope core			
Standing rigging	6 6	7 19[1]	1 fibre or steel core	Standard	1570 and 1770	fully galvanized
Hawers (towlines, mooring lines)	6 6 6 6 6	19 37 24 19 36	1 fibre core (7 fibre cores) 1 steel core	Standard Seale or Warrington. Warrington-Seale	1570	fully galvanized
Running riggings	6 6 6	36 37 24	1 fibre or steel core 7 fibre cores	Warrington-Seale Standard Standard	1570 and 1770	normally galvanized

1) This rope may also be used as a single reeved span rope not moved under load.

Table 14.2: Positive tolerances for nominal breaking strengths

Nominal wire diameter d [mm]	Limiting deviations [N/mm^2]
0,20 up to < 0,50	+ 390
0,50 up to < 1,00	+ 350
1,00 up to < 1,50	+ 320
1,50 up to < 2,00	+ 290
2,00 up to ≤ 6,00	+ 260

2. Ductility

Individual wires shall possess sufficient ductility, measured by their ability to withstand a fixed number of reverse bends and/or twists without starting to crack. These requirements are regarded as fulfilled if the values specified in EN 10264, or in an equivalent standard recognized by BKI are achieved.

3. Tolerance on diameter

The tolerance on the diameter of rope wires shall lie within the limits specified in recognized standards, e.g. in EN 10264.

4. Galvanizing method

Hawsers and standing rigging shall be manufactured from fully galvanized wires. Normally galvanized wires may be used for all other ropes. The zinc coating shall conform to the data shown in Table 14.3.

Table 14.3: Zinc coatings

Nominal wire diameter d [mm]	Minimum mass per unit area of zinc coating for type [g/m^2]	
	Normally galvanized	Fully galvanized
0,2 up to < 0,25	15	–
0,25 up to < 0,4	20	–
0,4 up to < 0,5	30	75
0,5 up to < 0,6	40	90
0,6 up to < 0,7	50	110
0,7 up to < 0,8	60	120
0,8 up to < 1,0	70	130
1,0 up to < 1,2	80	150
1,2 up to < 1,5	90	165
1,5 up to < 1,9	100	180
1,9 up to < 2,5	110	205
2,5 up to < 3,2	125	230
3,2 up to < 3,7	135	250
3,7 up to < 4,0	135	260
4,0 up to < 4,5	150	270
4,5 up to < 5,5	165	280
5,5 up to ≤ 6,0	180	280

E. Testing of Wire Ropes

The following tests are to be performed:

1. Testing the zinc coating

1.1 The specified weight of the zinc coating is to be determined and certified by the manufacturer by chemically stripping the coating and measuring the weight loss of the stripped wires according to a recognized method, e.g. in accordance with EN 10244-2.

Wires of the various diameters shall be removed from the rope for this purpose. BKI reserve the right to repeat this test in case of doubt.

1.2 The adhesion of the zinc coating shall be verified by the winding test, e.g. to ISO 7802. For this purpose, the wires shall be wound as follows on to a test mandrel of the diameter specified in Table 14.4 so as to form at least 10 adjacent turns.

The zinc coating shall continue to adhere firmly to the substrate after winding. At least 5 wires of each size shall be tested.

Table 14.4: Winding test

Method of galvanizing	Diameter of test mandrel expressed as a multiple of the wire diameter of:	
	< 1,5 mm	≥ 1,5 mm
Fully galvanized	4	6
Normally galvanized	2	3

2. Ductility test

At the option of the manufacturer, the ductility of the rope wires shall be tested either by the reverse bend test or by the twisting test specified in a recognized standard, e.g. ISO 7801 or ISO 7800. All the wires constituting a strand taken from the rope shall be subjected to this test. The test is considered successful if at least 95 % of the wires withstand the bend or twisting test specified in the relevant standard without breaking.

3. Tensile test

3.1 From every manufactured length of rope up to 10000 m a test sample is to be tensile tested in its entirety to destruction. The test length shall be equal to 30 times the diameter of the rope, subject to a minimum of 600 mm. The minimum breaking load shall achieve the value specified for the rope in question in the standard. In the case of manufactured lengths of more than 10000 m, a second test sample is to be taken and tested.

3.2 Where the tensile loading capacity of the testing machine is insufficient to test the rope in its entirety, the breaking load of the rope shall be determined from the results of tests performed on the individual wires. For this purpose a strand is to be taken from every manufactured length of rope of 5000 m or less, and its constituent wires shall be individually subjected to the tensile test, e.g. to EN 12385. The wire test specimens shall have an initial measured length of 100 or 200 mm. The tensile strength is determined on the basis of the nominal wire diameter.

The test shall be deemed successful if at least 95 % of the rope wires meet the requirements stated in D.1. and the calculated breaking load achieves the values specified in the relevant standard. For this purpose, the individual test values are to be applied to the total number of wires in the rope and multiplied by the realization factor shown in Table 14.5.

4. Dimensional check

The diameter of each rope is to be measured at two points located at least 1 m apart in two directions approximately perpendicular to each other. The difference between the smallest and the largest result may not be more than 4 %.

The average value of the four measurements shall be considered to be the actual rope diameter and shall lie within the permitted tolerances. The number and diameter of the individual wires shall also be verified.

Table 14.5: Realization factors

Rope construction	Ropes with fibre core	Ropes with steel core
6 × 7	0,9000	0,8379
6 × 19	0,8600	0,8007
6 × 24	0,8700	—
6 × 36	0,8400	0,7821
6 × 37	0,8250	0,7681

F. Verification of Characteristics

1. Companies which have been approved by BKI for the independent performance of tests may test wire ropes at their own responsibility. The result of the test shall be certified on a form prescribed by BKI.

2. Notwithstanding the provisions contained in 1., the test is to be performed in the presence of the Surveyor in the case of wire ropes of special construction in accordance with C.1., or if the company concerned has not been approved for independent testing, or if the purchaser has expressed a wish to this effect.

G. Marking

1. Wire ropes are to be provided with worked-in coloured threads as follows for the purpose of distinguishing the nominal strength of the wires:

— Nominal strength 1570 N/mm^2 : white

— Nominal strength 1770 N/mm^2 : green

— Nominal strength 1960 N/mm2 : yellow

For special rope constructions in accordance with C.1., the colour of the distinguishing thread shall be specially designated.

2. A tape shall also be worked into the ropes bearing the manufacturer's name and, in the case of companies approved by BKI for independent testing, the identification number allocated by BKI.

The coloured distinguishing thread may be dispensed with if the tape designating the company is of the colour specified in 1.

Ropes which have been tested in the presence of the Surveyor are also (to) be marked with a seal bearing the BKI stamp: .

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Section 15 Fibre Ropes

A. Scope

These Rules apply to fibre ropes made from natural and synthetic fibres and used as towlines and mooring lines as well as for cargo handling gear and other lifting tackle on board sea-going vessels.

B. Requirements to be met by the Manufacturers of Fibre Ropes

1. With regard to their production and quality control, fibre rope manufacturers shall meet the requirements stated in Section 1.C. and shall be approved by BKI.

2. Applications for approval are to be submitted to BKI in writing with a description containing at least the following details:

- Type, composition and material of the ropes concerned
- Manufacturing facilities
- Testing equipment: copies of the last calibration reports on the testing machines are to be attached

By a work's inspection, the manufacturer shall demonstrate the availability of the equipment necessary for the proper manufacture and testing of fibre ropes. BKI reserve the right to call for a preliminary test of suitability to be carried out on samples of the rope.

3. If the manufacturer wishes to be approved by BKI for the independent testing of fibre ropes (see E.), this shall also be applied for. BKI will allocate to the manufacturer a special identification number if the conditions for approval stated in 1. and 2. are satisfied.

C. Manufacture

1. The type, material and structure of the ropes shall conform to a national or international standard recognized by BKI and should, wherever possible, comply with Table 15.1. Ropes of a different type may be approved on application provided that they are suitable for the proposed application.

2. Fibre ropes are to be made either of natural fibres (manila, sisal and hemp) or of synthetic fibres (polyamide, polyester and polypropylene). Only new yarns may be used to manufacture the rope. If it is intended to use other materials, their suitability is to be specially demonstrated to BKI.

3. Ropes may normally comprise only one material. Excepted from this rule, and approved by BKI, are for example those rope constructions in which the outside layers are reinforced with polyester yarns in order to increase their resistance to abrasion.

The realization factors for (monofilament) poly-propylene are applicable to ropes with these outside layers.

D. Required Properties

The properties of fibre ropes shall fulfil the requirements specified in the standards recognized by BKI. These include for example:

ISO 9554 and the complementary DIN and ISO standards mentioned therein, see Table 15.1.

Table 15.1: Construction of customary rope types approved by BKI

Rope standards	Material	Rope construction DIN 83307		Corresponding ISO-standards [1]
		Form	Construction	
ISO 1181	Manila	A, B	hawser laid	1181
ISO 1181	Sisal	A, B	hawser laid	1181
DIN-EN 1261	Hemp	A, B, C	hawser laid cable laid	–
ISO 1140	Polyamide	A	hawser laid	1140
ISO 1141	Polyester	A	hawser laid	1141
ISO 1346	Polypropylene	A, B	hawser laid	R 1346 [2]

[1] These standards are only applicable to form A ropes.
[2] Data only for "3-strand hawser laid" with the same values

E. Testing the Breaking Load of Ropes

1. Test method [1]

The breaking load of ropes shall normally be determined by applying a tensile test to destruction to entire test sections of the rope in accordance with 3. If such a test is impossible for technical reasons, the breaking load of the rope may be calculated from the tensile values established in testing the individual yarns in accordance with 4. This applies, however, only to those ropes whose maximum loading capacity exceeds 30000 daN and for which reduction factors are given in Table 15.2.

2. Sampling

For the purpose of sampling, ropes of the same construction, the same material and the same nominal diameter which have been manufactured in an uninterrupted production run are to be grouped into test lengths.

The following number of test sections measuring about 2500 mm in length shall be taken from the test lengths:

- test lengths up to 2200 m (or 10 ropes up to 220 m long):
  - 1 test section
- excess test lengths up to 30000 m:
  - 1 additional test section per 5500 m
- excess test lengths over 30000 m:
  - 1 additional test section per 11000 m.

3. Tensile testing of test section

3.1 To perform the tensile test, the test sections are to be clamped in the testing machine as required by the standard and are to be loaded at a prescribed testing rate until breakage occurs.

[1] See EN 919 and ISO 2307.

3.2 To perform the tensile test, the test sections are to be clamped in the testing machine as required by the standard and are to be loaded at a prescribed testing rate until breakage occurs.

Note:
Adding 10% to the actual value when breakage occurs at the clamp or in the splice to determine the breaking load of the rope is not permitted.

4. Calculation of the breaking load of rope

4.1 In order to determine the breaking load by calculation, a number of yarns shall be taken from the test sections specified in 2. which shall be equal to half the numerical value of the rope diameter in mm, and these shall be subjected to a tensile test.

In taking the test specimens, attention shall be paid to the following:

The yarns shall be taken evenly from the outside, middle and inside positions of the strands of the rope.

When taking the yarns, care is to be taken not to alter the twist of the yarns.

4.2 The yarns shall be tested individually by the tensile test in accordance with ISO 2062.

4.3 The breaking load of the rope is to be determined from the results of the tests performed on the individual yarns by applying the formula:

$$F_{SR} = F_G \cdot n \cdot r$$

F_G = Average breaking load of yarn [daN]
n = Number of rope yarns in specimen
r = Reduction factor in accordance with Table 15.2

The breaking load of the rope determined in this way shall at least satisfy the data contained in the relevant standard.

5. The certification shall state which method was used to test the breaking load of the rope and whether the specimen broke at the clamp.

When required by the purchaser, and in the case of all companies which have not been approved for the independent performance of tests, the breaking load is to be tested in the presence of a Surveyor who will certify the result.

F. Verification of the Properties

1. The manufacturers of yarn and rope shall constantly monitor the characteristics of their products and shall ensure that the products meet the requirements specified in the standards. The manufacturers shall keep records of their quality control and shall present these to BKI on request.

2. If a manufacturer intends to determine the strength of rope by calculation based on the strength of the yarn, then the manufacturer shall demonstrate at least once a year in the presence of a Surveyor of BKI that he is capable of manufacturing rope with the specified reduction factors. This shall be demonstrated by the tensile test on a test section described in E.3.

Table 15.2: Reduction factors

Nominal diameter of rope [mm]	Reduction factors r for ropes					
	of natural fibres			of synthetic fibres		
	Manila, sisal or hemp rope acc. to ISO 1181 or DIN EN 1261 Form			Polyamide rope acc. to ISO 1140 Form	Polyester rope acc. to ISO 1141 Form	Polypropylene rope acc. to ISO 1346 Form
	A	B	C	A	A	A
44	–	–	–	0,68	–	–
48	–	–	–	0,68	0,51	0,82
52	–	–	–	0,68	0,51	0,82
56	–	–	–	0,68	0,50	0,82
60	–	–	–	0,68	0,49	0,82
64	–	–	–	0,67	0,48	0,81
72	0,58		–	0,67	0,48	0,81
80	0,58		–	0,66	0,48	0,80
88	0,57		–	0,66	0,48	0,80
96	0,57			0,65	0,47	0,80

3. Rope manufacturers who have been approved by BKI for the independent performance of tests may themselves test the breaking load using the methods described in E. They shall certify the results on a printed form prescribed by BKI. These forms are obtainable from BKI.

G. Marking

1. A tape indicating the rope standard designation and the manufacturers, mark shall be worked into the ropes, each ∼1m apart. Where companies have been approved for the independent performance of tests, this tape shall additionally bear the identification number allocated to the company by BKI. In addition, a coloured distinguishing thread denoting the yarn material in accordance with Table 15.3 is also to be worked into the rope.

2. The coloured distinguishing thread may be omitted where the tape has the colour code stipulated in 1.

Table 15.3: Distinguishing threads for fibre ropes

Material	Colour code
manila	black
sisal	red
hemp	green
polyamide	green
polyester	blue
polypropylen	brown

Section 16 Propellers Made of Cast Copper Alloys

A. Scope

1. These Rules are applicable to the manufacture„ testing and to the method of repairing propellers, propeller blades and propeller bosses made of cast copper alloys. By agreement with BKI, these Rules may also be applied to the repair of propellers which have been damaged in service.

(IACS UR W24 1.1 and 1.3)

2. Where the use of alternative alloys is proposed, particulars of chemical composition, mechanical properties and heat treatment are to be submitted for approval.

(IACS UR W24 1.2)

B. Approval of the Foundry

1. Approval

All propellers and propeller components shall be manufactured by foundries which have been approved by BKI. The castings are to be manufactured and tested in accordance with the requirements of these Rules.

(IACS UR W24 2.1)

2. Application for approval

It is the manufacturer’s responsibility to assure that effective quality, process and production controls during manufacturing are adhered to within the manufacturing specification. The manufacturing specification shall be submitted to BKI at the time of initial approval, and shall at least include the following particulars: description of the foundry facilities, copper alloy material specification, runner and feeder arrangements, manufacturing procedures, non-destructive testing and repair procedures.

(IACS UR W24 2.2)

3. Scope of the approval test

The scope of the approval test shall be in accordance with Guidance for The Approval and Type Approval of Materials and Equipments for Marine Use (Pt.1 Vol.W). Tests shall also include the provision of cast sample pieces of the grades of casting eligible for approval in order to demonstrate that their chemical composition and mechanical properties comply with the requirements set out in these Rules.

(IACS UR W24 2.3)

4. Test equipment

The foundry shall have at its disposal a suitably equipped laboratory staffed by qualified personnel to perform tests on moulding materials, chemical analyses, mechanical tests, microstructural examinations and non-destructive testing.

Where testing activities are assigned to other companies or other laboratory, additional information required by BKI is to be included.

(IACS UR W24 2.4)

C. Moulding and Casting Process

1. Casting

Casting shall be performed in dry moulds using degassed liquid metal. The casting process shall be supervised in order to prevent eddies occurring. Special devices and/or procedures shall be in place to ensure that no slag can enter the mould.

(IACS UR W24 3.1)

2. Stress-relieving heat treatment

Stress-relieving heat treatment may be required as appropriate to reduce residual stress. For this purpose, the manufacturer of the castings shall submit a specification containing details of the heat treatment to BKI for approval. Stress relieving temperatures and holding times are given in Tables 16.4 and 16.5.

(IACS UR W24 3.2)

D. General Requirements Applicable to Castings

1. Freedom from defects

All castings shall be in a perfect condition in conformity with the method of manufacture and shall be free from defects which would be prejudicial to their proper application in service. Minor casting defects which are still visible after machining, such as small sand and slag marks, small cold shuts and scabs shall be removed by the manufacturer, see K.

(IACS UR W24 4.1)

2. Repair of defects

Casting defects which may impair the serviceability of the castings, such as major non-metallic inclusions, shrinkage cavities, blow holes and cracks are not permitted. They are to be removed by one of the methods described in K. and repaired within the limits applicable for the severity zone in question. A comprehensive report on the repairs carried out is to be made available to the Surveyor.

(IACS UR W24 4.2)

E. Dimensions, Dimensional and Geometrical Tolerances

1. The verification of dimensions, the dimensional and geometrical tolerances is the responsibility of the manufacture.

The report on the relevant examinations is to be submitted to the Surveyor, who may require checks to be made in his presence.

(IACS UR W24 5.1)

2. All propellers shall be statically balanced as specified in the approved drawings. Dynamic balancing is required for propellers with an operating speed of more than 500 rpm.

(IACS UR W24 5.2)

F. Chemical Composition and Metallurgical Properties

1. Chemical composition

The commonly used standard cast copper alloys for propellers are subdivided into the grades CU1, CU2, CU3 and CU4 depending on their chemical composition, as shown in Table 16.1. Cast copper alloys whose chemical composition differs from the standard alloys shown in Table 16.1 shall be specially approved by BKI.

