TÜRK LOYDU

Chapter 2 – Material

JULY 2015

This latest edition incorporates all rule changes. The latest revisions are shown with a vertical line. The section title is framed if the section is revised completely. Changes after the publication of the rule are written in red colour.

Unless otherwise specified, these Rules apply to ships for which the date of contract for construction as defined in IACS PR No.29 is on or after 1st of July 2015. New rules or amendments entering into force after the date of contract for construction are to be applied if required by those rules. See Rule Change Notices on TL website for details.

"General Terms and Conditions" of the respective latest edition will be applicable (see Rules for Classification and Surveys).

If there is a difference between the rules in English and in Turkish, the rule in English is to be considered as valid. This publication is available in print and electronic pdf version.

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Material

SECTION 1

MANUFACTURE, TESTING AND CERTIFICATION

A. General

1. Scope

1.1 This section specifies the requirements for the manufacture, testing and certification of materials and products used for the construction, repair and equipping of vessels classed or intended to be classed by **TL**.

1.2 The scope of these Rules includes all those materials and products whose use is referred to in the Rules for Construction. **TL** reserve the right to extend the scope of these Rules to materials and products not specifically mentioned in the Rules for Construction.

1.3 Materials, test specimens and mechanical testing procedures having characteristics differing from those prescribed herein may be approved upon application, due regard being paid to established practices in the country in which the material is produced.

2. Other Relevant Specifications

2.1 Materials and products complying with international, national and proprietary specifications may be accepted by **TL** provided such specifications give reasonable equivalence to the requirements of these rules or are otherwise specially approved.

2.2 Unless otherwise agreed**,** inspection and certification of materials and products complying with other specifications are to be carried out in accordance with the requirements of these rules and other relevant rules.

2.3 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.

3. Information to be Supplied by the Purchaser

The purchaser is to supply the manufacturer with all information necessary to ensure that materials and products are tested in accordance with these rules and other relevant rules. Optional or additional conditions are also to be indicated.

B. Manufacturer Approval

1. All materials and products for hull construction and equipment are to be manufactured at works approved by **TL.** (See Section 3 Appendixes A, A1, A2 and B (Reference IACS UR W 11.Appendixes A, A1, A2 and B)

C. Manufacture and Material Quality

1. Manufacture

1.1 All materials are to 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 **TL**. According to the decision of **TL**, 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

2.1 The chemical composition of samples taken from each ladle of each cast is to be determined by the manufacturer in sufficiently equipped laboratory and is to satisfy the requirements relating to chemical composition and properties specified in these Rules.

2.2 The chemical analysis declared by the manufacturer is to be accepted subject to occasional checks if required by the surveyor.

3. Condition of Supply

3.1 Unless otherwise agreed, all materials and products are to be supplied in the finished condition according to these rules, including heat treatment if required.

3.2 Heat treatment is to be carried out in suitable and efficient furnaces, equipped with appropriate means for control and recording of temperature. The manufacturer is to maintain records of heat treatment identifying the furnace used, furnace charge, date and temperature. The records are to be presented to the surveyor on request.

3.3 The furnace dimensions are to be such as to allow the material to be uniformly heated to the specified temperature.

3.4 In the case of very large parts, alternative methods for heat treatment are to be specially considered.

4. Defects

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

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

4.3 Repair of defects by welding is only to be carried out when permitted by the appropriate specific requirements. Proposal to repair a defective material by welding is to be submitted to the surveyor for approval before repair work is commenced.

5. Weldability

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

D. Inspection and Testing

1. General

1.1 As far as practicable, the inspections and tests are to be carried out at the manufacturer's works before delivery.

1.2 If the necessary facilities are not available at the manufacturer's works, the testing is to be carried out at a recognised testing laboratory.

1.3 Interested parties are to apply for inspection in adequate time.

Prior to inspection and testing, the manufacturer is to provide the surveyor with details of the orders, technical specs and any special condition additional to the rule requirements.

1.4 The surveyor is to be given the opportunity to inspect and check at any time all plants and equipment used in the manufacture and testing.

The surveyor is to be supplied with the information necessary to assess whether production and tests are performed according to the rule requirements.

1.5 All tests and inspections required by the rules are to be carried out in the presence of the surveyors, or when expressly agreed with **TL,** in the presence of the person responsible for internal control.

1.6 The tests required are to be performed by qualified personnel in accordance with the procedures stated by **TL**.

The testing and measuring equipment is to be adequate, maintained in proper condition and regularly calibrated. The records of calibration is to be kept up to date and made available to the surveyor.

2. Test Material

2.1 For the purpose of test sampling the following definitions apply:

2.1.1 ***Unit,*** single plate, pipe, forging, casting or other single product.

2.1.2 ***Batch,*** number of similar units presented as a group for acceptance testing, on the basis of the tests to be carried out on the test sample.

2.1.3 ***Test Sample****,* a sufficient quantity of material taken from the sample product for the purpose of producing one or more test specimen. (See Figure 1.1)

2.1.4 ***Test specimen****,* part of sample with specified dimensions and conditions for submission to a given test. (See Figure 1.1)

2.2 Test material sufficient for the required tests and also for possible retests purposes is to be provided.

2.3 The test material is to be representative of the unit or sample product and is not to be seperated until all the specified heat treatment has been completed.

2.4 Where **TL**'s certification is required, all the test samples are to be selected and marked by the surveyor, unless otherwise agreed.

3. Mechanical Tests

3.1 The mechanical tests are to be carried out in the presence of the surveyor, unless otherwise agreed.

3.2 For checking of the mechanical properties of the material, test methods and specimens in compliance with the requirements of Section 2 are to be used.

3.3 The type of tests, the number and direction of the test specimens and the results of tests are to comply with the requirements relevant to the type of material or product.

4. Retesting

4.1 When the result of any test, other than impact test, fails to meet the requirements, two further tests may be made from the same sample. If both of these additional tests are satisfactory, the unit may be accepted.

4.2 When the results from a set of three impact test specimens fail to the requirements, three additional test specimens from the same sample may be tested and the results added to those previously obtained to form a new average. If this new average complies with the requirements and if not more than two individual results are lower than the required average and, of these, not more than one result is below 70% of the specified average value, the unit may be accepted.

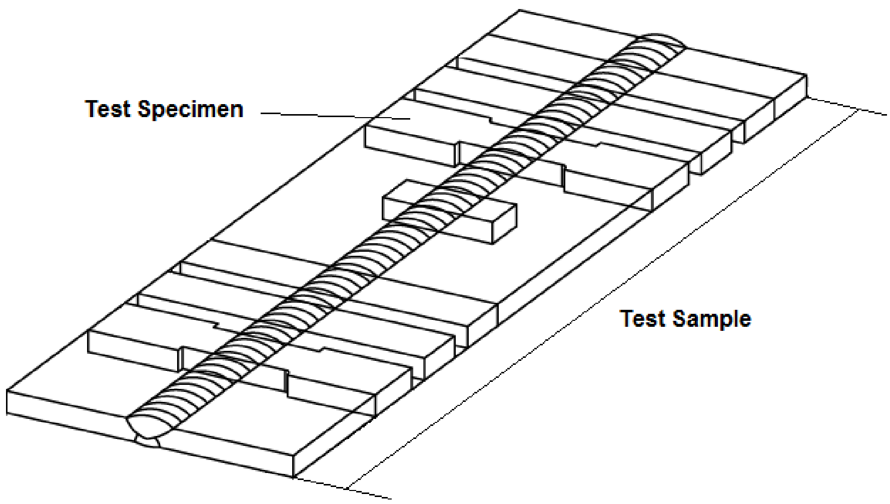


Figure 1.1 Test sample and test specimen to be taken for a welding test

4.3 If unsatisfactory results are obtained from retests representative of a batch, the unit from which the tests were made is to be rejected. The remaining material in the batch may be accepted provided that two further units are tested with satisfactory result.

4.4 When a batch is rejected, the remaining units in the batch may be resubmitted individually for test, and those which give satisfactory results may be accepted.

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

5. Visual and Non-Destructive Examinations

5.1 General

The materials and products are to be subjected to visual examination, dimensional check and, when applicable, non-destructive examination.

The above mentioned examinations are to be carried out on materials and products in appropriate conditions under the responsibility of the manufacturer and are to be witnessed by the surveyor, when require by the rules.

5.2 Visual examination

Unless otherwise specified, visual examination is performed by the surveyor on each unit, for products tested on individual units and randomly, for products tested by lot.

5.3 Verification of compliance with approved plans

Verification of compliance with approved plans is the responsibility of the manufacturer.

Some checks are to be made in presence of the surveyor, as deemed necessary or where expressly required in these rules.

5.4 Non-destructive examination

Non-destructive examination is to be performed by skilled and qualified personnel, using calibrated equipment according to approved procedures, recognized standards and requirements of **TL.**

The manufacturer or other organization responsible for non-destructive examination is required to issue a certificate indicating the results.

The various steps of non-destructive examinations are to be witnessed by the surveyor, when required.

E. Identification and Marking

1. Identification of Materials and Products

The manufacturer is to introduce a system of identification which enables all finished material and product to be traced to the original cast. The surveyor is to be given full facilities for tracing the materials when required.

2. Marking

2.1 Before acceptance, all materials and products which have been tested and inspected with satisfactory results are to be clearly marked 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 is normally to 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.

All marks are to 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 is to apply these to a different spot and shall arrange for the transfer of the **TL** stamp, unless another solution is adopted.

2.4 As a general rule, every product is to 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 TL Stamps

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

3.2 Products which have been tested in accordance with these Rules are to be marked with **TL** cold stamp, provided that all requirements of the **TL** Rules have been satisfied.

As an exception, shipbuilding steels of grades E and F which are subject to individual testing as well as the non-alloy pipes R 360, R 410 and R 490 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 "**TL**" may be either cast or stamped in.

3.4 Products which have to be tested in accordance with other specifications or supply conditions, i.e. which shall not be used within the scope of Classification, are to be marked, irrespective of the extent of the tests prescribed, with the special stamp in the presence of the surveyor, provided that, when tested, the products have met the requirements stipulated in the specifications or supply conditions:

3.5 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, the **TL** stamping shall be cancelled in a suitable manner.

4. Stamping of Specimens by the Works

Manufacturers of materials who have an independent quality control department may, with the consent of **TL** surveyor, allow members of this department to apply the specimen stamp. The surveyor is to be notified of the names of the persons authorized for stamping and of the marks identifying their personal stamps.

F. Documentation and Certification

1. TL Certificate

For materials or products tested with satisfactory results, **TL** issues a certificate stating that the materials or products have been tested in accordance with **TL** Rules.

A certificate issued by the manufacturer is to be attached to **TL**’s certificate and is to include, as applicable, manufacturer’s name, purchaser’s name, order and hull number, description of product, dimensions and weight, results of inspection and tests, identification and testing marks stamped on the materials or products.

1.1 Material certificate according to TL Rules

Materials and products intended for use within the scope of classification have to be delivered with a material certificate according to **TL** Rules.

To obtain this material certificate the **TL** Rules relevant for the material/product are to be satisfied. The manufacturer is to be approved by **TL** for the material/product.

1.2 Material certificate according to other rules

For materials and products which are not to be tested according to **TL** Rules but to other rules a material certificate may be issued. In this case **TL** will carry out an acceptance test on behalf of the orderer as neutral third party.

The rules which are to be met for the acceptance test have to be named in the material certificate, whereat here the **TL** Rules shall not be named. If the test requirements are fulfilled a material certificate will be issued.

Materials and products with this certificate shall not be used within the scope of Classification.

2. Works' Certificates

Where, in accordance with the Rules or special agreements, the task of material testing is left to the manufacturer, the latter is to issue a relevant certificate.

2.1 Test report of the manufacturer

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 (e.g.2.2 according to EN 10204). The manufacturer is to be approved for the material/product.

The test report is to specify the following:

- 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,
- Manufacturing process,
- Heat numbers and chemical composition,
- Condition of supply,
- Details of heat treatment, where necessary,
- Marking,
- Results of non-specific material testing of current production.

2.2 Manufacturer's inspection 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.

The inspection certificate is to specify the following:

- 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,
- 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

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 **TL** (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 **TL** Rules.

SECTION 2

MECHANICAL AND TECHNOLOGICAL TESTING PROCEDURES

A. General

1. Scope

1.1 This section gives the requirements for testing machines, testing procedures and test specimens when testing ferrous and non-ferrous metals.

1.2 Alternative test specimens, such as those complying with recognized national standards, may be accepted subject to special approval by **TL**. The same applies to the given testing procedures.

2. Preparation of Test Specimens

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

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

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

2.4 Any of the test specimens referred to as 'alternative' may be used except as otherwise stated or agreed.

3. Testing Machines

3.1 All tests are to be carried out by competent personnel.

3.2 Testing machines are to be maintained in a satisfactory and accurate condition and are to be recalibrated at approximately annual intervals. This calibration is to be traced to a nationally recognized authority and is to be to the satisfaction of **TL**. The calibration records are to be made available to the surveyor.

3.3 Tensile/compression testing machines are to be calibrated in accordance with ISO 7500-1 or other recognized standard.