Table 16.1: Chemical composition of standard cast copper alloys for propellers

Casting grade	Chemical composition [%]							
	Cu	Al	Mn	Zn	Fe	Ni	Sn	Pb
CU1 (Mn-bronze)	52 – 62	0,5 – 3,0	0,5 – 4,0	35 – 40	0,5 – 2,5	max. 1,0	max. 1,5	max. 0,5
CU2 (Mn-Ni-bronze)	50 – 57	0,5 – 2,0	1,0 – 4,0	33 – 38	0,5 – 2,5	3,0 – 8,0	max. 1,5	max. 0,5
CU3 (Ni-Al-bronze)	77 – 82	7,0 – 11,0	0,5 – 4,0	max. 1,0	2,0 – 6,0	3,0 – 6,0	max. 0,1	max. 0,03
CU4 (Mn-Al-bronze)	70 – 80	6,5 – 9,0	8,0 – 20,0	max. 6,0	2,0 – 5,0	1,5 – 3,0	max. 1,0	max. 0,05

The manufacturer is to maintain records of the chemical analyses of the production casts, which are to be made available to the Surveyor.

(IACS UR W24 6.1)

2. Metallurgical properties

Note

The main components of the microstructure of the CU1 and CU2 grades of copper alloy are the alpha and beta phases. Important operational characteristics, such as ductility and resistance to corrosion fatigue, are strongly influenced by the proportion of beta phase. (a high proportion of beta phase has a detrimental effect on these characteristics). To ensure adequate cold ductility and resistance to corrosion fatigue, the proportion of beta phase is to be kept low. The concept of the zinc equivalent shall be used as control since it summarizes the effect of the tendency of various chemical elements to produce beta phase in the structure.

The microstructure of CU1 and CU2 grade castings shall each contain an alpha phase component of at least 25% which the manufacturer is required to prove on a sample bar. To ensure adequate ductility and corrosion fatigue resistance, the proportion of beta phase is to be kept low. For this purpose the zinc equivalent is to be defined by the following formula; it may not exceed a value of 45%:

$$\text{Zinc Equivalent(\%)} = 100 - \frac{100 \times \%\text{Cu}}{100 + \text{A}}$$

In which A is the algebraic sum of the following values:

$$\text{A} = 1 \cdot \%\text{Sn} + 5 \cdot \%\text{Al} - 0,5 \cdot \%\text{Mn} - 0,1 \cdot \%\text{Fe} - 2,3 \cdot \%\text{Ni}$$

Note

The minus sign preceding the elements Mn, Fe and Ni signifies that these elements tend to reduce the proportion of beta phase.

The micro structure of alloy types CU1 and CU2 shall be verified by determining the proportion of alpha phase. For this purpose, at least one specimen shall be taken from each heat. The proportion of alpha phase shall be determined as the average value of 5 counts.

(IACS UR W24 6.2)

G. Mechanical Properties and Tests

1. Standard cast alloys

The mechanical properties are to comply with the data given in Table 16.2. These values are applicable to test specimens manufactured from separately cast samples in accordance with Fig. 16.1 or in accordance with a recognized standard.

Note

These properties are a measure of the mechanical quality of the metal in each heat; and they are generally not representative of the mechanical properties of the casting itself, which may be up to 30% lower than that of a separately cast sample piece.

The mechanical properties of integrally cast sample bars shall be subject to special agreement by BKI.

(IACS UR W24 7.1)

2. Other alloys

The mechanical properties of other alloys not shown in Table 16.2 shall comply with the requirements set out in a specification which has been approved by BKI.

(IACS UR W24 7.2)

Table 16.2: Mechanical properties of standard cast copper alloys for propellers (separately cast sample pieces)

Casting grade	Proof stress $R_{p0,2}$ [N/mm^2] min	Tensile strength Rm [N/mm^2] min.	Elongation A_5 [%] min.
CU1	175	440	20
CU2	175	440	20
CU3	245	590	16
CU4	275	630	18

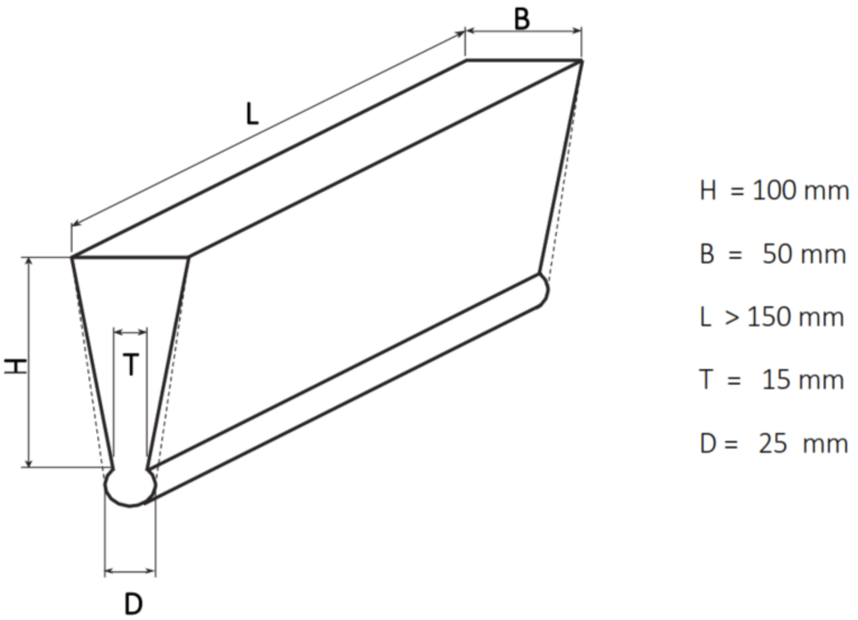


Figure 16.1: Separately cast sample pieces

3. Tensile tests and specimens

Tensile tests and specimens are to be in accordance with Section 2, D.

Generally, the specimens shall be taken from separately cast sample pieces in accordance with 1. The test samples shall be cast in moulds made of the same material as the mould for the propeller and they must be cooled down under the same conditions as the propeller. At least one tensile test specimen shall be taken from each ladle.

If propellers are subjected to a heat treatment the test samples are to be heat treated together with them.

Where test specimens are to be taken from integrally cast test samples, this shall be the subject of special agreement with BKI. Wherever possible, the test samples shall be located on the blades in an area lying between 0,5 to 0,6 R, where R is the radius of the propeller. The test sample material shall be removed from the casting by non-thermal procedures.

(IACS UR W24 7.3)

H. Definitions of Skew and Severity Zones

1. Definition of skew

The skew of a propeller is defined as follows:

The maximum skew angle of a propeller blade is the angle which, in a projected view of of the blade, is formed between one line drawn through the tip of the blade and the shaft centreline and a second line through the shaft centreline which acts as a tangent to locus of the mid-points of the helical blade section (see Fig. 16.2).

High-skew propellers have a skew angle of more than 25° and low-skew propellers an angle up to 25°.

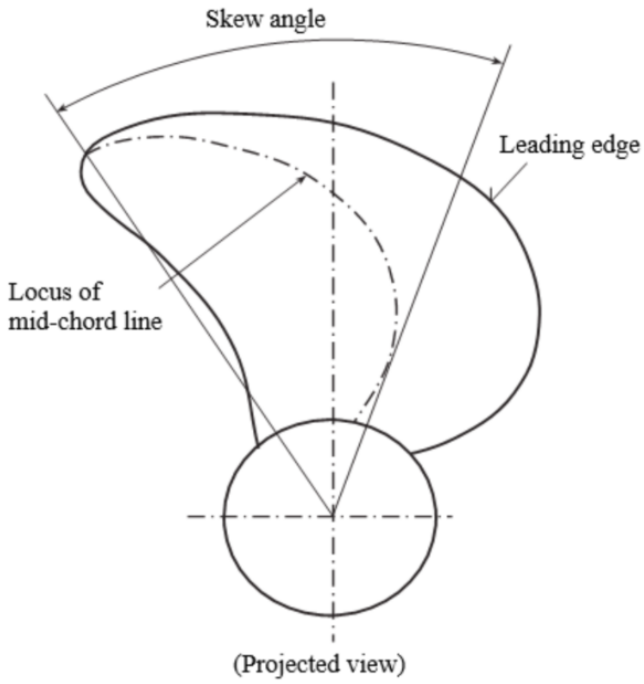


Figure 16.2: Definition of skew angle

(IACS UR W24 8.1)

1.1 Severity zones

In order to relate the degree of inspection to the criticality of defects in propeller blades and to help reduce the risk of fatigue fractures following repairs, the blades are divided into three severity zones designated A, B and C.

Zone A is the area subjected to the greatest operating stress and which, therefore, requires the highest degree of inspection. The blades in this area are normally at their thickest giving the greatest degree of restraint in repair welds and this in turn leads to the highest residual stresses in and around any repair welds. High residual tensile stresses often lead to fatigue cracks during subsequent operation so that relief of these stresses by heat treatment is essential for any welds made in this zone. Welding in Zone A is normally not permitted. Exceptions to this rule are only possible where BKI has given its approval based on a special consideration. In this area, every attempt shall be made to repair a defective or damaged propeller without resorting to welding, even where these results in the cross-section being reduced, provided that this possibility can be authorized. If approval is given for repair by welding this is to be followed by a stress-relieving heat treatment.

Zone B is the area where operating stresses can be high. In this case, repairs by welding are to be avoided wherever possible but May, in general, be performed if BKI has given prior approval. Complete details of the defects or damages and the intended repair procedure are to be submitted for each instance in order to obtain such approval.

Zone C is the area in which the operating stresses are low and where the propeller blades are comparatively thin, in which case repair by welding may be regarded as fairly safe. Repairs of this nature are permitted provided they are executed using an approved method.

(IACS UR W24 8.2)

1.2 Low-skew propellers

Zone ”A” is the area on the pressure side of of the blade between the fillet and the radius 0,4 R and is bounded on both sides by 0,15 × length of the chord Cr from the leading edge and 0,20 × Cr from the trailing edge, see Fig. 16.3.

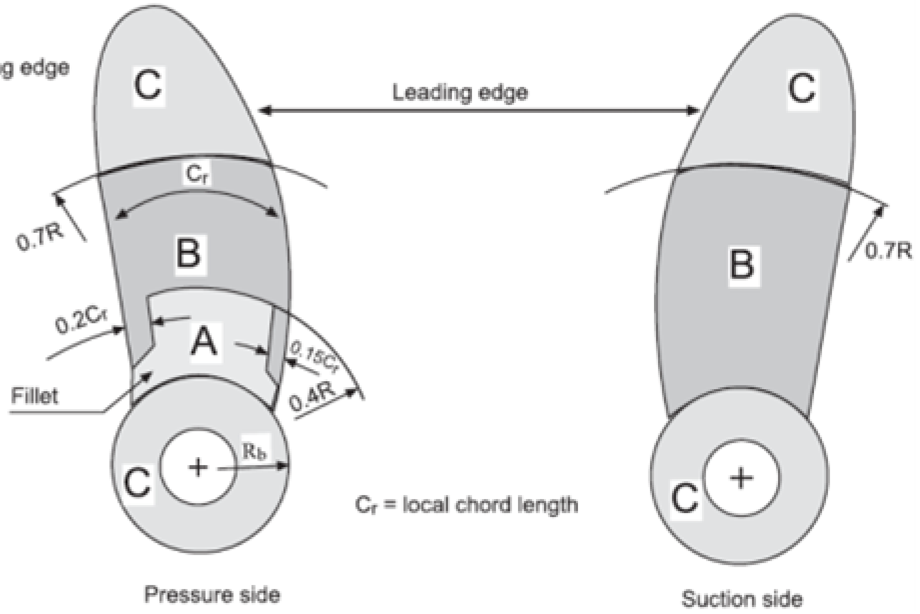


Figure 16.3: Severity zones, for integrally cast low- skew propellers

If the radius of the boss R_b is greater than 0,27 R, the limit of Zone "A" shall be increased to a value of 1,5 × R_b.

Zone A also incorporates the areas of the separate cast propeller bosses which are located in the area of the window shown in Fig. 16.5, and also the areas of flange and blade fillets of controllable pitch and built-up propellers blades, as described in Fig. 16.6. Further the inner taper surface of the boss is classed as Zone

Zone B is the remaining area of the pressure side up to the radius 0,7 R and on the suction side the area between the fillet and the radius 0,7 R, see Fig. 16.3.

Zone C is the area outside the radius 0,7 R on both side of the blade. This also incorporates the surface of the hub of a monoblock propeller and all the surfaces of the hub of a controllable pitch propeller other than those designated Zone A above.

(IACS UR W24 8.2.1)

1.3 High-skew propellers

Zone A is the area of the pressure side which lies within the following boundaries:

— from the fillet and a connecting curve starting at the fillet and the leading edge up to the radius 0,9 R and also the trailing edge, whereby the curve at 0,7 R is half the width of the blade (0,5 Cr); and 0,4 R at a chord length of 0,3 Cr. The suction face includes an area between the fillet and the radius 0,9 R which has a width of 0,15 Cr measured from the trailing edge.

— further the inner taper surface is classed as Zone A.

Zone B is made up of the remaining surface of the blade.

Zone A and Zone B are shown in Fig. 16.4.

(IACS UR W24 8.2.2)

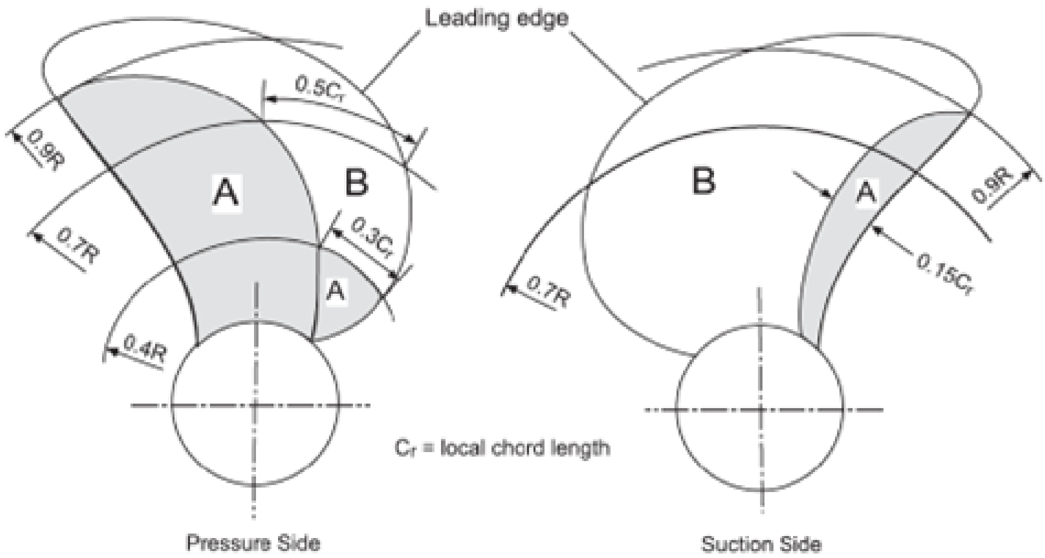


Figure 16.4: Severity zones in blades with skew angles greater than 25°

(IACS UR W24 Fig.4)

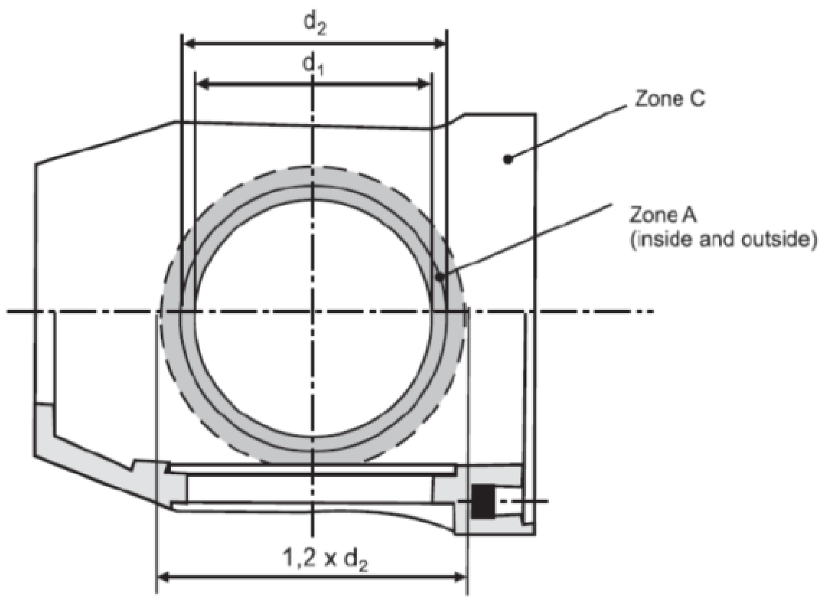


Figure 16.5: Severity zones of the bosses of controllable pitch propellers

(IACS UR W24 Fig.5)

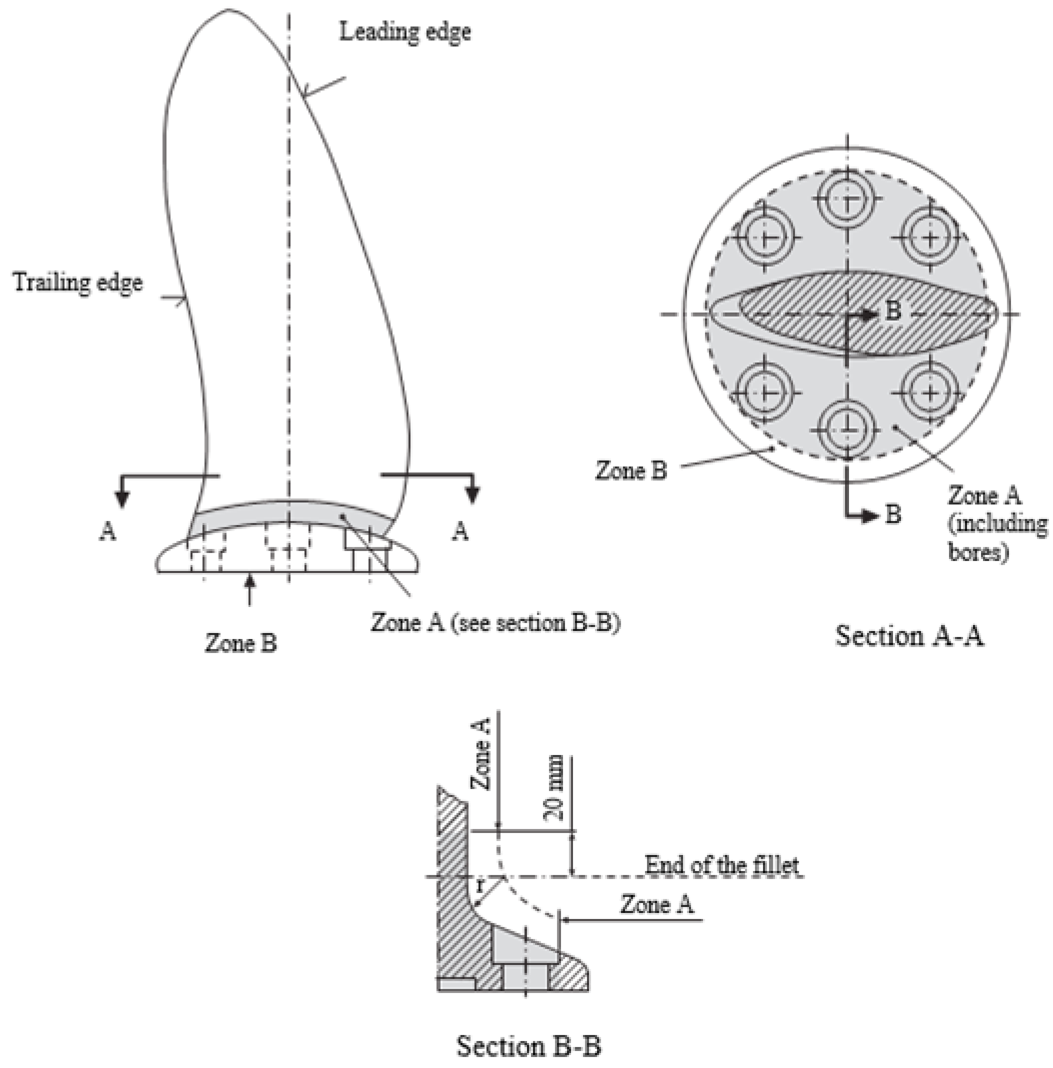


Figure 16.6: Severity zones of fixed- and controllable pitch propellers

Note

The remaining surface of the propeller blades is to be divided into the severity zones as given for solid cast propellers (cf. Fig. 16.3 and Fig. 16.4)

(IACS UR W24 Fig.6)

I. Non-Destructive Tests

1. Qualification of personnel involved in NDT

Refer to Rules for Approval Manufacturers and Service Suppliers (Pt.1, Vol.XI) Sec.3.S.6 and 7.

(IACS UR W24 9.1)

2. Visual testing

All finished castings are to be 100% visually inspected by the manufacturer. Castings are to be free from cracks, hot tears or other imperfections which, due to their nature, degree or extent, will interfere with the use of the castings. A general visual examination is to be carried out by the Surveyor.

(IACS UR W24 9.2)

3. Liquid penetrant testing

Liquid penetrant testing procedure is to be submitted to BKI and is to be in accordance with ISO 3452-1:2013 or a recognized standard. The acceptance criteria are specified in J.

The severity zone A is to be subjected to a liquid penetrant testing in the presence of the Surveyor.

In zones B and C the liquid penetrant testing is to be performed by the manufacturer and may be witnessed by the Surveyor upon his request.

If repairs have been made either by grinding, straightening or by welding the repaired areas are additionally to be subjected to the liquid penetrant testing independent of their location and/or severity zone.

(IACS UR W24 9.3)

4. Radiographic and ultrasonic testing

When required by BKI or when deemed necessary by the manufacturer, further non-destructive testing (e.g. radiographic and/or ultrasonic testing) are to be carried out. The acceptance criteria or applied quality levels are to be agreed between the manufacturer and BKI in accordance with a recognized standard.

Note

Due to the attenuating effect of ultrasound within cast copper alloys, ultrasonic testing may not be practical in some cases, depending on the shape/type/thickness, and grain growth direction of the casting.

In such cases, effective ultrasound penetration into the casting should be practically demonstrated on the item. This would normally be determined by way of back-wall reflection, and/or target features within the casting.

(IACS UR W24 9.4)

J. Acceptance Criteria for Liquid Penetrant Testing

1. Definitions of liquid penetrant indications

Indication : In liquid penetrant testing, an indication is the presence of detectable bleed-out of the penetrant liquid from discontinuities in the material appearing at least 10 minutes after the developer has been applied.

Relevant indication : Only indications which have any dimension greater than 1,5mm shall be considered relevant for the categorization of indications.

Non-linear indication : an indication with a largest dimension less than three times its smallest dimension (i.e. $l < 3$ w).

Linear indication : an indication with a largest dimension three or more times its smallest dimension (i.e. $l \geq 3$ w).

Aligned indications :

1) Non-linear indications form an alignment when the distance between indications is less than 2 mm and at least three indications are aligned. An alignment of indications is considered to be a unique indication and its length is equal to the overall length of the alignment.

2) Linear indications form an alignment when the distance between two indications is smaller than the length of the longest indication.

Illustration of liquid penetrant indication is given in Fig. 16.7.

(IACS UR W24 10.1)

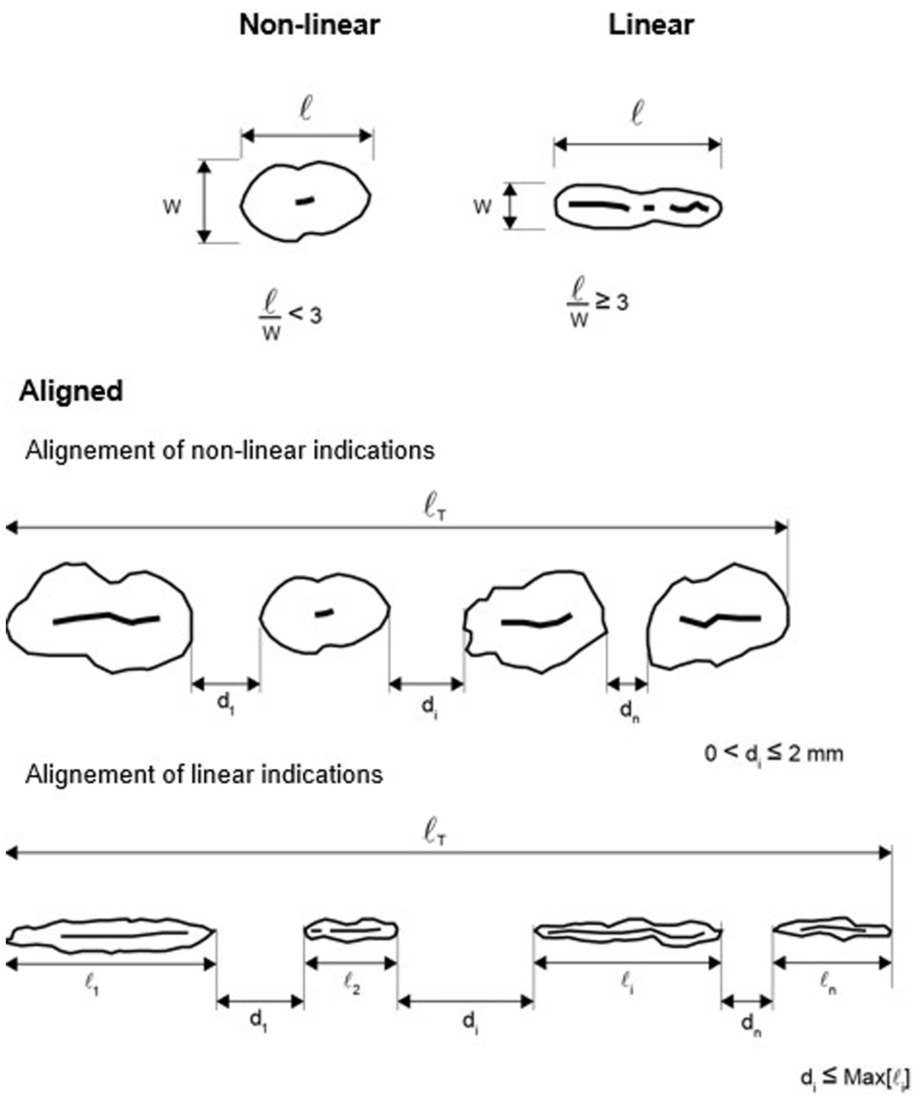


Figure 16.7: Forms of indication

(IACS UR W24 Fig.7)

2. Acceptance standard

2.1 The test surface shall be subdivided into reference areas of 100 cm^2. Each reference area may be square or rectangular with the major dimension not exceeding 250 mm.

The reference area for evaluation indications shall be located at the most unfavourable site for each.

The relevant indications detected shall, with respect to their size and number, not exceed the values given in the Table 16.3.

2.2 For welding purposes prepared areas shall always be evaluated as Zone A regardless of their location. The same applies for weld sites when they have been finished machined or ground.

(IACS UR W24 10.2)

Note

Bores of bosses of controllable pitch propellers intended for mounting the boss on the propeller shaft are to be classed as Zone A.

The remaining areas of the propeller blade are to be subdivided into the same endangered areas as the fixed-pitch propeller (see Figs. 16.3 and 16.4)

K. Repair of Defects

1. Definition

Indications which exceed the maximum values of the acceptance standard specified in Table 16.3, such as cracks, shrinkage cavities, scabs and slag inclusion, blow holes or other non-metallic inclusions and also other discontinuities, where they might impair the safe operation of the propeller, shall be regarded as defects and shall be repaired.

(IACS UR W24 11.1)

Table 16.3: Permitted number and size of indications in a reference area of 100 cm^2 as a function of the severity zones

Severity zones	Maximum number of indications	Form of indication	Maximum number for each form of indication [1)2)]	Maximum permitted dimension "a" or "l" for indication [mm]
A	7	non-linear	5	4
		linear	2	3
		aligned	2	3
B	14	non-linear	10	6
		linear	4	6
		aligned	4	6
C	20	non-linear	14	8
		linear	6	6
		aligned	6	6

1) Individual, non-linear indications with a diameter of less than 2 mm in Zone A and with a diameter of less than 3 mm in the other zones are not considered relevant.

2) The total number of non-linear indications may be increased to the maximum permitted number, or part thereof, represented by the absence of linear or aligned indications.

2. Repair methods

2.1 Defects shall normally be removed by mechanical methods such as grinding, chipping or milling. By consent of BKI, repairs by welding may be performed provided that the specifications given in 3., 4. and 5. have been complied with.

2.2 After milling or chipping, grinding is to be applied for such defects which are not to be welded. Grinding is to be carried out in such a manner that the contour of the ground depression is as smooth as possible in order to avoids stress concentrations or to minimize cavitation corrosion. Complete elimination of the defective material is to be verified by liquid penetrant testing.

2.3 Weld sites smaller than 5 cm^2 are to be avoided.

(IACS UR W24 11.2)

3. Repair of defects in Zone A

3.1 Repairs by welding in Zone A are generally not permitted unless specially approved by BKI.

In some cases the propeller designer may submit technical documentation to propose a modified zone A based on detailed hydrodynamic load and stress analysis for consideration by BKI.

3.2 Grinding is permitted to the extent that the blade thickness specified in the drawing is maintained.

3.3 Following milling or chiselling, defects which have not been welded shall be removed by grinding. Grinding shall be performed so that the groove formed by grinding forms a smooth contour to avoid the formation of stress peaks or the occurrence of cavity corrosion.

3.4 Where grinding has to be carried out more deeply than described above, this shall be inspected and approved on a case by case basis by BKI.

(IACS UR W24 11.3)

4. Repair of defects in Zone B

4.1 Defects with a depth d_B no more than d_B = t/40 mm (t = local minimum thickness as specified in the Rules) or not deeper than 2 mm below the local thickness as specified in the Rules shall be removed by grinding. For evaluation purposes, the greater dimension shall be the standard.

4.2 Defects with a depth greater than the figure permitted for grinding may be repaired by welding.

(IACS UR W24 11.4)

5. Repair of defects in Zone C

Repair by welding is normally permitted in Zone C.

(IACS UR W24 11.5)

6. Repair documentation

The foundry is to maintain records of inspections, welding, and any subsequent heat treatment, traceable to each casting.

Before welding is started, full details of the extent and location of the repair, the proposed welding procedure, heat treatment and subsequent inspection procedures are to be submitted to BKI for approval.

(IACS UR W24 11.6)

L. Welding Repair Procedure

1. General

Before welding is started, manufacturer shall submit to BKI a detailed welding procedure specification covering the weld preparation, welding parameters, filler metals, preheating and post weld heat treatment and inspection procedures.
All weld repairs are to be carried out in accordance with qualified procedures, and, by welders who are qualified to a recognized standard. Welding Procedure Qualification Tests are to be carried out in accordance with Annex 1 and witnessed by the Surveyor.

(IACS UR W24 12.1)

2. Preparation of weld sites

Defects which are required to be removed by welding shall be ground down to the sound base material in conformity with the requirements stated in K.2. The welding grooves are to be prepared in such a manner which will allow a good fusion of the groove bottom. To ensure that the defects have been completely removed by grinding, the grinding sites shall be subjected to a liquid penetrant testing in the presence of the Surveyor.

(IACS UR W24 12.2)

3. Welding repair procedure

3.1 Metal arc welding is to be used for all types of welding repairs on cast copper alloy propellers.

Arc welding with coated electrodes and gas-shielded metal arc process (GMAW) are generally to be applied. Argon-shielded tungsten welding (GTAW) shall be used with care due to the higher specific heat input of this process. The recommendations applicable to filler metals, preheating and stress-relieving treatment temperatures are given in Table 16.4.

Table 16.4: Recommended filler metals and heat treatments

Grade of casting	Filler material	Preheating temperature [°C] min.	Interpass-temperature [°C] max.	Stress relieving heat treatment temperature [°C]	Hot straightening temperature [°C]
CU1	Al bronze [1)] Mn bronze	150	300	350 - 550	500 - 800
CU2	Al bronze Ni-Mn bronze	150	300	350 - 550	500 - 800
CU3	Al bronze Ni-Al bronze [2)] Mn-Al bronze	50	250	450 – 500	700 - 900
CU4	Mn-Al bronze	100	300	450 - 600	700 - 850

1) Ni-Al bronze and Mn-Al bronze may also be used.

2) Stress relieving heat treatment is not necessary if Ni-Al bronze filler metals are used.

3.2 All propellers shall normally be welded in the downhand (flat) position. Where this is not possible, inert gas shielding arc welding methods shall be employed.

Weld sites shall be clean and dry. Covered welding rods shall be dried before use according to the manufacturer's specifications.

To limit the risk of distortion and crack formation, the interpass temperatures shall be kept low. This is particularly applicable in the case of CU3 alloys.

Slag, undercuts and other welding defects shall be removed before the next run is performed.

3.3 All welding work shall be carried out preferably in the workshop, shielded from draughts and the effects of the weather.

3.4 With the exception of CU3 alloys, all repair welds shall be subjected to a stress-relieving treatment to avoid stress corrosion cracking. Stress-relieving treatment for grade CU3 castings may, however, be required where major repairs have to be carried out in Zone B (and in Zone A subject to special approval) or where the filler metals used are susceptible to stress corrosion cracking. In these instances, depending upon the extent of the repair required, the propeller shall either be subjected to a stress-relieving heat treatment following welding, at temperatures ranging from 450°C to 500°C, or be annealed within the temperature range 650°C and 800°C (see Table 16.4).

3.5 The holding times for the stress-relieving treatment of copper alloys for propellers shall conform to the values given in Table 16.5. The heating up and cooling down process shall be slow and be performed under controlled conditions. The rate of cooling following any stress-relieving treatment may not exceed 50°C/h down to a temperature of 200°C.

(IACS UR W24 12.3)

M. Straightening Operations

1. Application of straightening load

Only static loads shall be employed for hot and cold straightening operations.

(IACS UR W24 13.1)

2. Hot straightening

Weld repaired areas may be subject to hot straightening, provided it can be demonstrated that weld properties are not impaired by the hot straightening operations.

When straightening a deformed propeller or changing the pitch of the propeller, the working area, together with a 500 mm zone on either side of the area, shall be heated up to the recommended hot straightening temperature specified in Table 16.5.

The heating up process shall be performed slowly and uniformly and point sources of heat such as oxyacetylene or oxy-propane should not be used. Sufficient time shall be allowed to ensure that the entire thickness of the blade section is uniformly soaked. The temperature shall be maintained within the recommended temperature range throughout the entire straightening process. Thermocouple elements or temperature indicating crayons shall be used to measure temperature.

(IACS UR W24 13.2)

3. Cold straightening

Cold straightening should only be used where minor repairs are required to blade tips and edges. Stress-relieving treatment shall be performed following the cold straightening of blades made from the CU1, CU2 and CU4 grades of casting see Table 16.4.

(IACS UR W24 13.3)

Table 16.5: Holding times [h] for the stress-relieving heat treatment of cast copper alloys for propellers

Stress relieving heat treatment temperature [°C]	CU1 and CU2 grades of casting		CU3 and CU4 grades of casting	
	Hours for each 25 mm of thickness [h]	Maximum recommended hours [h]	Hours for each 25 mm of thickness [h]	Maximum recommended hours [h]
350	5	15	—	—
400	1	5	—	—
450	1/2	2	5	15
500	1/4	1	1	5
550 [1)]	1/4	1/2	1/2	2
600 [1)]	—	—	1/4	1

[1)] Temperatures within the range 550°C and 600°C shall only be employed for CU4 alloys.

N. Identification and Marking

1. Identifications

The manufacturer is to adopt a system for the identification of all castings, which enable the material to be traced to its original cast. The Surveyor is to be given full facilities for so tracing the castings when required.

(IACS UR W24 14.1)

2. Marking

Each finished casting propeller shall be marked by the manufacturer at least with the following particulars:

- Grade of casting or corresponding abbreviated designation
- Manufacturer's mark
- Heat number, casting number or another mark enabling the manufacturing process to be traced back
- Date of final inspection
- Number of BKI's test certificate
- Ice class symbol, where applicable
- Blade skew angle for high-skew propellers.