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

3.5 The accuracy of tensile test machines is to be within minus or plus one per cent.

B. Tensile Tests

1. Tensile Test Specimens

1.1 Designations

The following designations are used (see Figure 2.1 and 2.2):

d_0 = Diameter of round specimen

a = Thickness of flat specimen

b = Width of flat specimen

L_0 = Original gauge length

L_c = Parallel length

S_0 = Original cross sectional area

r = Transition radius

D = External tube diameter

t = Plate thickness

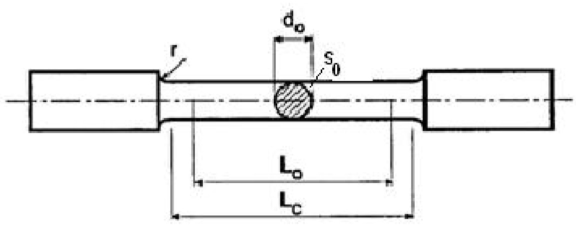


Figure 2.1 Round specimen

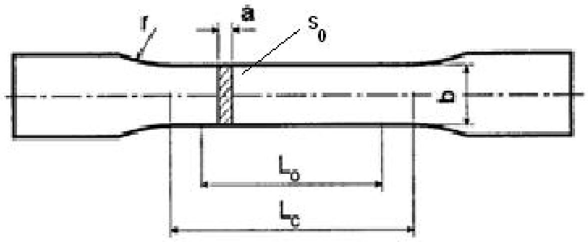


Figure 2.2 Flat specimen

1.2 Dimensions

1.2.1 General

Proportional test specimens with a gauge length

$L_o = 5.65\sqrt{S_o}$

or $L_0 = 5\ d_0$ should preferably be used as the minimum percentage elongation values specified in the following sections refer to this gauge length, L_0 should preferably be greater than 20 mm. The gauge length may be rounded off to the nearest 5 mm provided that the difference between this length and L_o is less than 10% of L_0.

1.2.2 Plates, strips and sections

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

1.2.2.1 Proportional flat specimen

a = t

b = 25 mm

$L_o = 5.65\sqrt{S_o}$

$L_c = L_o + 2\sqrt{S_o}$

r = 25 mm

1.2.2.2 Non-proportional flat specimen

a = t

b = 25 mm

L_0 = 200 mm

$L_C \geq$ 212.5 mm

r = 25 mm

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

1.2.2.3 Round specimen

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

$d_0 \geq$ 10 mm to 20 mm, preferably 14 mm

$L_0 = 5\ d_0$

$L_c \geq L_0 + d/2$

r = 10 mm (for nodular cast iron and materials with a specified elongation less than 10 %, $r \geq 1.5\ d_0$).

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

1.2.3 Aluminium alloys

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

1.2.4 Forgings, castings (excluding grey cast iron)

Proportional round test specimens with dimensions as specified in 1.2.2.3 are usually to be used.

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

1.2.5 Tubes

The test specimen is to conform the following:

1.2.5.1 Full cross-section specimen with plugged ends (see Figure 2.3):

$$L_o = 5.65\sqrt{S_o}$$

$$L_c \geq 5.65\sqrt{S_o} + D/2$$

where L_c is the distance between the grips or the plugs, whichever is the smallest.

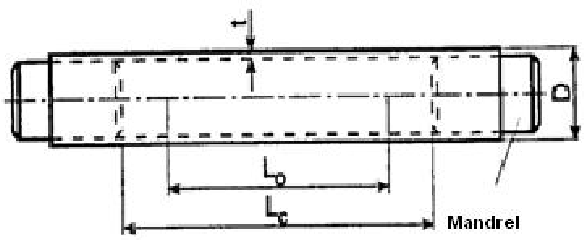


Figure 2.3 Full cross-section specimen

1.2.5.2 Strips cut longitudinally (see Figure 2.4):

a = t

b ≥ 12 mm

$$L_o = 5.65\sqrt{S_o}$$

$L_C = L_0 + 2b$

The parallel test length is not to be flattened, but the enlarged ends may be flattened for gripping in the testing machine.

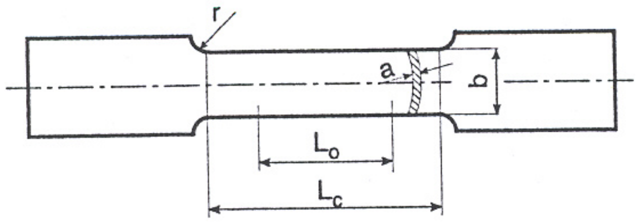


Figure 2.4 Specimen taken from the tube wall

Round test specimens may also be used provided that the wall thickness is sufficient to allow the machining of such specimens to the dimensions given in 1.2.2.3, with their axes located at the mid-wall thickness.

1.2.6 Wires

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

L_0 = 200 mm.

$L_C = L_0$ + 50 mm

1.2.7 Grey cast iron

Round non-cylindrical machined test specimen is to be used (see Figure 2.5):

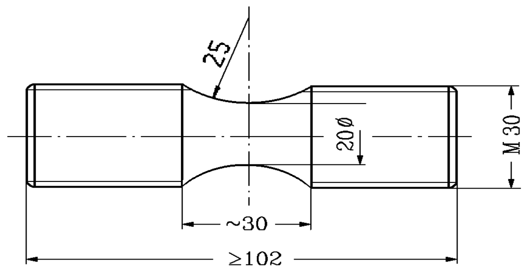


Figure 2.5 Test specimen for grey cast iron

1.2.8 Weldings

1.2.8.1 Deposited metal tensile test

Round specimen with the following dimensions is to be used:

d_0 = 10 mm

L_0 = 50 mm

$L_C \geq$ 55 mm

r $\geq$ 10 mm

For specially small or large dimensions other specimens may be used after agreement with **TL**, provided them to conform the geometrical relationship given in 1.2.2.3.

1.2.8.2 Butt weld tensile test

Flat specimen, the weld to be machined (or ground) flush with the surface of the plate, with the following dimensions is to be used (see Figure 2.6):

a = t

b = 12 mm for t $\leq$ 2 mm

b = 25 mm for t > 2 mm

L_C = width of weld + 60 mm

R $\geq$ 25 mm

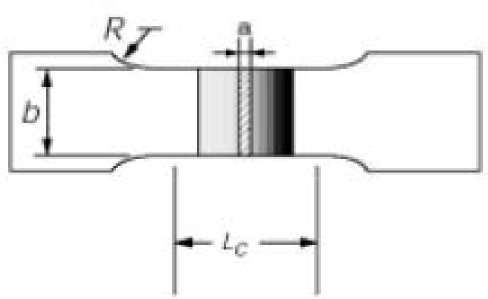


Figure 2.6 Specimen for tensile test on butt weld

1.2.9 Through thickness tensile test specimen

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

1.2.10 Tolerances

The tolerances on specimen dimensions are to be in accordance with ISO 6892-1 or other recognized standards as appropriate.