(IACS UR W24 14.2)

O. Manufacturer's Certificates

- Purchaser and order number
- Shipbuilding project number, if known
- Description of the casting with drawing number
- Diameter, number of blades, pitch and direction of turning
- Grade of alloy and chemical composition of each heat
- Heat or casting number
- Final weight
- Results of non-destructive tests and details of test procedure, where applicable
- Portion of alpha-structure for CU1 and CU2 alloys
- Results of the mechanical tests
- Casting identification number
- Skew angle for high skew propellers, see H.1

(IACS UR W24 15)

Section 17 Propellers Made of Stainless Cast Steel Alloys

A. Scope

These Rules are applicable to the manufacture, testing and to the method of repairing propellers, propeller blades and propeller bosses made of stainless cast steel alloys.

Where the use of alternative alloys is proposed, particulars of chemical composition, mechanical properties and heat treatment are to be submitted for approval.

By agreement with BKI these Rules may also be applied to the repair of propellers which have been damaged in service.

(IACS UR W27 1.1, 1.2 and 1.3)

B. Approval of the Foundry

1. Approval

All propellers and propeller components shall be manufactured by foundries which have been approved by BKI. The castings are to be manufactured and tested in accordance with the requirements of these Rules.

(IACS UR W27 2.1)

2. Application for approval

It is the manufacturer's responsibility to assure that effective quality, process and production controls during manufacturing are adhered to within the manufacturing specification. The manufacturing specification shall be submitted to BKI at the time of initial approval, and shall at least include the following particulars: description of the foundry facilities, steel material specification, runner and feeder arrangements, manufacturing procedures, non-destructive testing and repair procedures.

(IACS UR W27 2.2)

3. Scope of the approval test

The scope of the approval test shall be in accordance with Guidance for The Approval and Type Approval of Materials and Equipments for Marine Use (Pt.1 Vol.W). Tests shall also include the provision of cast sample pieces of the grades of casting eligible for approval in order to demonstrate that their chemical composition and mechanical properties comply with the requirements set out in these Rules.

(IACS UR W27 2.3)

4. Test equipment

The foundry shall have at its disposal a suitably equipped laboratory staffed by qualified personnel to perform tests on moulding materials, chemical analyses, mechanical tests, microstructural examinations of metallic materials and non-destructive testing. Where testing activities are assigned to other companies or other laboratory, additional information required by BKI shall be included.

(IACS UR W27 2.4)

C. General Requirements Applicable to Castings

1. Freedom from defects

All castings shall be in a perfect condition in conformity with the method of manufacture and shall be free from defects which would be prejudicial to their proper application in service. Minor casting defects which are still visible after machining, such as small sand and slag marks, small cold shuts and scabs shall be removed by the manufacturer, see K.

(IACS UR W27 3.1)

2. Repair of defects

Casting defects which may impair the serviceability of the castings, such as major non-metallic inclusions, shrinkage cavities, blow holes and cracks are not permitted. They are to be removed by one of the methods described in K. and repaired within the limits applicable for the severity zone in question. A comprehensive report on the repairs carried out is to be made available to the Surveyor.

(IACS UR W27 3.2)

D. Dimensions, Dimensional and Geometrical Tolerances

1. The verification of dimensions the dimensional and geometrical tolerances is the responsibility of the manufacturer.

The report on the relevant examinations shall be submitted to the Surveyor, who may require checks to be made in his presence.

(IACS UR W27 4.1)

E. Chemical Composition and Heat Treatment

1. The chemical composition of the commonly used standard cast alloys for propellers made of stainless steels is shown in Table 17.1. Propeller alloys whose chemical composition differs from the standard alloys shown in Table 17.1 shall be specially approved by BKI.

(IACS UR W27 5.1)

Table 17.1: Chemical composition of standard propeller alloys made from stainless cast steel

Alloy type	Chemical composition [%] 1)				
	C max. (%)	Mn Max. (%)	Cr (%)	Mo 1) (%)	Ni (%)
Martensitic 12Cr1Ni	0,15	2	11,5 –17,0	0,5	Max. 2,0
Martensitic 13Cr4Ni	0,06	2	11,5 – 17,0	1	3,5 – 5,0
Martensitic 16Cr5Ni	0,06	2	15,0 –17,5	1,5	3,5 – 6,0
Austenitic 19Cr11Ni	0,12	1,6	16,0 – 21,0	4	8,0 – 13,0

1) Minimum values are to be in accordance with recognised national or international standards.

2. The manufacturer is to maintain records of the chemical analyses of the production casts, which shall be made available to the Surveyor so that he can satisfy himself that the chemical composition of each casting is within the specified limits.

(IACS UR W27 5.2)

3. Martensitic castings shall be austenitized and tempered. Austenitic castings should be solution treated.

(IACS UR W27 6.)

F. Mechanical Properties

1. The mechanical characteristics of standard propeller alloys shall conform to the data given in Table 17.2. These values are applicable to test specimens taken from integrally cast sample bars attached to the hub or on the blade. The thickness of test coupon shall be in accordance with a recognized standard.

(IACS UR W27 7.1)

2. Where sample bars are located on the propeller blades, this shall be at a point lying between 0,5 to 0,6 R, where R is the radius of the blade. The sample bars may only be removed from the casting when heat treatment has been completed. Removal shall be by non-thermal procedures.

(IACS UR W27 7.2 7.3)

3. The mechanical properties of propeller alloys not shown in Table 17.2 shall comply with the requirements set out in a specification which has been approved by BKI.

Table 17.2: Mechanical properties of standard propeller alloys made of stainless cast steel (Integrally cast sample bars)

Alloy type	Proof stress $R_{p0,2}$ [N/mm^2] min.	Tensile strength R_m [N/mm^2] min.	Elongation A [%] min.	Red. Of area Z min. (%)	KV 1) [J] min.
12Cr1Ni	440	590	15	30	20
13Cr4Ni	550	750	15	35	30
16Cr5Ni	540	760	15	35	30
19Cr11Ni	180 2)	440	30	40	-

1) Not required for general service and the lowest Ice class notations. For other Ice class notations, tests are to be made at -10 °C.

2) $R_{p1,0}$ value is 205 N/mm^2.

4. Separately cast test bars may be used subject to prior approval of BKI. The test bars shall be cast from the same heat as the castings represented and heat treated with the castings represented.

(IACS UR W27 7.4)

G. Inspections and Tests

The following inspections and tests shall be performed. The dimensions of test specimens and methods of testing are given in Section 2.

1. Chemical composition

The manufacturer shall determine the chemical composition of each heat.

2. Tensile test

2.1 The tensile strength (R_m), the 0,2 % and/or 1,0 % proof stress ($R_{p0,2}$ or $R_{p1,0}$) and elongation (A) shall be determined by tensile test. For this purpose, one test specimen shall be taken from each casting.

(IACS UR W27 7.5)

2.2 As an alternative to 2.1, where a number of small propellers of about the same size, and less than 1 m in diameter, are made from one cast and heat treated in the same furnace charge, a batch testing procedure may be adopted using separately cast test samples of suitable dimensions. At least one test specimen is to be provided for each multiple of five castings in the batch.

3. Notched bar impact test

One set of notched bar impact specimens, each consisting of 3 Charpy V-notch specimens, is to be taken from each casting or test batch, see 2. Unless otherwise specified or agreed, testing shall be carried out at room temperature. The result shall be calculated as the average from 3 specimens of which one result may fall below the average value but not lower than 70% of this value.

4. Surface finish and dimensions

4.1 Propeller castings shall be monitored throughout all the production phases; the entire surface shall be subjected to a comprehensive inspection by the Surveyor in its finish machined condition. The inspection shall also include the bore of the boss.

4.2 The manufacturer shall check the dimensions and then submit a report on the dimensional inspection to the Surveyor. The Surveyor may insist on dimensional checks being carried out in his presence.

4.3 Static balancing is to be carried out on all propellers in accordance with the approved drawing. Dynamic balancing may be necessary for propellers running above 500 rpm.

(IACS UR W27 4.2)

4.4 The Surveyor may require certain areas of the propeller to be slightly etched to show up production welds.

Note

The following solutions may be used for etching:

— *Martensitic-ferritic steels:*

12,5 ml HCl + 2.5 g picric acid + 250 ml alcohol

— *Austenitic steels:*

- *3 parts by volume glycerine, 2 parts HCl and 1 part HNO_3*

H. Definition of skew, severity zones

1. In order to relate the degree of inspection to the criticality of imperfections in propeller blades and to help reduce the risk of failure by fatigue cracking after repair, propeller blades are divided into three severity zones designated A, B and C. Definition of skew, and, severity zones are given in Section 16, H.

(IACS UR W27 8.1)

I. Non-Destructive Tests

1. Qualification of personnel involved in NDT

Refer to Rules for Approval Manufacturers and Service Suppliers (Pt.1, Vol.XI) Sec.3.S.6 and 7.

(IACS UR W27 9.1)

2. Visual testing

All finished castings shall be 100% visually inspected by the manufacturer. Castings shall be free from cracks, hot tears or other imperfections which, due to their nature, degree or extent, will interfere with the use of the castings. A general visual examination shall be carried out by the Surveyor.

(IACS UR W27 9.3)

3. Liquid penetrant testing

Liquid penetrant testing procedure shall be submitted to BKI and shall be in accordance with ISO 3452-1:2013 or a recognized standard. The acceptance criteria are specified in J.

For all propellers, separately cast blades and hubs, the surfaces covered by severity zones A, B and C shall be liquid penetrant tested. Testing of zone A shall be undertaken in the presence of the Surveyor, whilst testing of zone B and C may be witnessed by the Surveyor upon his request.

If repairs have been made either by grinding or by welding, the repaired areas shall additionally be subjected to the liquid penetrant testing independent of their location and/or severity zone. Weld repairs shall, independent of their location, always be assessed according to zone A.

(IACS UR W27 9.3)

4. Magnetic particle testing

Magnetic particle testing may be used in lieu of liquid penetrant testing for examination of martensitic stainless steels castings.

Magnetic particle testing procedure shall be submitted to BKI and shall be in accordance with ISO 9934-1:2016 or a recognized standard.

(IACS UR W27 9.4)

5. Radiographic and ultrasonic tests

When required by BKI or when deemed necessary by the manufacturer, further non-destructive testing (e.g. radiographic and/or ultrasonic testing) shall be carried out. The acceptance criteria or applied quality levels shall then be agreed between the manufacturer and BKI in accordance with a recognized standard.

Note:

Due to the attenuating effect of ultrasound within austenitic steel castings, ultrasonic testing may not be practical in some cases, depending on the shape/type/thickness, and grain-growth direction of the casting.

(IACS UR W27 9.5)

J. Acceptance Criteria for Liquid Penetrant Testing and Magnetic Particle Testing

1. Definitions of liquid penetrant indications

Indication: In the liquid penetrant testing, an indication is the presence of detectable bleed-out of the penetrant liquid from discontinuities in the material appearing at least 10 minutes after the developer has been applied.

Relevant indication: only indications which have any dimension greater than 1,5 mm shall be considered relevant for the categorization of indications.

Non-linear indication: an indication with a largest dimension less than three times its smallest dimension (i.e. $l < 3$ w).

Linear indication: an indication with a largest dimension three or more times its smallest dimension (i.e. $l \geq 3$ w).

Aligned indications:

1) Non-linear indications form an alignment when the distance between indications is less than 2 mm and at least three indications are aligned. An alignment of indications is considered to be a unique indication and its length is equal to the overall length of the alignment.

2) Linear indications form an alignment when the distance between two indications is smaller than the length of the longest indication.

Illustration of liquid penetrant indications is given in Fig. 17.1.

(IACS UR W27 10.1)

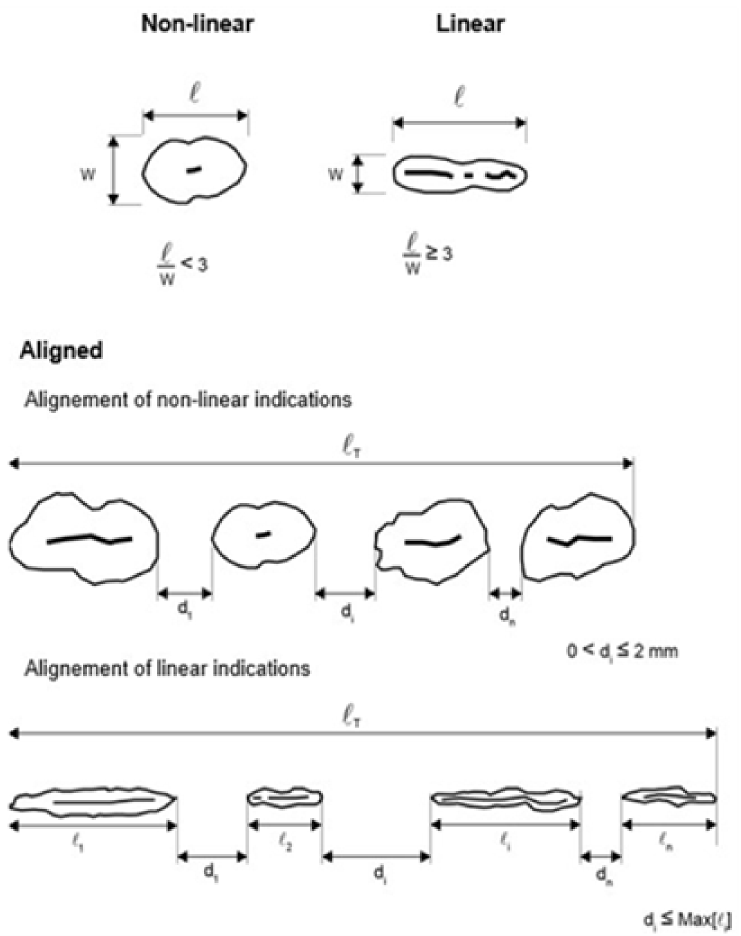


Figure 17.1: Shape of indications

2. Acceptance standard

2.1 The surface to be inspected shall be subdivided into reference areas of 100 cm^2. Each reference area may be square or rectangular with the major dimension not exceeding 250 mm.

The reference area for evaluation indications shall be located at the most unfavourable site for each.

2.2 The relevant indications detected shall with respect to their size and number, not exceed the values given in the Table 17.3.

2.3 For welding purposes, prepared areas shall always be evaluated as Zone A regardless of their location. The same applies for weld sites when they have been finished machined. and/or grinded.

(IACS UR W27 10.2)

Table 17.3: Allowable number and size of relevant indications in a reference area of 100 cm^2, depending on severity zones [1)]

Severity zones	Max. total number of indications	Type of indication	Max. number for each type [1) 2)]	Max. dimension of indication (mm)
A	7	Non-linear	5	4
		Linear	2	3
		Aligned	2	3
B	14	Non-linear	10	6
		Linear	4	6
		Aligned	4	6
C	20	Non-linear	14	8
		Linear	6	6
		Aligned	6	6

1) Single non-linear indications less than 2 mm in zone A and less than 3 mm in for the other zones are not considered relevant.

2) The total number of non-linear indications may be increased to the maximum total number, or part thereof, represented by the absence of linear or aligned indications.

K. Repair of Defects

1. Defective castings shall be repaired in accordance with the requirements given in 2. to 7. and, where applicable, the requirements of L.

2. In general, the repairs shall be carried out by mechanical means, e.g. by grinding, chipping or milling. The resulting grooves shall be blended into the surrounding surface so as to avoid any sharp contours. Complete elimination of the defective material shall be verified by liquid penetrant testing, or magnetic particle testing if applicable.

(IACS UR W27 11.2)

3. Weld repairs are to be undertaken only when they are considered to be necessary and have prior approval of the Surveyor. Weld sites smaller than 5 cm^2 are to be avoided.

(IACS UR W27 11.3)

4. The excavations shall be suitably shaped to allow good access for welding. The resulting grooves shall be subsequently ground smooth and complete elimination of the defective material shall be verified by liquid penetrant testing. Welds having an area less than 5 cm^2 are to be avoided.

(IACS UR W27 11.4)

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

In some cases the propeller designer may submit technical documentation to propose a modified zone A based on detailed hydrodynamic load and stress analysis for consideration by BKI.

(IACS UR W27 11.5)

6. Defects in severity zone B that are not deeper than t/40 mm (t = local minimum thickness as specified in the Rules) or 2 mm, whichever is greatest, shall be removed by grinding. For evaluation purposes, the greater dimension shall be the standard. Those defects that are deeper may be repaired by welding subject to prior approval from BKI.

(IACS UR W27 11.6)

7. Repair by welding is normally permitted in Zone C.

(IACS UR W27 11.7)

8. Repair documentation

The foundry is to maintain records of inspections, welding, and any subsequent heat treatment, traceable to each casting.

Before welding is started, full details of the extent and location of the repair, the proposed welding procedure, heat treatment and subsequent inspection procedures shall be submitted to BKI for approval.

(IACS UR W27 11.8)

L. Welding Repair Procedure

1. General rules

1.1 Before welding is started, manufacturer shall submit to BKI a detailed welding specification containing all the welding details such as preparation of weld sites, welding parameters, filler metals, preheating, post-weld heat treatment and inspection procedures.

(IACS UR W27 12.1)

1.2 All weld repairs are to be carried out in accordance with qualified procedures, and, by welders who are qualified to a recognized standard. Welding Procedure Qualification Tests are to be carried out in accordance with Annex 2 and witnessed by the Surveyor.

2. Preparation of weld sites

Defects which are required to be removed by welding shall be ground down to the sound parent metal in conformity with the requirements stated in J.2. The welding grooves are to be prepared in such a manner which will allow a good fusion of the groove bottom. To ensure that the defects have been completely removed by grinding, the grinding sites shall be subjected to liquid dye penetrant testing in the presence of the Surveyor.

(IACS UR W27 12.2)

3. Welding procedures

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

(IACS UR W27 12.4)

3.2 Welding is to be done under controlled conditions free from draughts and adverse weather.

(IACS UR W27 12.3)

3.3 Slag, notches and other welding defects shall be removed before the next run is applied.

(IACS UR W27 12.5)

4. Post-weld heat treatment

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

(IACS UR W27 12.6)

4.2 On completion of heat treatment, the weld repairs and adjacent material are to be ground smooth. All weld repairs shall be liquid penetrant tested.

(IACS UR W27 12.7)

M. Identification and Marking

1. Identification

The manufacturer shall employ a production monitoring system which enables the castings to be traced back to their heat. On request, the Surveyor shall be given full facilities for so tracing the castings.

(IACS UR W27 13.1)

2. Marking

Prior to final inspection by the Surveyor, the manufacturer shall mark each finished castings propeller at least with the following particulars:

- grade of casting or corresponding abbreviated designation
- manufacturer's mark
- BKI's certificate number
- heat number, casting number or another mark enabling the manufacturing process to be traced back
- date of final inspection
- ice class symbol, where applicable
- blade skew angle for high-skew propellers.

The BKI's stamp is to be put on when the casting has been accepted.

(IACS UR W27 13.1 and 13.2)

N. Certificates Issued by the Manufacturer

For each propeller which has been accepted, the manufacturer shall submit to the Surveyor an inspection certificate containing the following details:

- purchaser's name and order number
- new building number, if known
- description of the casting and drawing number
- diameter, number of blades, pitch and direction of rotation
- skew angle for high skew propellers

— final weight

— alloy type, heat number and chemical composition

— casting identification number

— details of time and temperature of heat treatment

— results of the mechanical test

— results of non-destructive tests and details of test procedure where applicable.

(IACS UR W27 14.1)

Annex 1 Welding Procedure Qualification Tests for Repair of Cast Copper Alloys Propellers

A. General

1. This Annex gives requirements for qualification tests of welding procedures intended for the repair of cast copper alloy propellers.

(IACS UR W24 Appendix 1.1)

2. For the welding procedure approval, the welding procedure qualification tests are to be carried out with satisfactory results. The qualification tests are to be carried out with the same welding process, filler metal, preheating and stress-relieving treatment as those intended applied by the actual repair work. Welding procedure specification (WPS) is to refer to the test results achieved during welding procedure qualification testing.

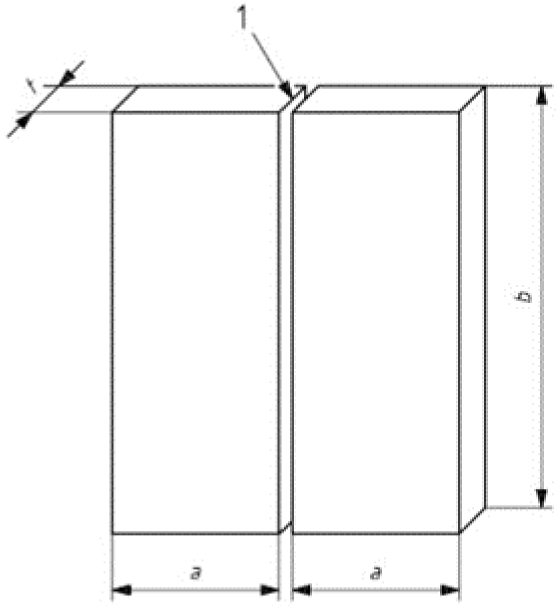
(IACS UR W24 Appendix 1.2)

3. Welding procedures qualified at a manufacturer are valid for welding in workshops under the same technical and quality management.

(IACS UR W24 Appendix 1.3)

B. Test Pieces and Welding of Sample

1. The test assembly, consisting of cast samples, is to be of a size sufficient to ensure a reasonable heat distribution and according to Fig. A1.1 with the minimum dimensions:



1 : Joint preparation and fit-up as detailed in the preliminary welding procedure specification
a : minimum value 150 mm
b : minimum value 300 mm
t : material thickness

Figure A1.1: Test piece for welding repair procedure

A test sample of minimum 30 mm thickness is to be used.

(IACS UR W24 Appendix 2.1)

2. Preparation and welding of test pieces are to be carried out in accordance with the general condition of repair welding work which it represents.

(IACS UR W24 Appendix 2.2)

3. Welding of the test assemblies and testing of test specimens are to be witnessed by the Surveyor.

(IACS UR W24 Appendix 2.3)

C. Examinations and Tests

1. Test assembly is to be examined non-destructively and destructively in accordance with the Table A1.1 and Fig. A1.2:

(IACS UR W24 Appendix 3.1)

Table A1.1: Type of tests and extent of testing

Type of test [1]	Extent of testing
Visual testing	100% as per 2.
Liquid penetrant testing	100% as per 2.
Transverse tensile test	Two specimens as per 3.
Macro examination	Three specimens as per 4.
[1] Bend or fracture test are at the discretion of BKI.	

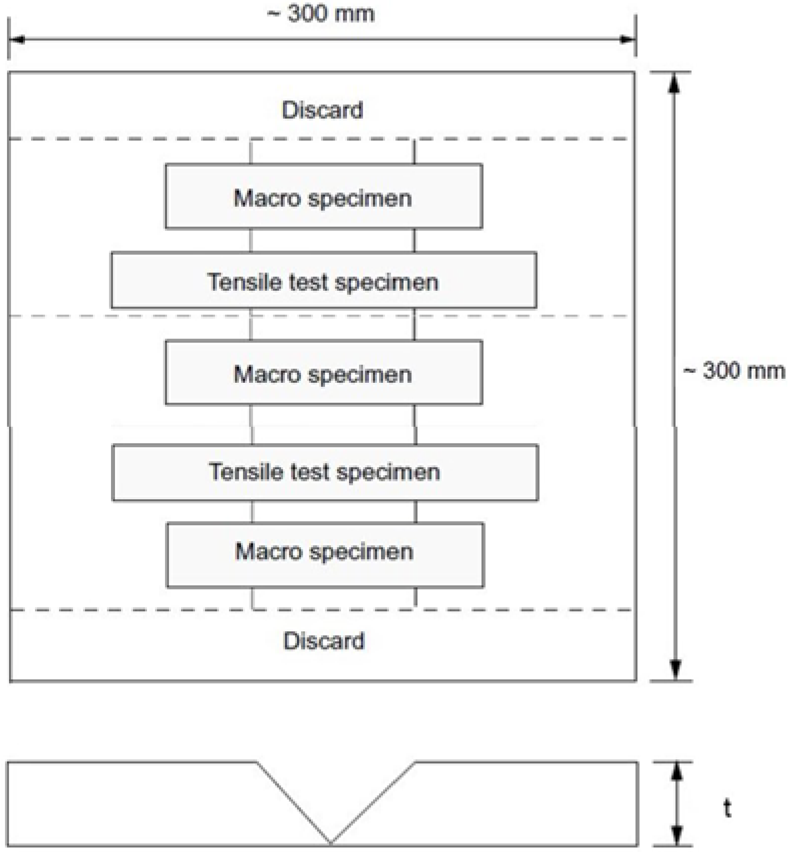


Figure A1.2: Test specimen

2. Non-destructive test

Test assembly shall be examined by visual and liquid penetrant testing prior to the cutting of test specimen. In case, that any post-weld heat treatment is required or specified, non-destructive testing shall be performed after heat treatment. Cracks are not allowed. Imperfections detected by liquid penetrant testing are to be assessed in accordance with the evaluation standard for Zone A given in Table 16.3.

(IACS UR W24 Appendix 3.2)

3. Tensile test

Two tensile tests are to be prepared as shown in Rules for Welding (Pt.1, Vol.VI) Sec.11, Fig.11.1. Alternatively, tensile test specimens according to recognized standards acceptable to BKI may be used. The tensile strength shall meet the values given in Table A1.2.

(IACS UR W24 Appendix 3.3)

Table A1.2: Required Tensile strength values

Alloy Type	Tensile Strength R_m (N/mm^2) min.
CU1	370
CU2	410
CU3	500
CU4	550

4. Macroscopic examination

Three test specimens shall be prepared and etched on one side to clearly reveal the weld metal, the fusion line and the heat affected zone as shown in Fig. A1.2. An etching medium with the following constituents would be suitable for this purpose:

- 5 g ferric (III) chloride
- 30 ml hydrochloric acid
- 100 ml distilled water

The test specimens are to be examined for imperfections present in the weld metal and the heat affected zone. Cracks and lack of fusion are not permitted. Imperfections such as Voids or slag inclusions larger than 3 mm are not permitted.

(IACS UR W24 Appendix 3.4)

5. Re-testing

If the test piece fails to comply with any of the requirements of this Annex, reference is made to re-test procedures given in Section 2, H.

(IACS UR W24 Appendix 3.5)

D. Test Record

1. Welding conditions for test assemblies and test results are to be recorded in welding procedure qualification record. Forms of welding procedure qualification records can be taken from BKI's Rules or from relevant standards.

(IACS UR W24 Appendix 4.1)

2. A statement of the results of assessing each test piece, including repeat tests, is to be made for each welding procedure qualification records. The relevant items listed for the WPS are to be included.

(IACS UR W24 Appendix 4.2)

3. The welding procedure qualification record is to be signed by the Surveyor witnessing the test and is to include BKI´s identification.

(IACS UR W24 Appendix 4.3)

E. Range of Approval

1. General

All the conditions of validity stated below are to be met independently of each other. Changes outside of the ranges specified are to require a new welding procedure test.

A qualification of a WPS obtained by a manufacturer is valid for welding in workshops or sites under the same technical and quality control of that manufacturer.

(IACS UR W24 Appendix 5.1)

2. Base metal

The range of qualification related to base metal is given in Table A1.3.

(IACS UR W24 Appendix 5.2)

Table A1.3: Range of qualification for base metal

Copper alloy material grade used for qualification	Range of approval
CU1	CU1
CU2	"CU1; CU2"
CU3	CU3
CU4	CU4

3. Thickness

The qualification of a WPS carried out on a weld assembly of thickness t is valid for the thickness range given in Table A1.4.

(IACS UR W24 Appendix 5.3)

Table A1.4: Range of qualification for thickness

Thickness of the test piece, t (mm)	Range of approval
30 t	$\geq$3 mm

4. Welding position

Approval for a test made in any position is restricted to that position.

(IACS UR W24 Appendix 5.4)

5. Welding process

5.1 The approval is only valid for the welding process used in the welding procedure test. Single run is not qualified by multi-run butt weld test used in this Annex.

(IACS UR W24 Appendix 5.5)

6. Filler metal

The approval is only valid for the filler metal used in the welding procedure test.

(IACS UR W24 Appendix 5.6)

7. Heat input

The upper limit of heat input approved is 25% greater than that used in welding the test piece.

The lower limit of heat input approved is 25% lower than that used in welding the test piece.

(IACS UR W24 Appendix 5.7)

8. Preheating and interpass temperature

The minimum preheating temperature is not to be less than that used in the qualification test.

The maximum interpass temperature is not to be higher than that used in the qualification test.

(IACS UR W24 Appendix 5.8)

9. Post-weld heat treatment

The heat treatment used in the qualification test is to be specified in pWPS. Soaking time may be adjusted as a function of thickness.

(IACS UR W24 Appendix 5.9)

Annex 2 Welding Procedure Qualification Test for Repair of Propellers made of Stainless Cast Steel Alloy

A. General

1. This Annex gives requirements for qualification tests of welding procedures intended for the repair of cast steel propellers.

(IACS UR W27 Appendix A.1.1)

2. For the welding procedure approval, the welding procedure qualification tests shall be carried out with satisfactory results. The qualification tests shall be carried out with the same welding process, filler metal, preheating and stress-relieving treatment as those intended applied by the actual repair work. Welding procedure specification is to refer to the test results achieved during welding procedure qualification testing.

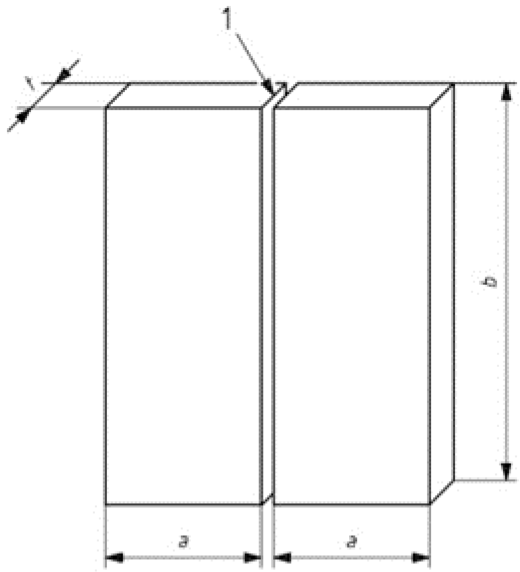
(IACS UR W27 Appendix A.1.2)

3. Welding procedures qualified at a manufacturer are valid for welding in workshops under the same technical and quality management.

(IACS UR W27 Appendix A.1.3)

B. Test pieces and Welding of Sample

1. The test assembly, consisting of cast samples, shall be of a size sufficient to ensure a reasonable heat distribution and according to Fig. A2.1 with the minimum dimensions:



1 : Joint preparation and fit-up as detailed in the preliminary welding procedure specification
a : minimum value 150 mm
b : minimum value 300 mm
t : material thickness

Figure A2.1: Test piece for welding repair procedure

The dimensions and shape of the groove shall be representative of the actual repair work.

(IACS UR W27 Appendix A.2.1)

2. Preparation and welding of test pieces shall be carried out in accordance with the general condition of repair welding work which it represents.

(IACS UR W27 Appendix A.2.2)

3. Welding of the test assemblies and testing of test specimens shall be witnessed by the Surveyor.

(IACS UR W27 Appendix A.2.3)

C. Examinations and Tests

Test assembly shall be examined non-destructively and destructively in accordance with Table A2.1 and Fig. A2.2:

Table A2.1: Type of tests and extent of testing

Type of test	Extent of testing
Visual testing	100% as per article 1.
Liquid penetrant testing [1)]	100% as per article 1.
Transverse tensile test	Two specimens as per article 2.
Bend test [2)]	Two root and two face specimens as per article 3.
Macro examination	Three specimens as per article 4.
Impact test	Two sets of three specimens as per article 5.
Hardness test	As per article 6.
[1)] Magnetic particle testing may be used in lieu of liquid penetrant testing for martensitic stainless steels. [2)] t $\geq$ 12 mm, the face and root bend may be substituted by 4 side bend test	

(IACS UR W27 Appendix A.3.1)

1. Non-destructive tests

Test assembly shall be examined by visual and liquid penetrant testing, or magnetic particle testing if applicable, prior to the cutting of test specimen. In case, that any post-weld heat treatment is required or specified, non-destructive testing shall be performed after heat treatment.

No cracks are permitted. Imperfections detected by liquid penetrant testing, or magnetic particle testing if applicable, shall be assessed in accordance with Sec. 17, J.

(IACS UR W27 Appendix A.3.2)

2. Tensile test

Two flat transverse tensile test specimens shall be prepared. Testing procedures shall be in accordance with Rules for Welding (Pt.1, Vol.VI) Sec.11, Fig.11.1. Alternatively tensile test specimens according to recognized standards acceptable to BKI may be used.

The tensile strength shall meet the specified minimum value of the base material. The location of fracture shall be reported, i.e. weld metal, HAZ or base material.

(IACS UR W27 Appendix A.3.3)

3. Bend test

Transverse bend tests for butt joints shall be in accordance with Section 2.G, or, according to a recognized standard. The mandrel diameter shall be 4 x thickness except for austenitic steels, in which case the mandrel diameter shall be 3 x thickness.

The bending angle is to be 180°. After testing, the test specimens are not to reveal any open defects in any direction greater than 3 mm. Defects appearing at the corners of a test specimen during testing are to be investigated case by case.

Two root and two face bend specimens shall be tested. For thickness 12 mm and over, four side bend specimens may alternatively be tested.

(IACS UR W27 Appendix A.3.4)

4. Macro-examination

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

(IACS UR W27 Appendix A.3.5)

5. Impact test

Impact test is required, where the base material is impact tested. Charpy V-notch test specimens shall be in accordance with Section 2. Two sets shall be taken, one set with the notch positioned in the centre of the weld and one set with the notch positioned in the HAZ (i.e. the mid-point of the notch shall be at 1 mm to 2 mm from the fusion line), respectively.

The test temperature, and impact energy shall comply with the requirement specified for the base material.

(IACS UR W27 Appendix A.3.6)

6. Hardness test

The macro-sections representing the start of welding shall be used for HV 10 hardness testing. Indentations shall traverse 2 mm below the surface. At least three individual indentations are to be made in the weld metal, the HAZ (both sides) and in the base material (both sides). The values are to be reported for infor-mation.

(IACS UR W27 Appendix A.3.7)

7. Re-testing

If the test piece fails to comply with any of the requirements of this Annex, reference is made to re-test pro-cedures given in Rules for Welding (Pt.1, Vol.VI) Sec.12.F.4.4.

(IACS UR W27 Appendix A.3.8)

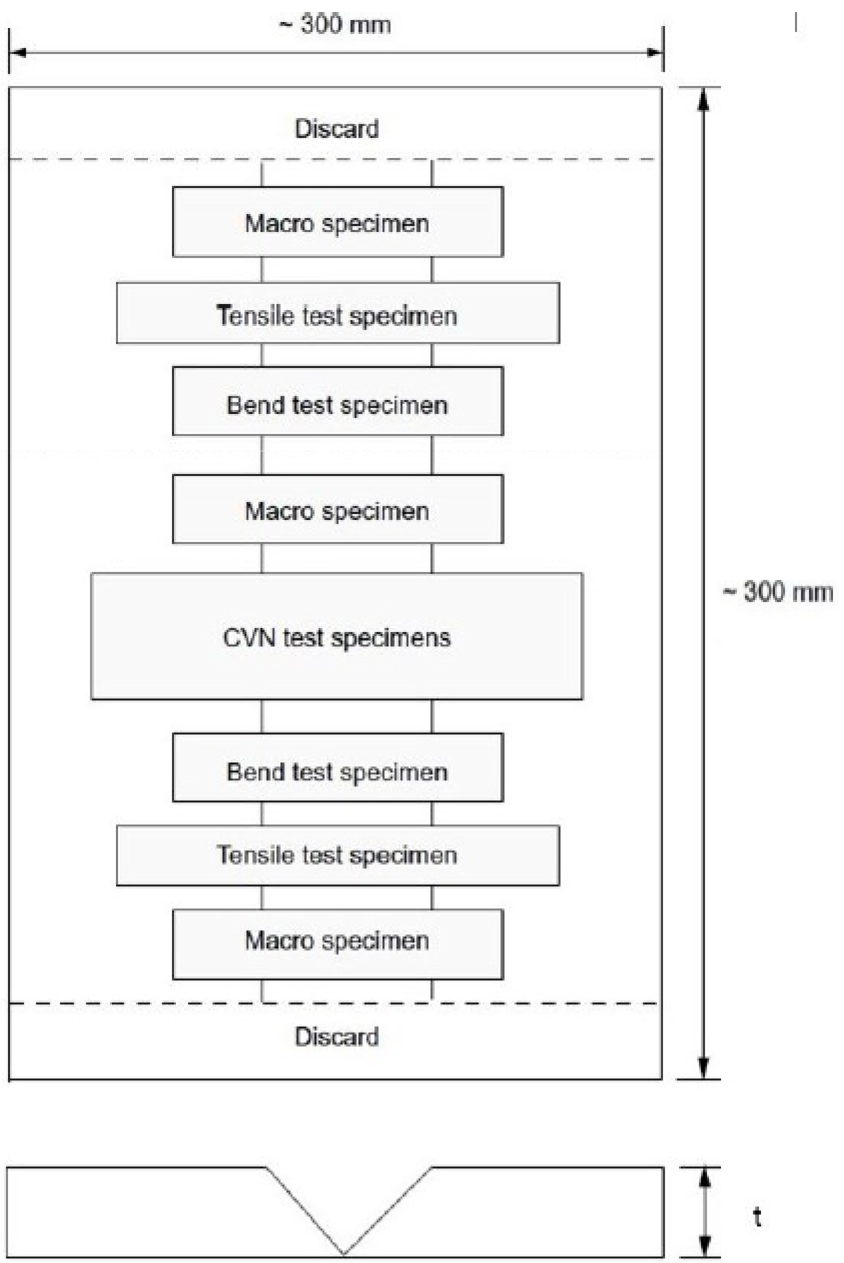


Figure A2.2: Weld Test Assembly

D. Test record

1. Welding conditions for test assemblies and test results shall be recorded in welding procedure qualification. Forms of welding procedure qualification records can be taken from the BKI's Rules or from relevant standards.