2. Tensile Properties at Ambient Temperature

2.1 Yield stress (yield point)

The value of stress measured at the commencement of plastic deformation at yield, or the value of stress measured at the first peak obtained during yielding even when that peak is equal to or less than any subsequent peaks observed during plastic deformation at yield.
The test is to be carried out with an elastic stress within the limits shown in Table 2.1.

Table 2.1 Stress rate within elastic range

Modulus of elasticity of the material (E) [N/mm^2]	Rate of stressing [N/mm^2 s^{-1}]	
	Min.	**Max.**
< 150 000	2	20
≥ 150 000	6	60

2.2 Proof stress (yield strength)

When no well defined yield phenomenon exists, the 0.2% proof stress ($R_{p0.2}$) is to be determined according to the applicable specification. For austenitic and duplex stainless steel products, the 1 % proof stress ($R_{p1.0}$) may be determined in addition to $R_{p0.2}$.

The rate of loading is to be as stated in 2.1 above.

2.3 Tensile strength (R_m)

After reaching the yield or proof load, for ductile material the machine speed during the tensile test is not to exceed that corresponding to a strain rate of 0.008s^{-1}.

For brittle materials, such as cast iron, the elastic stress rate is not to exceed 10 N/mm^2 per second.

2.4 Fracture elongation (A)

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

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

If the material is a ferritic steel of low or medium strength and not cold worked and the elongation as measured on a non-proportional gauge length, the required elongation A_0 on that gauge length L_0 may after agreement be calculated from the following formula:

$$A_0 = 2 \cdot A_5 \cdot \left(\frac{\sqrt{S_0}}{L_0} \right)^{2/5}$$

For tables and graphs see ISO 2566.

3. Tensile Retest Procedure

When the tensile test fails to meet the requirements, two further tests may be made from the same piece. If both of these additional tests are satisfactory the item and/or batch (as applicable) is acceptable. If one or both of these tests fail, the item and/or batch is to be rejected.
The additional tests detailed above are to be taken, preferably from material taken adjacent to the original tests, but alternatively from another test position or sample representative of the item/batch.

C. Bend Tests

1. Bend Test Specimen

1.1 Flat bend test specimen, as given in Figure 2.7 is to be used. Edges on tension side to be rounded to a radius of 1 to 2 mm.

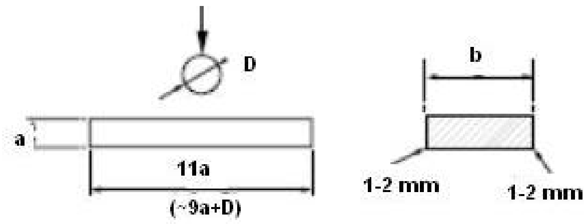


Figure 2.7 Flat bend test specimen

1.2 Forgings, castings and semi-finished products

a = 20 mm

b = 25 mm

1.3 Plates, structural sections, sheets

a = t

b = 30 mm

1.4 Butt welds, transverse specimen

1.4.1 Face and root bend

a = t

b = 30 mm

If the as rolled thickness t is greater than 25 mm, it may be reduced to 25 mm by machining on the compression side of the bend specimen.

The surfaces of the weld are to be machined (ground) flush with the surface of the plate.

1.4.2 Side bend

a = 10 mm

b = t

If t ≥ 40 mm, the side bend specimen may be subdivided, each part being at least 20 mm wide.

1.5 Butt welds, longitudinal specimen

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

2. Bend Test Procedure

2.1 The bend test is to be performed by applying a continuous mechanical compressive action on one of the surfaces of the test specimen.

2.2 The required mandrel diameter and the minimum bend angle are specified in the applicable recognized standards.

D. Toughness Tests

1. Charpy V-Notch Impact Test

1.1 Sampling

1.1.1 The charpy V-notch impact test is performed on a set of 3 test specimens.

The longitudinal axis of the test specimens can be:

- Parallel to the rolling direction of the plate, section or piece
- Perpendicular to the rolling direction of the plate, section or piece
- Parallel to other directions.

1.1.2 The axis of the V-notch is to be perpendicular to the faces of the plate, section or piece.

The position of the V-notch is not to be nearer than 25 mm to a flame cut or sheared edge.

1.1.3 For rolled products with thickness less than or equal to 40 mm, the test specimen are to be taken retaining the original raw surface of the product or within 2 mm from it.

For rolled products with thickness higher than 40 mm, the test specimens are to be taken with their longitudinal axis located at ¼ of the product thickness from one of the rolled surface, or as close as possible to such position.

1.2 Charpy V-notch impact test specimens

1.2.1 The test specimens are to comply with the requirements shown in Table 2.2 (see Figure 2.8):

Table 2.2 Charpy V-notch test specimen

Dimensions	Nominal	Tolerance
Length	55 mm	± 0.60 mm
Width - standard test specimen - sub size test specimen - sub size test specimen	 10 mm 7.5 mm 5.0 mm	 ± 0.11 mm ± 0.11 mm ± 0.06 mm
Thickness	10 mm	± 0.06 mm
Depth below notch	8 mm	± 0.06 mm
Angle of notch	45°	± 2°
Root radius	0.25 mm	± 0.025mm
Distance of notch from end of test specimen	27.5 mm	± 0.42 mm
Angle between plane of symmetry of notch and longitudinal axis of test specimen	90°	± 2 °

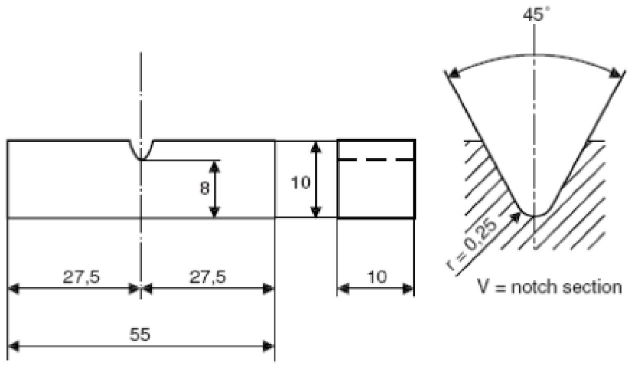


Figure 2.8 Charpy V-notch impact test specimen

1.2.2 Test specimens with the largest possible size, reduced sectional area 10x7.5 or 10x5 are to be used if the thickness of the product does not allow taking test specimens of the standard size with sectional area 10x10.

The minimum average energy values for sub sized specimens are given in Table 2.3.