(IACS UR W27 Appendix A.4.1)

2. A statement of the results of assessing each test piece, including repeat tests, shall be made for each weld-ing procedure qualification records. The relevant items listed for the WPS shall be included.

(IACS UR W27 Appendix A.4.2)

3. The welding procedure qualification record shall be signed by the Surveyor witnessing the test and is to in-clude BKI´s identification.

(IACS UR W27 Appendix A.4.3)

E. Range of approval

1. General

All the conditions of validity stated below shall be met independently of each other. Changes outside of the ranges specified are to require a new welding procedure test.

(IACS UR W27 Appendix A.5.1)

A qualification of a WPS obtained by a manufacturer is valid for welding in workshops or sites under the same technical and quality control of that manufacturer.

2. Base metal

Range of approval for steel cast propeller is limited to steel grade tested.

(IACS UR W27 Appendix A.5.2)

3. Thickness

The qualification of a WPS carried out on a weld assembly of thickness t is valid for the thickness range given in Table A2.2.

(IACS UR W27 Appendix A.5.3)

Table A2.2: Range of qualification for thickness

Thickness of the test piece, t (mm)	Range of approval
$15 < t \leq 30$	3 mm to 2t
t > 30	0,5t to 2t or 200 mm, whichever is the greater

4. Welding position

Approval for a test made in any position is restricted to that position.

(IACS UR W27 Appendix A.5.4)

5. Welding process

The approval is only valid for the welding process used in the welding procedure test. Single run is not qualified by multi-run butt weld test used in this Annex.

(IACS UR W27 Appendix A.5.5.1)

6. Filler metal

The approval is only valid for the filler metal used in the welding procedure test.

(IACS UR W27 Appendix A.5.6)

7. Heat input

The upper limit of heat input approved is 15% greater than that used in welding the test piece.

The lower limit of heat input approved is 15% lower than that used in welding the test piece.

(IACS UR W27 Appendix A.5.7)

8. Preheating and interpass temperature

The minimum preheating temperature is not to be less than that used in the qualification test.

The maximum interpass temperature is not to be higher than that used in the qualification test.

(IACS UR W27 Appendix A.5.8)

9. Post-weld heat treatment

The heat treatment used in the qualification test is to be specified in pWPS. Holding time may be adjusted as a function of thickness.

(IACS UR W27 Appendix A.5.9)

Annex 3 Test Procedures for Qualification of Corrosion Resistant Steel for Cargo Oil Tanks in Crude Oil Tankers

A. Scope

These Procedures provide details of the test procedure referred to in Section 4, B.1.5 of this Rules.

B. Testing

Corrosion resistant steel shall be verified by the following tests.

1. Test on Simulated Upper Deck Conditions

1.1 Test Condition

Tests on simulated upper deck conditions in cargo oil tank (COT) shall satisfy each of the following conditions:

1.1.1 Corrosion resistant steel and conventional steel shall be tested at the same time.

1.1.2 The chemical composition of conventional steel shall comply with the requirements of Table A3.1. The mechanical properties of the test specimen should be representative of steel used in its intended shipboard application.

Table A3.1: Chemical composition for conventional steel (%)

C	Mn	Si	P	S	Al (acid soluble)$_{min}$	Nb$_{max}$	V$_{max}$
0,13 – 0,17	1,00 – 1,20	0,15 – 0,35	0,010 – 0,020	0,002 – 0,008	0,015	0,02	0,1
Ti$_{max}$	**(Nb+V+Ti)$_{max}$**	**Cu$_{max}$**	**Cr$_{max}$**	**Ni$_{max}$**	**Mo$_{max}$**	**Other$_{max}$**	
0,02	0,12	0,1	0,1	0,1	0,02	0,02 (each)	

1.1.3 The tests for corrosion resistant steel shall be carried out for 21, 49, 77 and 98 days. The tests for conventional steel shall be carried out for 98 days. The tests for welded joints shall be carried out for 98 days.

1.1.4 There are to be five test pieces for each test period

1.1.5 The size of each test piece is 25 $\pm$ 1 mm x 60 $\pm$ 1 mm x 5 $\pm$ 0,5 mm. The surface of the test piece shall be polished with an emery paper #600. The size of the test piece for a welded joint is 25 $\pm$ 1 mm x 60 $\pm$ 1 mm x 5 $\pm$ 0,5 mm, including 15 $\pm$ 5 mm width of the weld metal part.

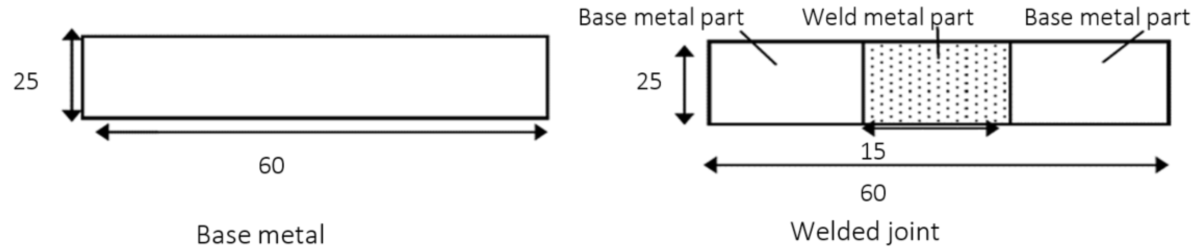


Figure A3.1: Test piece for corrosion test

1.1.6 The surface of the test piece, except for the tested surface, shall be protected from corrosive environment in order not to affect the test results.

1.1.7 The test apparatus consists of a double chamber, and the temperature of the outer chamber is to be controlled.

1.1.8 Simulating the condition of the actual upper deck, the test cycle runs with distilled water and simulated COT gas (4 $\pm$ 1% O_2 - 13 $\pm$ 2% CO_2 - 100 $\pm$ 10 ppm SO_2 - 500 $\pm$ 50 ppm H_2S - 83 $\pm$ 2% N_2). A sufficient distance between the surface of the test piece and the distilled water is to be kept to avoid splashing of distilled water. The minimum gas flow rate is 100 cc per minute for the first 24 h and 20 cc per minute after 24 h.

1.1.9 The test pieces shall be heated for 19 $\pm$ 2 h at 50 $\pm$ 2°C and 3 $\pm$ 2 h at 25 $\pm$ 2°C and the transition time is to be at least 1 h. The time for 1 cycle is 24 h. The temperature of the distilled water is to be kept at not higher than 36°C, while the temperature of the test pieces is 50°C.

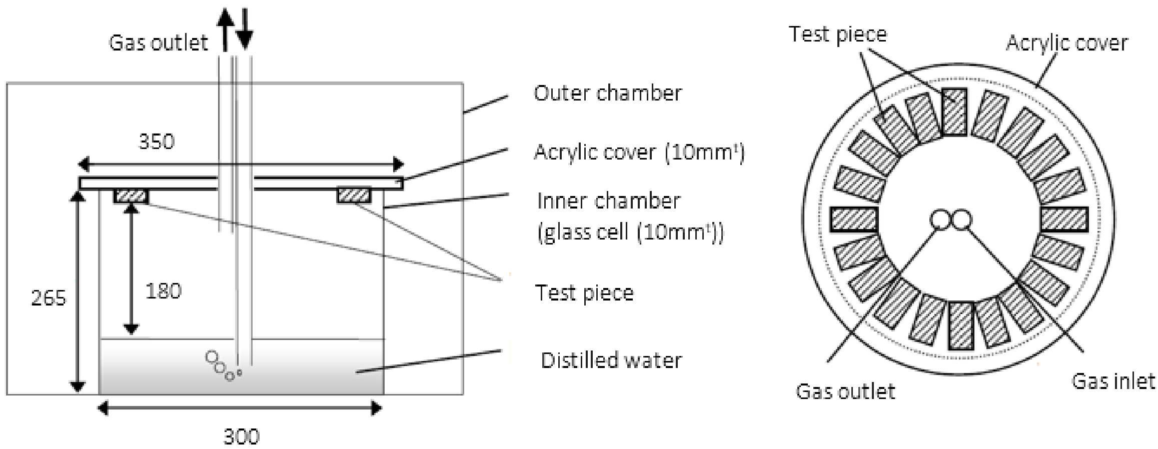


Figure A3.2: An example of simulated corrosion test apparatus for upper deck

1.2 Test Results of Base Metal

Prior to the testing, the following measured data shall be reported:

— Size and weight of the test piece;

and, after the testing, the following measured data shall be reported:

— Weight loss (difference between initial weight and weight after testing) of conventional steel (WC) and corrosion resistant steel (W_{21}, W_{49}, W_{77} and W_{98});

- Corrosion loss of conventional steel (CL_C) and corrosion resistant steel (CL_{21}, CL_{49}, CL_{77} and CL_{98}), calculated by the following formulae:

$$CL_C(mm) = \frac{10 \times W_C}{S \times D}$$

$$CL_{21}(mm) = \frac{10 \times W_{21}}{S \times D}$$

$$CL_{49}(mm) = \frac{10 \times W_{49}}{S \times D}$$

$$CL_{77}(mm) = \frac{10 \times W_{77}}{S \times D}$$

$$CL_{98}(mm) = \frac{10 \times W_{98}}{S \times D}$$

whereby:

W_C	=	weight loss of conventional steel (g) (average of five test pieces)
W_{21}	=	weight loss of corrosion resistant steel after 21 days (g) (average of five test pieces)
W_{49}	=	weight loss of corrosion resistant steel after 49 days (g) (average of five test pieces)
W_{77}	=	weight loss of corrosion resistant steel after 77 days (g) (average of five test pieces)
W_{98}	=	weight loss of corrosion resistant steel after 98 days (g) (average of five test pieces)
S	=	surface area (cm^2)
D	=	density (g/cm^3)

The test is considered to be carried out appropriately if CL_C is between 0,05 and 011 (corrosion rate is between 0,2 and 0,4 mm/year). The concentration of H_2S in simulated COT gas may be increased for adjusting CL_C;

- Coefficients A and B of corrosion resistant steel, calculated from the test results for 21, 49, 77 and 98 days by least square method.

Corrosion loss of corrosion resistant steel is described as follows:

$$CL = A \times t^B$$

A(mm) and B	=	coefficient
T	=	test period(days);

- Estimated corrosion loss after 25 years (ECL) calculated by the following formula:

$$ECL\ (mm) = A \times (25 \times 365)^B$$

1.3 Test Results of Welded Joint

The surface boundary between base metal and weld metal shall be observed by microscope at 1000 times magnification.

1.4 Acceptance Criterion

The test results based on provisions of 1.2 and 1.3 shall satisfy the following criteria:

- ECL(mm) $\leq$ 2 (for base metal); and
- no discontinuous surface (e.g., step) between the base metal and weld metal (for welded joint).

1.5 Test report

The test report shall include the following information:

- name of the manufacturer;
- date of tests;
- chemical composition and corrosion resistant process of steel;
- test results according to 1.2 and 1.3; and
- judgment according to 1.4.

2. Test on Simulated Inner Bottom Conditions

2.1 Test Condition

Tests on simulated inner bottom conditions in cargo oil tanks (COT) should satisfy each of the following conditions:

2.1.1 The test shall be carried out for 72 h for base metal, and 168 h for welded joint.

2.1.2 There are to be at least five test pieces of corrosion resistant steel for base metal and welded joint, respectively. For comparison, at least five test pieces of base metal of conventional steel should be tested in the same condition.

2.1.3 The size of each test piece is 25 $\pm$ 1 mm x 60 $\pm$ 1 mm x 5 $\pm$ 0,5 mm for a specimen with base metal only, and is 25 $\pm$ 1 mm x 60 $\pm$ 1 mm x 5 $\pm$ 0,5 mm for a specimen with welded joint including 15 $\pm$ 5 mm width of weld metal part as shown in Fig. A3.3. The surface of the test pieces shall be polished with an emery paper #600, except a hole for hanging.

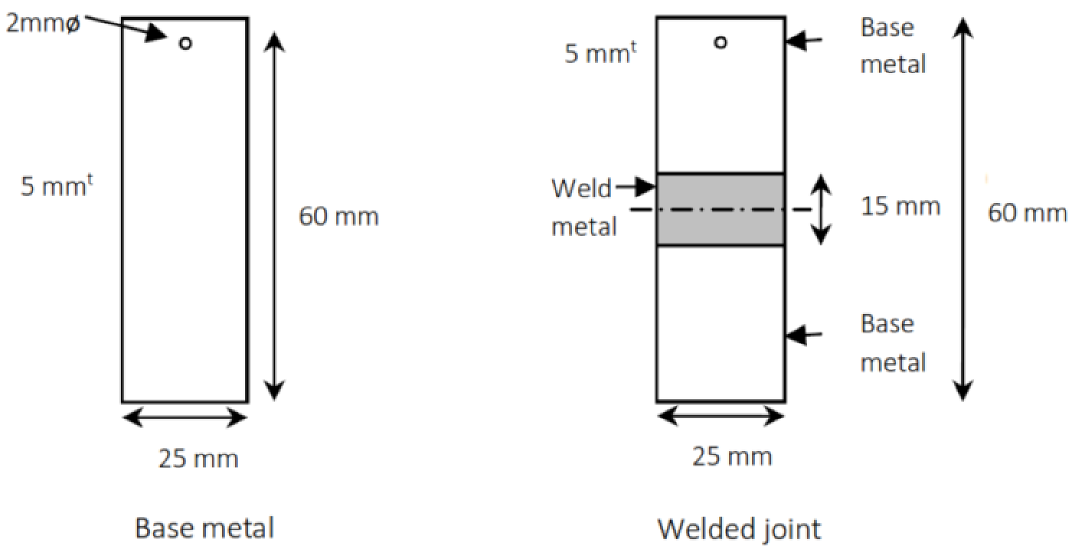


Figure A3.3: Test piece for corrosion test

2.1.4 The samples are hung in a solution from a fishing line (0,3 mm to 0,4 mm in diameter, made of nylon) to avoid crevice-like and/or localized corrosion. An example of a corrosion test configuration is shown in Fig. A3.4.

2.1.5 The test solution contains 10 mass% NaCl and its pH is 0,85 adjusted by HCl solution. The test solution should be changed to a new one every 24 h to minimize pH change of the test solution. The volume of the solution is more than 20 cc/cm^2 (surface area of test piece). The temperature of the test solution is to be kept at 30 $\pm$ 2°C.

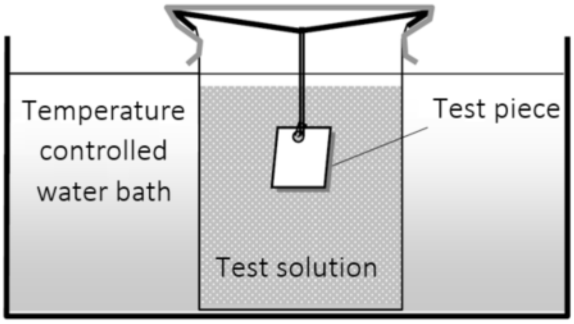


Figure A3.4: Test piece for corrosion test

2.2 Test Results of Base Metal

Prior to the testing, the following data shall be measured and reported:

- Size and weight of test piece;

and, after the testing, the following measured data shall be reported:

- Weight loss (difference between initial weight and weight after testing);
- Corrosion rate (CR) calculated by the following formula:

$$\text{CR (mm/year)} = \frac{365(\text{days}) \times 24(\text{hours}) \times \text{W} \times 10}{\text{S} \times 72(\text{hours}) \times \text{D}}$$

whereby:

W = weight loss (g),
S = surface area (cm^2)
D = density (g/cm^3)

- To identify specimen which hold crevice and/or localized corrosion, the CR is to be plotted on a normal distribution statistic chart. CR. data which deviate from the normal statistical distribution must be eliminated from the test results. An example is shown in Fig. A3.5 for reference;
- Calculation of average of CR's data (CR_{ave}):

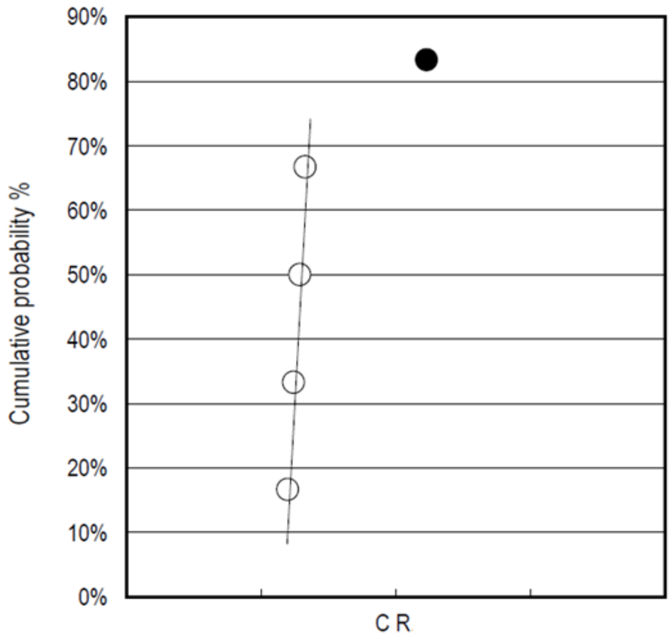


Figure A3.5: An example of plot of CRs on a normal distribution chart (In this case CR data ● should be abandoned and eliminated.)