Table 2.3 Minimum average values for sub sized test specimens

Charpy V-notch specimen size	Minimum energy, average of 3 specimens
10 mm x 10 mm	E
10 mm x 7.5 mm	5E/6
10 mm x 5.0 mm	2E/3
E = The values of energy specified for full thickness 10 mm x 10 mm specimens. All other dimensions and tolerances are to be as specified in Table 2.2 In all cases, the largest size Charpy specimens possible for the material thickness shall be machined	

1.3 Testing machines

All impact tests are to be carried out on Charpy machines complying with the requirements of ISO 148-1 or other national and international recognized standards, and having a striking energy of not less than 150 J.

1.4 Charpy V-notch test procedure

1.4.1 Where the test temperature is lower than ambient (ambient temperature is any temperature within the range of 18 ÷ 27 ºC), the temperature of the test specimen at the moment of breaking is to be the specified test temperature within ± 2 ºC.

The test temperature is to be clearly stated in the test documents.

1.4.2 The unit used to report the energy values is to be clearly stated in the testing documents and should be preferably joule [J].

The average of the three results from the test of the set is to comply with the value required for the product. Only one individual value may be less than the required average value, provided it is not less than 70 % of that value.

1.5 Charpy V-notch retest procedure

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

2. Drop Weight Test

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

Type P-1 : 25 x 90 x 360 [mm]

Type P-2 : 19 x 50 x 130 [mm]

Type P-3 : 16 x 50 x 130 [mm]

2.2 Unless otherwise agreed, the following is to be applied:

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

E. Ductility Tests for Pipes and Tubes

1. Flattening Test

1.1 The test specimen consists of a ring cut with smoothed ends perpendicular to the tube axis.

The length of the specimen is to be from 10 mm to 100 mm.

1.2 The test consists of compression the test specimen between two rigid and parallel flat plates in a direction perpendicular to its longitudinal axis; the plates are to cover the whole test specimen after flattening.

The test specimen is flattened between two plates to the prescribed distance H or until fracture occurs, see Figure 2.9. 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.

Examples of applicable standards: EN ISO 8492 Pipe Flattening Test.

1.3 After the test, the specimens are to 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.

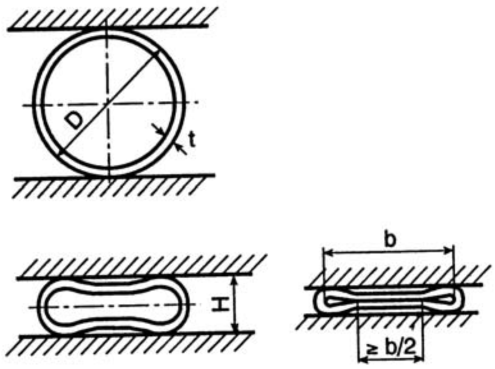


Figure 2.9 Pipe flattening test

2. Drift Expanding Test

2.1 The test specimen consists of a tube section having the ends perpendicular to the tube axis; the edges of the end to be tested may be rounded by filing. The length L of the drift expanding test specimen is to be as shown in Figure 2.10 and Table 2.4

2.2 The rate of penetration of the mandrel is not to exceed 50 mm/min.

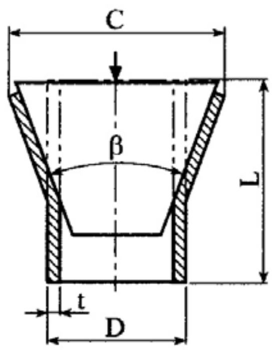


Figure 2.10 Drift expanding test

Table 2.4 Drift expanding test

Material	Length of specimen L	Taper angle β
Steel	≤ 2 D ≤ 1.5 D; min. 50 mm	30º 45º, 60º or 120º
Copper and copper alloys	2 D	45º
Aluminium alloys	≥ 2 D min. 50 mm.	60º

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

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: EN ISO 8493 Drift Expanding Test on Pipes.

3. Flanging Test

3.1 The test specimen consists of a tube section cut with the ends perpendicular to the tube axis; the edges of the end to be tested may be rounded by filing.

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

The radius r shall match that prescribed for the product.

3.3 The test is carried out in two stages and consists of symmetrical forming a flange at one end of the test specimen by means of a special mandrel of hardened steel.

The rate of penetration of the forming tool is not to exceed 50 mm/min.

During the first stage of flanging, the end of the test specimen is expanded by means of truncated-cone shaped mandrel having an included angle of 90º; the test is then continued during the second stage using a special forming mandrel to complete the flange.

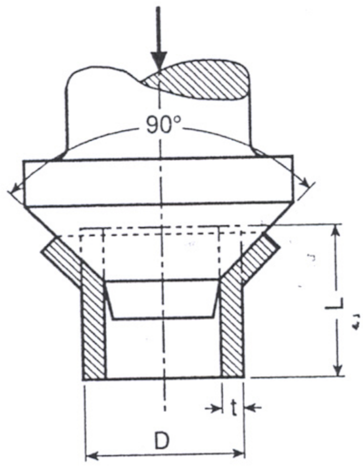
The test is to be continued until the expanded zone forms a flange perpendicular to the longitudinal axis of the test specimen, with an increase in the external diameter of the end of the test specimen not less than the value specified (see Figure 2.11).

The cylindrical and flanged portion of the test specimen is not to present any cracks or other flaws.

After testing, the remaining cylindrical portion is to be not less than half the external diameter of the tube.

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

Pre-forming



Flanging

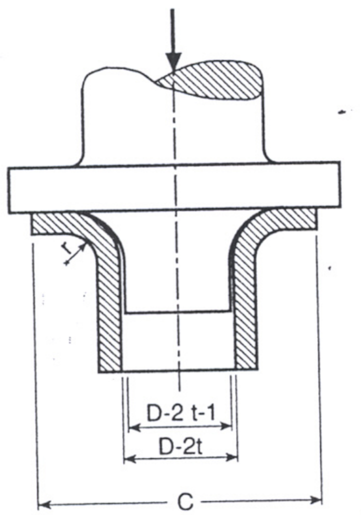


Figure 2.11 Flanging test

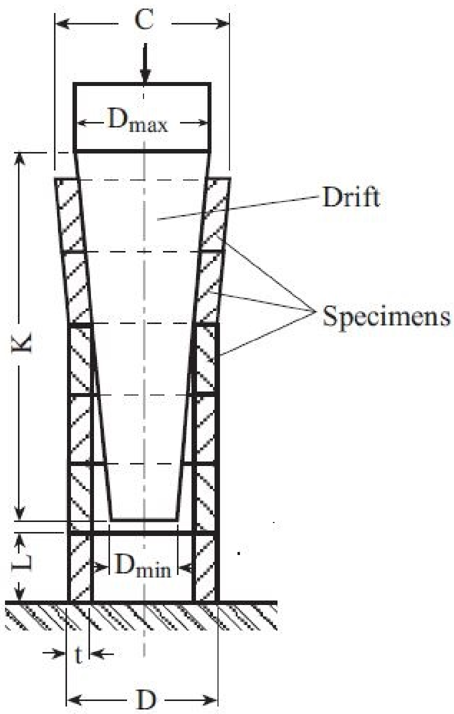
4. Ring expanding test

4.1 The test specimen consists of a tube section cut with ends perpendicular to the tube axis and the length between 10 and 16 mm (Reference is made to ISO 8495).

4.2 The rate of penetration of the mandrel is not to exceed 30 mm/s.

4.3 The test specimen is to be expanded to the prescribed diameter or until fracture occurs (see Figure 2. 12).

The expanded test specimen is not to reveal defects such as cracks, grooves or laminations and is to reach the prescribed expansion.



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

Figure 2.12 Ring expanding test

5. Ring Tensile Test

5.1 The test specimen consists of a tube section with plain and smoothed ends cut perpendicular to the tube axis and with a length of about 15 mm.

5.2 The test specimen is to be drawn to fracture in a tensile test machine by means of two mandrels having diameter equal to at least three times the wall thickness of the pipe (see Figure 2.13).

The rate is not to exceed 5 mm/s.

In the case of welded pipes, the weld seam is to be at 90º to the direction of the tensile load.

5.3 The test specimen after fracture is not to reveal defects such as cracks, grooves or laminations and is to show visible deformation at the point of fracture.

The dimensions of the pipe sections are to be stated.

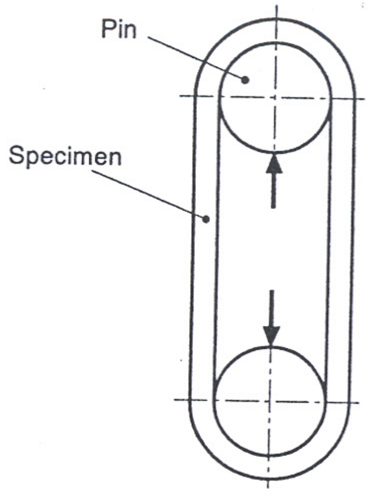


Figure 2.13 Ring tensile test

Example of standards to be applied: EN ISO 8496 Ring Tensile on Pipes.

F. Hardness Tests

1. General

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 Brinell Hardness Test

EN ISO 6507-1 Vickers Hardness Test

ISO 6508-1 Rockwell Hardness Test

2. Purpose

Hardness tests are not to 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.

G. Bend Tests on Pipes and Tubes

1. Test Specimen

1.1 Where feasible, the test specimen consists of full thickness strip not less than 40 mm in width cut perpendicular to the pipe axis.

The edges of the test specimen may be rounded to 1.5 mm radius.

The result is considered satisfactory if, after being bent through the required angle in the direction of the original curvature, the test specimen is free from cracks and laminations; however, small cracks on the edges may be disregarded.

1.2 For smaller diameter tubes, in general not exceeding 50 mm, the test specimen consists of a tube section of sufficient length.

The test specimen is to be bent on a cylindrical mandrel with appropriate procedures as stated below, depending on the specification of the product:

- On a mandrel having a diameter 12 times the nominal diameter of the tube until an angle of 90˚ is reached

- On a mandrel having a diameter 8 times the nominal diameter of the tube, until an angle of 180˚ is reached.

The test specimen after bending is not to present any cracks or other flaws.

H. Non-Destructive Testings

1. General

1.1 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 **TL**.

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

2. Standards and Regulations

2.1 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.

2.2 Testing according to other comparable standards or regulations require prior consent of **TL**. For this they shall be submitted to **TL** for assessment and approval before starting the testing.

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

3. Requirements Applicable to the Inspection Body

3.1 For performing non-destructive testing the manufacturer shall set up a qualified inspection body which is independent of the manufacturing departments and part of a manufacturing site certified according to ISO 9001, or which is accredited according to ISO/IEC 17025.

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

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

This external inspection body shall be accredited according to ISO/IEC 17025 or shall be part of a manufacturing site certified according to ISO 9001.

4. Inspection Personnel, Supervisors

4.1. Inspection personnel

4.1.1 The inspection personnel charged with the non-destructive testing shall be familiar with the test method concerned and shall be qualified and certified to ISO 9712.

4.1.2 For the evaluation of results of nondestructive tests only such inspection personnel shall be charged that holds level-2 certificates for the test method concerned which were issued:

- By an independent certification authority according to ISO 9712

- By the employer of the inspection personnel according to ASNT "Recommended Practice No. SNT-TC-1A"

4.2 Inspection supervisors

For scheduling and monitoring the testing and for evaluating the results an inspection supervisor qualified at least according to 4.1.2 shall be available.

The inspection supervisor shall hold as far as possible a level-3 certificate for the test method concerned according to the Rules indicated in 4.1.2.

5. Test Methods, Equipment and Test Media

5.1 Test methods

For detecting surface and/or volumetric discontinuities in the components indicated in 1.1. the test methods from Table 2.5 or combinations of them shall be employed in dependence of the material, the geometry of the component, the expected service condition and the possible flaw position.

5.2 Equipment and test media

5.2.1 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.

Table 2.5 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
(1) *Definition according to ISO 9712.*		

5.2.2 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 3. and 4. are fulfilled.

6. Preparation and Performance of Tests

6.1 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.

6.2 Performance of tests

6.2.1 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.

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

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

7. Certification of Test Results

7.1 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.

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

8. Visual Testing (VT)

8.1 The surfaces of the components that shall be subjected to testing shall be at least in the condition specified in 6.1. or in the final machined condition.

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

8.3 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 sections.

8.4 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 or EN 13018.

Light and surface reflections shall be avoided by appropriate means.

9. Magnetic Particle Testing (MT)

9.1 Magnetization equipment and method

9.1.1 The surfaces of the components that shall be subjected to testing shall be at least in the condition specified in 6.1. or in the final machined condition.

9.1.2 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.

9.1.3 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).

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

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

9.2 Test media

9.2.1 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.

9.2.2 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 9934-2*
- *JIS-test block according to JIS Z 2343-1*

9.3 Performance of magnetic particle testing

9.3.1 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.

9.3.2 Mechanized testing

When mechanized testing is performed the conditions stated in 9.3.1 shall be provided by an adequate choice or combination of magnetization currents and methods.

9.3.3 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-aluminum alloys shall be employed.

9.3.4 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 9.3.1 shall be proved by the manufacturer by means of measurement of the effective tangential field strength or by means of "Berthold" test blocks.