2.3 Test Results of Welded Joint

The surface boundary between base metal and weld metal shall be observed by microscope at 1000 times magnification.

2.4 Acceptance Criterion

The test results based on 2.2 and 2.3 shall satisfy the following criteria:

— CR_{ave} (mm/ year) $\leq$ 1,0 (for base metal); and

— no discontinuous surface (e.g., step) between the base metal and weld metal (for welded joint).

2.5 Test Report

The test report shall include the following information:

— name of the manufacturer;

— date of tests;

— chemical composition and corrosion resistant process of steel;

— test results according to 2.2 and 2.3; and

— judgment according to 2.4.

Annex 4 Test Method for Brittle Crack Arrest Toughness, K_{ca}

A. Scope

ISO 20064: 2019 provides a test method for the determination of brittle crack arrest toughness of steel by using wide plates with a temperature gradient. This Annex specifies the test procedure for brittle crack arrest toughness (i.e. K_{ca}) of steel using fracture mechanics parameter and determination method of K_{ca} at a specific temperature which are specified in ISO 20064:2019. Additionally, this Annex specifies the evaluation method of K_{ca} of test plate. This Annex is applicable to hull structural steels with the thickness over 50 mm and not greater than 100 mm specified in Sec. 4, B. and L.

B. Test Procedure

The test procedures including testing equipment, test specimens, test methods, determination of arrest toughness, reporting of test results, etc. are to be in accordance with ISO 20064: 2019. As a method for initiating a brittle crack, a secondary loading mechanism can be used in accordance with Annex D of ISO 20064: 2019, except that the first sentence in Annex B.2.4 of ISO 20064: 2019 is revised to "Obtain the value $\{K_{ca}/[K_0 * \exp(-c/T_{caK})]\}$ for each data point".

C. Determination of K_{ca} at a Specific Temperature and the Evaluation

1. Method

The method for conducting multiple tests to obtain K_{ca} value at a specific temperature is to be in accordance with Annex B of ISO 20064: 2019.

2. Evaluation

The straight-line approximation of Arrhenius plot for valid Kca data by interpolation method are to comply with either the following 1) or 2):

1) The evaluation temperature of K_{ca} (i.e. - 10 degree C) is located between the upper and lower limits of the arrest temperature, with the K_{ca} corresponding to the evaluation temperature not lower than the required K_{ca} (e.g. 6000 N/mm$^{3/2}$ or 8000 N/mm$^{3/2}$), as shown in Fig. A4.1.

2) The temperature corresponding to the required K_{ca} (e.g. 6000 N/mm$^{3/2}$ or 8000 N/mm$^{3/2}$) is located between the upper and lower limits of the arrest temperature, with the temperature corresponding to the required K_{ca} not higher than the evaluation temperature (i.e. -10 degree C), as shown in Fig. A4.2.

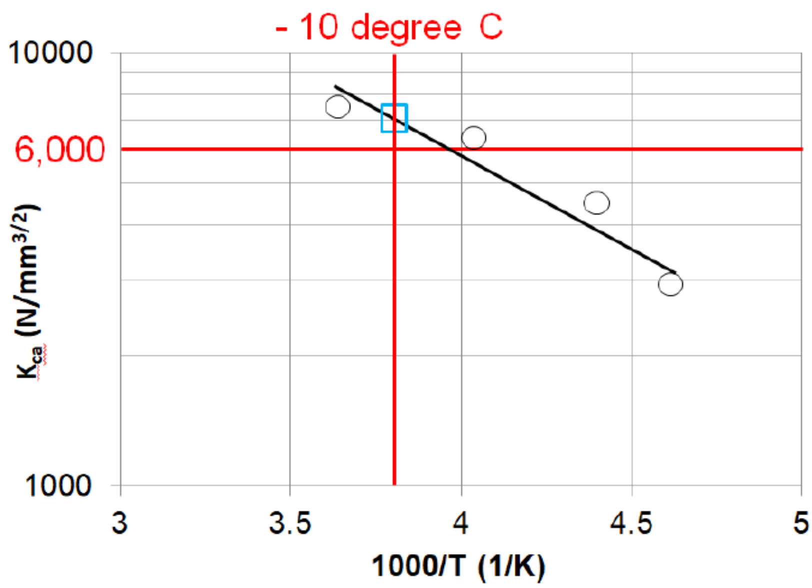


Figure A4.1: Example for evaluation of K_{ca} at - 10 degree C

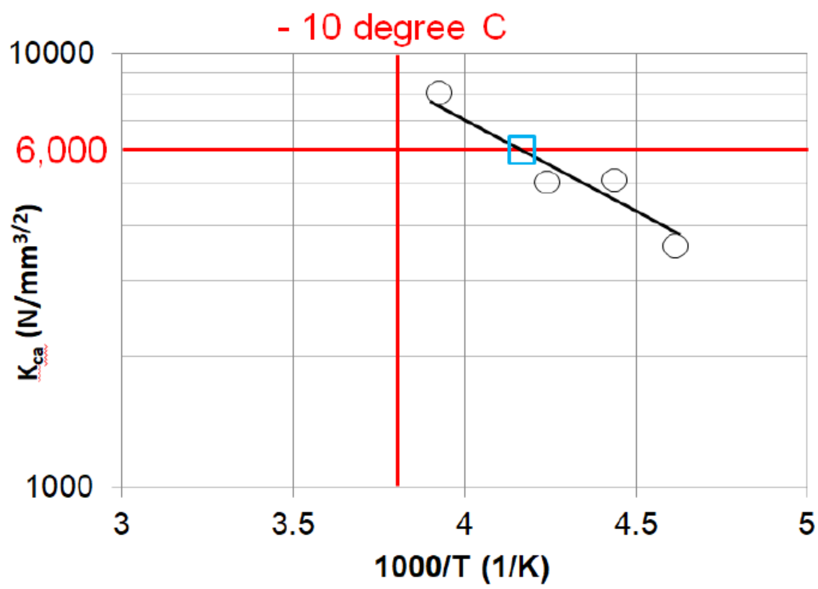


Figure A4.2: Example for evaluation of temperature corresponding to the required K_{ca}

If both of 1) and 2) above are not satisfied, conduct additional tests to satisfy this condition.

Annex 5 Outline of Requirements for Undertaking Iso-thermal Crack Arrest Temperature (CAT) Test

A. Scope of Application

1. This Annex is to be applied according to the scope defined in Section 4, L.

2. This Annex specifies the requirements for test procedures and test conditions when using the isothermal crack arrest test to determine a valid test result under isothermal conditions and in order to establish the crack arrest temperature (CAT). This Annex is applicable to steels with thickness over 50 mm and not greater than 100 mm.

3. This method uses an isothermal temperature in the test specimen being evaluated. Unless otherwise specified in this Annex, the other test parameters are to be in accordance with ISO 20064: 2019.

4. Table 4.28 gives the relevant requirements for the brittle crack arrest property described by the crack arrest temperature (CAT).

5. The manufacturer is to submit the test procedure to BKI for review prior to testing.

B. Symbols and Their Significance

Table A5.1 supplements Table 1 in ISO 20064: 2019 with specific symbols for the isothermal test.

C. Testing Equipment

1. The test equipment to be used is to be of the hydraulic type of sufficient capacity to provide a tensile load equivalent to ⅔ of SMYS of the steel grade to be approved.

2. The temperature control system is to be equipped to maintain the temperature in the specified region of the specimen within $\pm 2^{\circ}$C from T_{target}.

3. Methods for initiating the brittle crack may be of drop weight type, air gun type or double tension tab plate type.

4. The detailed requirements for testing equipment are to be in accordance with ISO 20064: 2019.

Table A5.1: Nomenclature supplementary to Table 1 in ISO 20064: 2019

Symbol	Unit	Significance
t	mm	Test specimen thickness
L	mm	Test specimen length
W	mm	Test specimen width
a_{MN}	mm	Machined notch length on specimen edge
L_{SG}	mm	Side groove length on side surface from the specimen edge. L_{SG} is defined as a groove length with constant depth except a curved section in depth at side groove end.
d_{SG}	mm	Side groove depth in section with constant depth
L_{EB-min}	mm	Minimum length between specimen edge and electron beam re-melting zone front
$L_{EB-s1,-s2}$	mm	Length between specimen edge and electron beam re-melting zone front appeared on both specimen side surfaces
L_{LTG}	mm	Local temperature gradient zone length for brittle crack runway
a_{arrest}	mm	Arrested crack length
T_{target}	°C	Target test temperature
T_{test}	°C	Defined test temperature
T_{arrest}	°C	Target test temperature at which valid brittle crack arrest behaviour is observed
σ	N/mm^2	Applied test stress at cross section of W x t
SMYS	N/mm^2	Specified minimum yield strength of the tested steel grade to be approved
CAT	°C	Crack arrest temperature, the lowest temperature, Tarrest, at which running brittle crack is arrested

D. Test specimens

1. Impact type crack initiation

1.1 Test specimens are to be in accordance with ISO 20064: 2019, unless otherwise specified in this Annex.

1.2 Specimen dimensions are shown in Fig. A5.1. The test specimen width, W shall be 500 mm. The test specimen length, L shall be equal to or greater than 500 mm.

1.3 V-shape notch for brittle crack initiation is machined on the specimen edge of the impact side. The whole machined notch length shall be equal to 29 mm with a tolerance range of $\pm$1 mm.

1.4 Requirements for side grooves are described in 4.

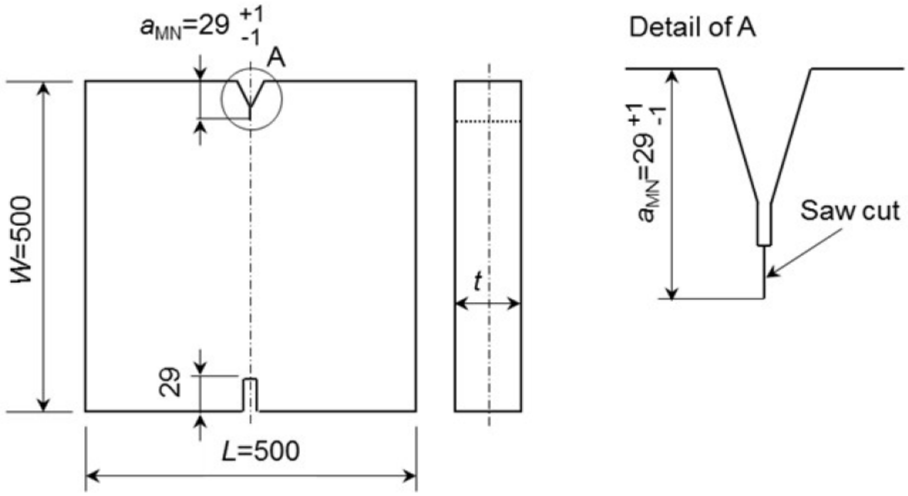


Figure A5.1: Test specimen dimensions for an impact type specimen

Note:

Saw cut notch radius may be machined in the range 0,1 mmR and 1 mmR in order to control a brittle crack initiation at test.

2. Double tension type crack initiation

2.1 Reference shall be made to ISO 20064: 2019 for the shape and sizes in secondary loading tab and secondary loading method for brittle crack initiation.

2.2 In a double tension type test, the secondary loading tab plate may be subject to further cooling to enhance an easy brittle crack initiation.

3. Embrittled zone setting

3.1 An embrittled zone shall be applied to ensure the initiation of a running brittle crack. Either Electron Beam Welding (EBW) or Local Temperature Gradient (LTG) may be adopted to facilitate the embrittled zone.

3.2 In EBW embrittlement, electron beam welding is applied along the expected initial crack propagation path, which is the centre line of the specimen in front of the machined V- notch.

3.3 The complete penetration through the specimen thickness is required along the embrittled zone. One side EBW penetration is preferable, but dual sides EB penetration may be also adopted when the EBW power is not enough to achieve the complete penetration by one side EBW.

3.4 The EBW embrittlement is recommended to be prepared before specimen contour machining.

3.5 In EBW embrittlement, zone shall be of an appropriate quality.

Note:

EBW occasionally behaves in an un-stable manner at start and end points. EBW line is recommended to start from the embrittled zone tip side to the specimen edge with an increasing power control or go/return manner at start point to keep the stable EBW.

3.6 In LTG system, the specified local temperature gradient between machined notch tip and isothermal test region is regulated after isothermal temperature control. LTG temperature control is to be achieved just before brittle crack initiation, nevertheless the steady temperature gradient through the thickness shall be ensured.

4. Side grooves

4.1 Side grooves on side surface can be machined along the embrittled zone to keep brittle crack propagation straight. Side grooves shall be machined in the specified cases as specified in this Section.

4.2 In EBW embrittlement, side grooves are not necessarily mandatory. Use of EBW avoids the shear lips. However, when shear lips are evident on the fractured specimen, e.g. shear lips over 1 mm in thickness in either side then side grooves should be machined to suppress the shear lips.

4.3 In LTG embrittlement, side grooves are mandatory. Side grooves with the same shape and size shall be machined on both side surfaces.

4.4 The length of side groove, L_{SG} shall be no shorter than the sum of the required embrittled zone length.

4.5 When side grooves would be introduced, the side groove depth, the tip radius and the open angle are not regulated, but are adequately selected in order to avoid any shear lips over 1 mm thickness in either side. An example of side groove dimensions are shown in Fig. A5.2.

4.6 Side groove end shall be machined to make a groove depth gradually shallow with a curvature larger than or equal to groove depth, d_{SG}. Side groove length, L_{SG} is defined as a groove length with constant depth except a curved section in depth at side groove end.

5. Nominal length of embrittled zone

5.1 The length of embrittled zone shall be at least 150 mm.

5.2 EBW zone length is regulated by three measurements on the fracture surface after test as shown in Fig. A5.3, L_{EB-min} between specimen edge and EBW front line, and L_{EB-s1} and L_{EB-s2}.

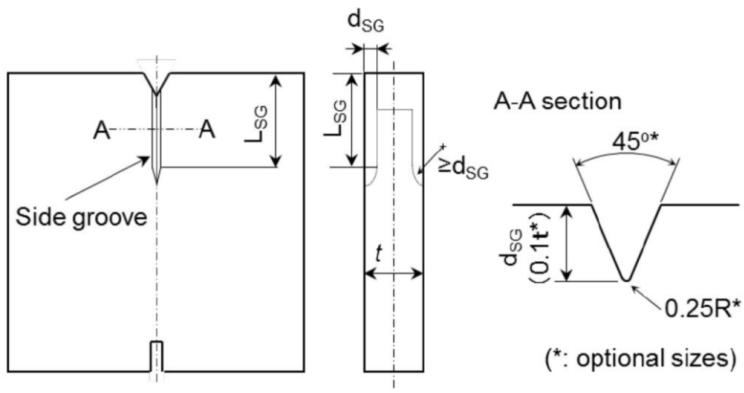


Figure A5.2: Side groove configuration and dimensions

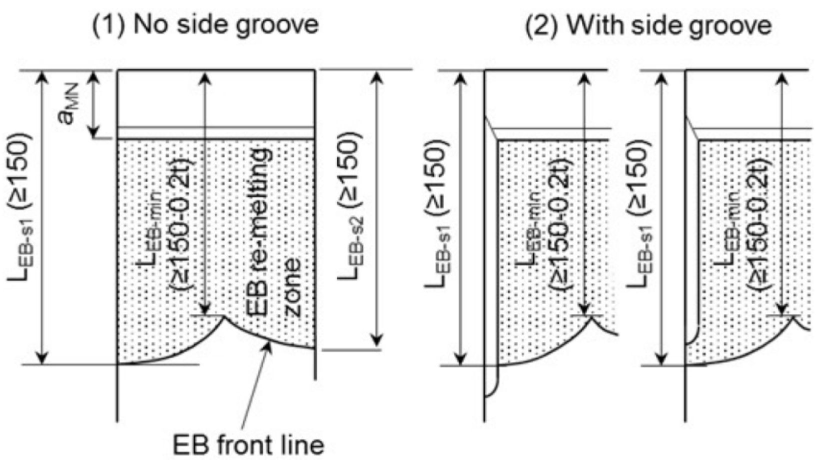


Figure A5.3: Definition of EBW length

5.3 The minimum length between specimen edge and EBW front line, LEB-min should be no smaller than 150 mm. However, it can be acceptable even if L_{EB-min} is no smaller than 150 mm-0,2t, where t is specimen thickness. When L_{EB-min} is smaller than 150 mm, a temperature safety margin shall be considered into T_{test} (see H.1.2).

5.4 Another two are the lengths between specimen edge and EBW front appeared on both side surfaces, as denoted with L_{EB-s1} and L_{EB-s2}. Both of L_{EB-s1} and L_{EB-s2} shall be no smaller than 150 mm.

5.5 In LTG system, L_{LTG} is set as 150 mm.

6. Tab plate / pin chuck details and welding of test specimen to tab plates

6.1 The configuration and size of tab plates and pin chucks shall be referred to ISO 20064: 2019. The welding distortion in the integrated specimen, which is welded with specimen, tab plates and pin chucks, shall be also within the requirement in ISO 20064: 2019.

E. Test method

1. Preloading

Preloading at room temperature can be applied to avoid unexpected brittle crack initiation at test. The applied load value shall be no greater than the test stress. Preloading can be applied at higher temperature than ambient temperature when brittle crack initiation is expected at preloading process. However, the specimen shall not be subjected to temperature higher than 100°C.