9.4 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.

9.5 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.

9.6 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 9934-3

- 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 sections.

10. Penetrant Testing

10.1 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.

10.2 Test media and their verification

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

10.2.2 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.

10.3 Performing penetrant testing

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

10.3.2 Pre cleaning of test surface

The surface to be tested shall correspond to the requirements specified in 6.1. 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 sections.

10.3.3 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.

10.3.4 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.

10.3.5 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.

10.3.6 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.

10.3.7 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.

10.4 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 9.5.

10.5 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 sections.

10.6 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.

10.7 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.

11. Ultrasonic Testing (UT)

11.1 Methods

11.1.1 Ultrasonic testing is to be performed with the impulse echo technique in accordance with recognized standards. Such are e.g. EN 12223, EN ISO 7963, EN 12668-3, ISO 16810, EN 10228-3, EN 10160 and EN 12680-1.

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

11.1.2 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.

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

11.2 Test specification

11.2.1 The manufacturer or the orderer 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 related Sections,

- Evaluation criteria for the specific testing areas and severity levels, respectively,

- Indication of other applicable standards and regulations.

11.3 Test appliances and accessories

Ultrasonic testing appliances and probes shall comply with the state of the art and with recognized standards (e.g. EN 12668-1, EN 12668-2 and EN 12668-3) and shall fulfill at least the following requirements:

11.3.1 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.

11.3.2 Requirements for the probes

11.3.2.1 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.

11.3.2.2 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.

11.3.2.3 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.

11.4 Calibration blocks

For verification of the inspection system calibration blocks type 1 according to DIN EN 12223 and calibration blocks type 2 according to EN ISO 7963 or other adequate calibration blocks with reference reflectors are to be used.

11.5 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.

11.6 Performing ultrasonic testing

Ultrasonic testing of machinery parts is to be performed in accordance with the method, standards and regulations specified in 11.1.1 and/or according to specifications of the manufacturer or the order.

11.6.1 Calibration of the inspection system

11.6.1.1 Calibration of the distance

The calibration of the distance is to be performed at the calibration block type 1 in accordance with EN 12223 or at the component.

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

11.6.1.2 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 orderer and/or manufacturer and **TL** in technically justified exceptional cases.

11.6.2 Scanning of the test area and testing velocity

11.6.2.1 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 %.

11.6.2.2 Testing velocity

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

11.7 Evaluation of indications

11.7.1 Indications without extension

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

11.7.2 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 related Sections.

11.8 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 standards to be applied and/or testing specifications,

- 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 KSR, 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.

12. Radiographic Testing

12.1 Method

12.1.1 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.

12.1.2 As a rule radiographic testing is to be performed in accordance with recognized standards such as ISO 5579, EN ISO 17636 for the radiographic examination of welded joints or EN 12681 for the testing of cast components.

12.2 Scope of validity

The following specifications apply for radiographic testing of components indicated in Section 6.

12.3 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 **TL** on condition that the conditions of the standards indicated in 12.1.2 will be fulfilled.

12.4 Testing specification

12.4.1 The orderer 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.

12.4.2 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 **TL** for evaluation.

12.5 Selection of radiation source

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

12.6 Selection of film system and intensifying screens

12.6.1 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 2.6.

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

12.6.2 For the selection of the film class ISO 5579 is to be observed. A comparison of comparable international standards for film system classes is contained in Table 2.7.

12.7 Film density

12.7.1 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 ISO 5579 is larger than S > 2,0 for test category A and larger than S > 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 orderer and the manufacturer is made and that the multiple film technique is employed. This agreement is to be submitted to **TL**.

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

12.7.3 In order to depict different wall thickness regimes of cast components without loss of quality within the density limits specified in 12.7.1 on one screen, the procedures for multiple film technique as indicated in EN 12681 shall be employed.

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

12.8 Verification of image quality

12.8.1 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.

12.8.2 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.

12.9 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 6, G.9.

12.10 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 cast 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,

- 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.

Table 2.6 Film System classes and metal screens in accordance with ISO 5579 and EN 12681

Radiation source	Penetrated thickness ω	Film system class (1) Class A	Film system class (1) Class B	Type and thickness of metal screens Class A	Type and thickness of metal screens Class B
X-ray potentials ≤100kV		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 to0,15 mm	
Yb 169 Tm 170	ω < 5 mm.		C3	None, or front and rear lead screens up to max. 0,03 mm	
	ω ≥ 5 mm.		C4	Front and rear lead screens from 0,02 to 0,15 mm	
X- ray potentials > 250 kV to 500 kV	ω ≤ 50 mm.	C5	C4	Front lead screens from 0,02 to 0,2 mm	
	ω > 50 mm.		C3	Front lead screens from 0,1 to 0,2 mm **(2)** Rear lead screens from 0,02 to 0,2 mm	
Se-75	ω > 5 mm.	C5	C4	Front and rear lead 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
				Rear lead screens from 0,1 to 0,2 mm.	
Co 60	ω ≤ 100 mm.	C5	C4	Front and rear screens of steel or copper from 0,25 to 0,7 mm **(3)**	
	ω > 100 mm.		C5		
X- ray equipment with energy from 1 MeV to 4 MeV	ω ≤ 100 mm.	C5	C3	Front and rear screens of steel or copper from 0,25 to 0,7 mm	
	ω > 100 mm.		C5		
X- ray equipment with energy from 4 MeV to 12 MeV	ω ≤ 100 mm.	C4	C4	Front screens of steel, copper or tantalum up to max. 1 mm **(4)** Rear screens of steel or copper up to max. 1 mm and tantalum up to max. 0,5 mm **(4)**	
	100 mm. < ω ≤ 300 mm.	C5	C4		
	ω > 300 mm.		C5		
X- ray equipment with energy above 12 MeV	ω ≤ 100 mm.	C4		Front screens of tantalum up to max. 1 mm **(5)** No rear screens	
	100 mm. < ω ≤ 300 mm.	C5	C4		
	ω > 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 a0,1 mm lead screen is placed between the component to be tested and the film*
(3) *For class A 0,1 to 0,5 mm 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) *Tungsten screens may be used if agreed on.*