2. Temperature measurement and control

2.1 Temperature control plan showing the number and position of thermocouples is to be in accordance with this section.

2.2 Thermocouples are to be attached to both sides of the test specimen at a maximum interval of 50 mm in the whole width and in the longitudinal direction at the test specimen centre position (0,5 W) within the range of ±100 mm from the centreline in the longitudinal direction, refer to Fig. A5.4.

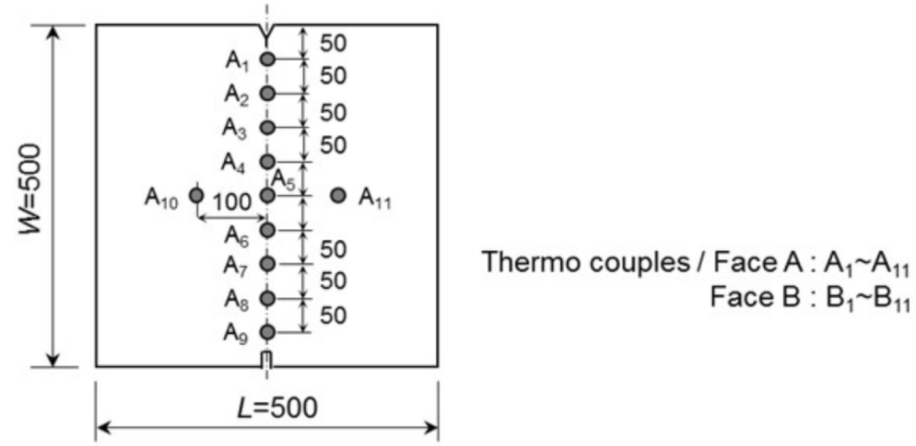


Figure A5.4: Locations of temperature measurement

2.3 For EBW embrittlement

2.3.1 The temperatures of the thermocouples across the range of 0,3W ∼ 0,7W in both width and longitudinal directions are to be controlled within ± 2°C of the target test temperature, T_{target}.

2.3.2 When all measured temperatures across the range of 0,3W ∼ 0,7W have reached Ttarget, steady temperature control shall be kept at least for 10 + 0,1 x t [mm] minutes to ensure a uniform temperature distribution into mid-thickness prior to applying test load.

2.3.3 The machined notch tip can be locally cooled to easily initiate brittle crack. Nevertheless, the local cooling shall not disturb the steady temperature control across the range of 0,3W $\sim$ 0,7W.

2.4 For LTG embrittlement:

2.4.1 In LTG system, in addition to the temperature measurements shown in Fig. A5.4, the additional temperature measurement at the machine notch tip, A_0 and B_0 is required. Thermocouples positions within LTG zone are shown in Fig. A5.5.

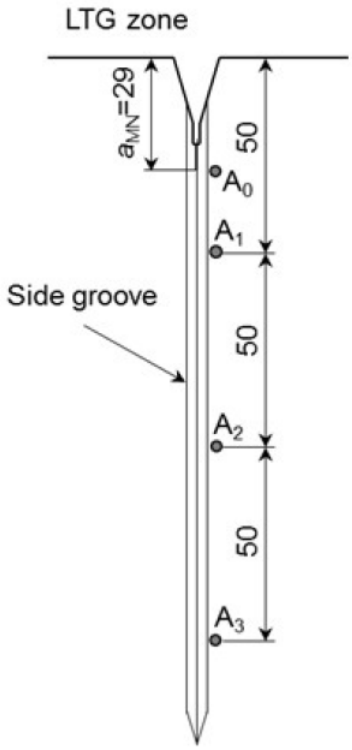


Figure A5.5: Detail of LTG zone and additional thermocouple A_0

2.4.2 The temperatures of the thermocouples across the range of 0,3W $\sim$ 0,7W in both width and longitudinal directions are to be controlled within $\pm$ 2°C of the target test temperature, T_{target}. However, the temperature measurement at 0,3W (location of A3 and B3) shall be in accordance with 2.4.6 below.

2.4.3 Once the all measured temperatures across the range of 0,3W $\sim$ 0,7W have reached T_{target}, steady temperature control shall be kept at least for 10 + 0,1 x t [mm] minutes to ensure a uniform temperature distribution into mid-thickness, then the test load is applied.

2.4.4 LTG is controlled by local cooling around the machined notch tip. LTG profile shall be recorded by the temperature measurements from A_0 to A_3 shown in Fig. A5.6.

2.4.5 LTG zone is established by temperature gradients in three zones, Zone I, Zone II and Zone III. The acceptable range for each temperature gradient is listed Table A5.2.

2.4.6 Temperature measurements at A_2, B_2 and A_3, B_3 shall be satisfied the following requirements:

T at A_3, T at B_3 < $T_{target} - 2°C$

T at A_2 < T at $A_3 - 5°C$

T at B_2 < T at $B_3 - 5°C$

2.4.7 No requirements for T at A_0 and T at A_1 temperatures when T at A_3 and T at A_2 satisfy the requirements above. Face B is the same.

2.4.8 The temperatures from A_0, B_0 to A_3, B_3 should be decided at test planning stage refer to Table A5.2 which gives the recommended temperature gradients in three zones, Zone I, Zone II and Zone III in LTG zone.

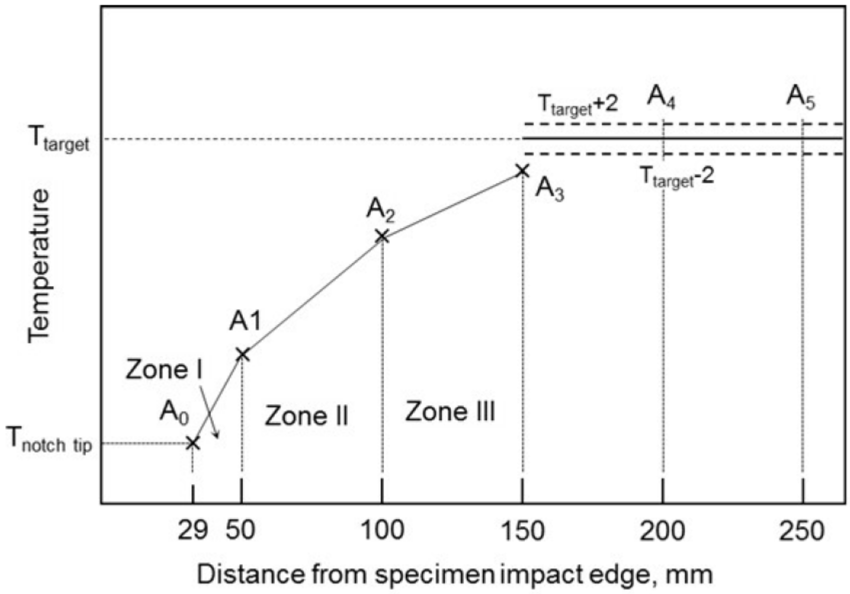


Figure A5.6: Schematic temperature gradient profile in LTG zone

Table A5.2: Acceptable LTG range

Zone	Location from edge	Acceptable range of temperature gradient
Zone I	29 mm – 50 mm	2,00 °C/mm – 2,30 °C/mm
Zone II	50 mm – 100 mm	0,25 °C/mm – 0,60 °C/mm
Zone III 1)	100 mm – 150 mm	0,10 °C/mm – 0,20 °C/mm

Note 1: The Zone III arrangement is mandatory

2.4.9 The temperature profile in LTG zone mentioned above shall be ensured after holding time at least for 10 + 0,1 x t [mm] minutes to ensure a uniform temperature distribution into mid-thickness before brittle crack initiation.

2.4.10 The acceptance of LTG in the test shall be decided from Table A5.2 based on the measured temperatures from A_0 to A_3.

2.5 For double tension type crack initiation specimen:

2.5.1 Temperature control and holding time at steady state shall be the same as the case of EBW embrittlement specified in 2.3 or the case of LTG embrittlement specified in 2.4.

3. Loading and brittle crack initiation

3.1 Prior to testing, a target test temperature (T_{target}) shall be selected.

3.2 Test procedures are to be in accordance with ISO 20064: 2019 except that the applied stress is to be $\frac{2}{3}$ of SMYS of the steel grade tested.

3.3 The test load shall be held at the test target load or higher for a minimum of 30 seconds prior to crack initiation.

3.4 Brittle crack can be initiated by impact or secondary tab plate tension after all of the temperature measurements and the applied force are recorded.

F. Measurements after Test and Test Validation Judgement

1. Brittle crack initiation and validation

1.1 If brittle crack spontaneously initiates before the test force is achieved or the specified hold time at the test force is not achieved, the test shall be invalid.

1.2 If brittle crack spontaneously initiates without impact or secondary tab tension but after the specified time at the test force is achieved, the test is considered as a valid initiation. The following validation judgments of crack path and fracture appearance shall be examined.

2. Crack path examination and validation

2.1 When brittle crack path in embrittled zone deviates from EBW line or side groove in LTG system due to crack deflection and/or crack branching, the test shall be considered as invalid.

2.2 All of the crack path from embrittled zone end shall be within the range shown in Fig. A5.7. If not, the test shall be considered as invalid.

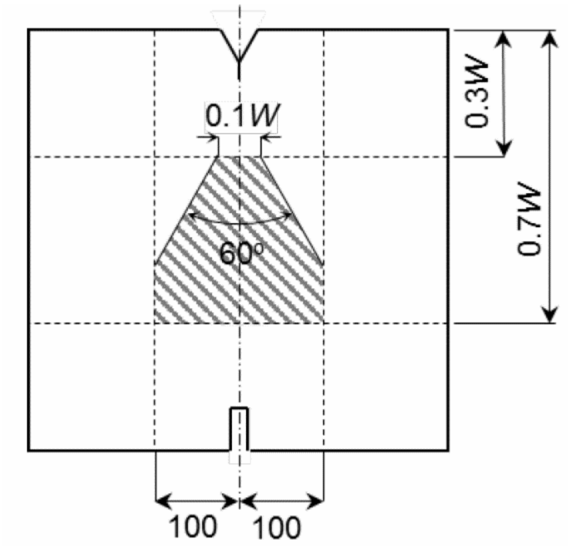


Figure A5.7: Allowable range of main crack propagation path

3. Fracture surface examination, crack length measurement and their validation

3.1 Fracture surface shall be observed and examined. The crack “initiation” and “propagation” are to be checked for validity and judgements recorded. The crack “arrest” positions are to be measured and recorded.

3.2 When crack initiation trigger point is clearly detected at side groove root, other than the V-notch tip, the test shall be invalid.

3.3 In EBW embrittlement setting, EBW zone length is quantified by three measurements of L_{EB-s1}, L_{EB-s2} and L_{EB-min}, which are defined in D.5. When either or both of L_{EB-s1} and L_{EB-s2} are smaller than 150 mm, the test shall be invalid. When L_{EB-min} is smaller than 150 mm - 0,2t, the test shall be invalid.

3.4 When the shear lip with thickness over 1 mm in either side near side surfaces of embrittled zone are visibly observed independent of the specimens with or without side grooves, the test shall be invalid.

3.5 In EBW embrittlement setting, the penetration of brittle crack beyond the EBW front line shall be visually examined. When any brittle fracture appearance area continued from the EB front line is not detected, the test shall be invalid.

3.6 The weld defects in EBW embrittled zone shall be visually examined. If detected, it shall be quantified. A projecting length of defect on the thickness line through EB weld region along brittle crack path shall be measured, and the total occupation ratio of the projected defect part to the total thickness is defined as defect line fraction (See Fig. A5.8). When the defects line fraction is larger than 10%, the test shall be invalid.

3.7 In EBW embrittlement by dual sides' penetration, a gap on embrittled zone fracture surface which is induced by miss meeting of dual fusion lines is visibly detected at an overlapped line of dual side penetration, the test shall be invalid.

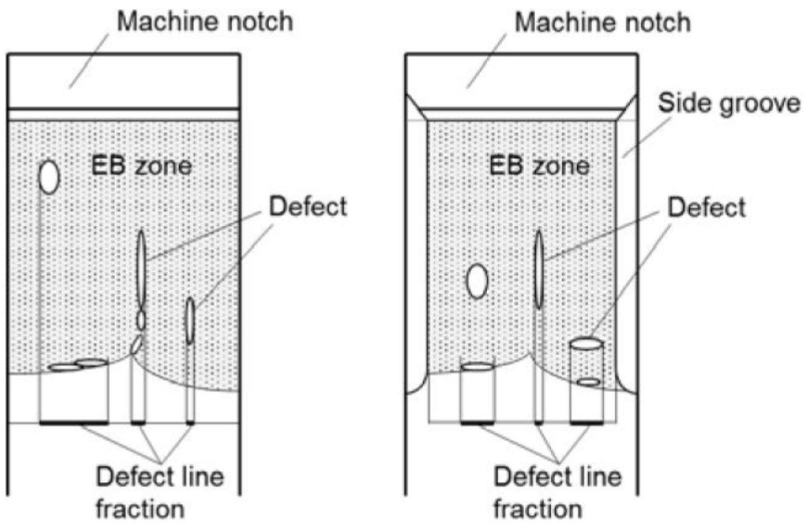


Figure A5.8: Counting procedure of defect line fraction

G. Judgement of "arrest" or "propagate"

1. The final test judgment of "arrest", "propagate" or "invalid" is decided by the following requirements of 2 through 6.

2. If initiated brittle crack is arrested and the tested specimen is not broken into two pieces, the fracture surfaces should be exposed with the procedures specified in ISO 20064: 2019.

3. When the specimen was not broken into two pieces during testing, the arrested crack length, aarrest shall be measured on the fractured surfaces. The length from the specimen edge of impact side to the arrested crack tip (the longest position) is defined as a_{arrest}.

4. For LTG and EBW, a_{arrest} shall be greater than L_{LTG} and L_{EB-s1}, L_{EB-s2} or L_{EB-min}. If not, the test shall be considered as invalid.

5. Even when the specimen was broken into two pieces during testing, it can be considered as "arrest" when brittle crack re-initiation is clearly evident. Even in the fracture surface all occupied by brittle fracture, when a part of brittle crack surface from embrittled zone is continuously surrounded by thin ductile tear line, the test can be judged as re-initiation behaviour. If so, the maximum crack length of the part surrounded tear line can be measured as a_{arrest}. If re-initiation is not visibly evident, the test is judged as "propagate".

6. The test is judged as "arrest" when the value of a_{arrest} is no greater than 0,7W. If not, the test is judged as "propagate".

H. T_{test}, T_{arrest} and CAT Determination

1. T_{test} determination

1.1 It shall be ensured on the thermocouple measured record that all temperature measurements across the range of 0,3W ~ 0,7W in both width and longitudinal direction are in the range of $T_{target} \pm 2°C$ at brittle crack initiation. If not, the test shall be invalid. However, the temperature measurement at 0,3W (location of A_3 and B_3) in LTG system shall be exempted from this requirement.

1.2 If L_{EB-min} in EBW embrittlement is no smaller than 150 mm, T_{test} can be defined to equal with T_{target}. If not, T_{test} shall be equalled with T_{target} + 5°C.

1.3 In LTG embrittlement, T_{test} can be equalled with T_{target}.

1.4 The final arrest judgment at T_{test} is concluded by at least two tests at the same test condition which are judged as “arrest”.

2. T_{arrest} determination

When at least repeated two “arrest” tests appear at the same T_{target}, brittle crack arrest behaviour at T_{target} will be decided (T_{arrest} = T_{target}). When a “propagate” test result is included in the multiple test results at the same T_{target}, the T_{target} cannot to be decided as T_{arrest}.

3. CAT determination

3.1 When CAT is determined, one “propagate” test is needed in addition to two “arrest” tests. The target test temperature, T_{target} for “propagate” test is recommended to select 5°C lower than T_{arrest}. The minimum temperature of T_{arrest} is determined as CAT.

3.2 With only the “arrest” tests, without “propagation” test, it is decided only that CAT is lower than T_{test} in the two “arrest” tests, i.e. not deterministic CAT.

I. Reporting

The following items are to be reported:

1) Test material: grade and thickness
2) Test machine capacity
3) Test specimen dimensions: thickness t; width W and length L; notch details and length a_{MN}, side groove details if machined;
4) Embrittled zone type: EBW or LTG embrittlement
5) Integrated specimen dimensions: Tab plate thickness, tab plate width, integrated specimen unit length including the tab plates, and distance between the loading pins, angular distortion and linear misalignment
6) Brittle crack trigger information: impact type or double tension. If impact type, drop weight type or air gun type, and applied impact energy.
7) Test conditions; applied load; preload stress, test stress
   - Judgements for preload stress limit, hold time requirement under steady test stress.
8) Test temperature: complete temperature records with thermocouple positions for measured temperatures (figure and/or table) and target test temperature.
   - Judgements for temperature scatter limit in isothermal region.
   - Judgement for local temperature gradient requirements and holding time requirement after steady local temperature gradient before brittle crack trigger, if LTG system is used.
9) Crack path and fracture surface: tested specimen photos showing fracture surfaces on both sides and crack path side view; Mark at “embrittled zone tip” and “arrest” positions.

- Judgment for crack path requirement.
- Judgment for cleavage trigger location (whether side groove edge or V-notch edge).

10) Embrittled zone information:

When EBW is used: L_{EB-s1}, L_{EB-s2} and L_{EB-min}

- Judgement for shear lip thickness requirement
- Judgment whether brittle fracture appearance area continues from the EBW front line
- Judgement for EBW defects requirement
- Judgement for EBW lengths, L_{EB-s1}, L_{EB-s2} and L_{EB-min} requirements

When LTG is used: LLTG

- Judgment for shear lip thickness requirement

Test results:

When the specimen did not break into two pieces after brittle crack trigger, arrested crack length a_{arrest}

When the specimen broke into two pieces after brittle crack trigger,

- Judgement whether brittle crack re-initiation or not.

If so, arrested crack length a_{arrest}:

- Judgement for a_{arrest} in the valid range ($0,3W < a_{arrest} \leq 0,7W$)
- Final judgement either “arrest”, “propagate” or “invalid”

11) Dynamic measurement results: History of crack propagation velocity, and strain change at pin chucks, if needed.

J. Use of test for material qualification testing

Where required, the method can also be used for determining the lowest temperature at which a steel can arrest a running brittle crack (the determined CAT) as the material property characteristic in accordance with H.3.

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