Table 2.7 Comparison of international comparable recognized film system classes

Manufacturer/film type	ASTM (1)	DIN (3)	EN (3)	ISO (2)	RCC-M (4)
AGFA (5)					
Structurix D2	Special	G1	C1	GI	1
Structurix D3	1	G1	C2	GI	1
Structurix D3 s.c.	1	G1	C2	GI	2
Structurix D4	1	G2	C3	GI	3
Structurix D5	1	G2	C4	GII	3-4
Structurix D7	2	G3	C5	GIII	4
Structurix D8	2	G4	C6	GIII	5
Fuji (5)					
IX 25	1	G2	C3	GI	3
IX 50	Special	G1	C1	GI	1
IX 80	1	G2	C3	GI	3
IX 100	1	G2	C4	GII	3-4
IX 150	2	G4	C6	GIII	4-5
Kodak (5)					
DR	Special	G1	C1	GI	
M	1	G1	C2	GI	
MX 125	1	G2	C3	GI	
T 200	1	G2	C4	GII	
AA 400	2	G3	C5	GIII	
CX	3	G4	C6	GIII	
B	W-B			GIII	

(1) *ASTM E 94-04*

(2) *ISO 5579*

(3) *Classification according to EN ISO 11699-1*

(4) *French standard*

(5) *Equivalent film types from other manufacturers may also be considered, provided that appropriate proof has been furnished.*

SECTION 3

ROLLED STEEL PLATES, SECTIONS AND BARS

A. General

1. Scope

1.1 The requirements of this section apply to hot-rolled steel plates, sections and bars intended for use in hull construction, boilers, pressure vessels and machinery parts.

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

2. Manufacture

2.1 Method of manufacture

2.1.1 Steel is to be manufactured by the basic oxygen process, the electric furnace process or open hearth process.

The use of other processes may be approved by **TL.**

2.1.2 The deoxidation practice used for each grade is to comply with the appropriate requirements of Tables 3.3 and 3.4.

2.1.3 The rolling practice applied for each grade is to comply with the appropriate condition of supply of Tables 3.6 and 3.7.

2.2 Definitions

The definitions of applicable rolling procedures are given as follows.

2.2.1 As-Rolled, AR

This procedure involves the rolling of steel at high temperature followed by air cooling. The rolling and finishing temperatures are typically in the austenite recrystallization region and above the normalizing 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.

2.2.2 Normalizing, N

Normalizing involves heating rolled steel above the critical temperature, Ac3 and in the lower end of the austenite recrystallization region followed by air cooling. The process improves the mechanical properties of as-rolled steel by refining the grain size.

2.2.3 Controlled Rolling, CR (Normalizing Rolling, NR)

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

2.2.4 Quenching and Tempering, QT

Quenching involves a heat treatment process in which steel is heated to an appropriate temperature above the Ac3 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 to restore toughness properties by improving the microstructure.

2.2.5 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 Ar3 temperature and may involve the rolling in the dual phase temperature region.

Unlike controlled rolled (normalized rolling) the properties conferred by TM (TMCP) cannot be reproduced by subsequent normalizing or other heat treatment.

The use of accelerated cooling on completion of TM-rolling may also be accepted subject to the special approval of **TL.** The same applies for the use of tempering after completion of the TM-rolling. See Table 3.1.

2.2.6 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.

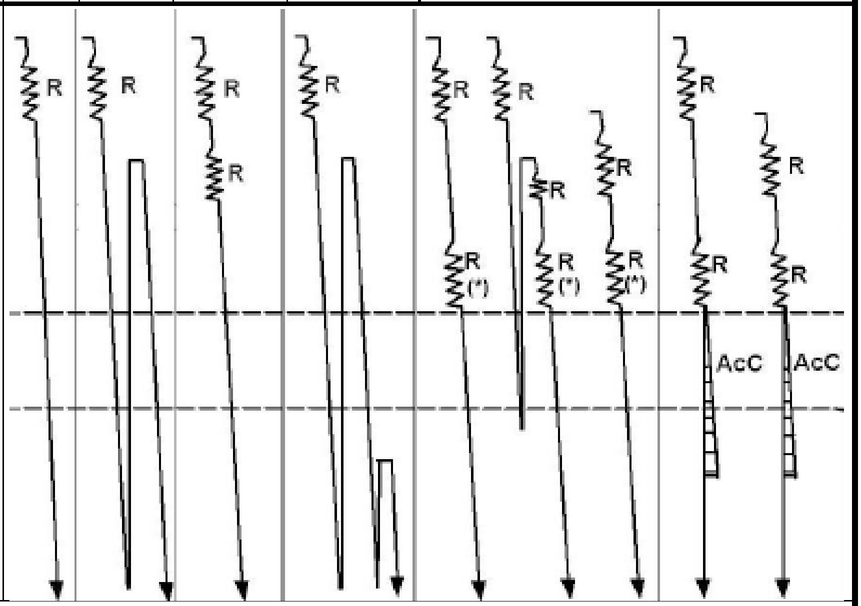
The material properties conferred by TM and AcC cannot be reproduced by subsequent normalizing or other heat treatment. Where CR and TM with/without AcC are applied, the programmed rolling schedules are to be verified by **TL** at the time of the steel works approval, and are to be made available when required by the attending surveyor. On the manufacturer's responsibility, the programmed rolling schedules are to be adhered to during the rolling operation. To this effect, the actual rolling records are to be reviewed by the manufacturer and occasionally by the surveyor. When deviation from the programmed rolling schedules or normalizing or quenching and tempering procedures occurs, the manufacturer shall take further measures to the surveyor's satisfaction. See Table 3.1.

3. Approval

3.1 All materials are to be manufactured at works which have been approved by TL for the type and grade of steel which is being supplied. The suitability of each grade of steel for forming and welding is to be demonstrated during the initial approval tests at the steelworks. Approval of the steel works is to follow a scheme given in the Appendix A. For the steels intended for high heat input welding over 50 kJ/cm, the approval of the manufacturer is to follow a scheme given in the Appendix B. For steels intended for a corrosion resistant designation, the approval of the manufacturer is to additionally follow the scheme given in Appendix C.

Table 3.1 Schematic Diagrams of Thermo-Mechanical and Convertional Processes

Structure	Temperature	Type of Processing				
		Conventional Processes				Thermo-Mechanical Processes
		AR	N	CR (NR)	QT	TM
Recrystallized Austenite	Normal Slab Heating Temp. Normalizing or Quenching Temp.					
Non-recreystallized Autsenite	Ar$_3$ or Ac$_3$					
Autsenite + Ferrite	Ar$_1$ or Ac$_1$					
Ferrite+Perlite or Ferrite + Bainite	Temperating Temp.					



Notes :

AR : As Rolled

N : Nomallizing

CR(NR) : Controlled Rolling (Normalizing Rolling)

QT : Quenching and Tempering

TM : Thermo-Mechanical Rolling (thermo-Mechanical Controlled Process)

R : Reduction

(*) : Sometings rolling in the dual-phase temperature region of austenite and ferrite

AcC : Accelerated Cooling

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

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

Note:

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

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

4. Condition of Supply

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 rolled (controlled rolled) or thermo-mechanically rolled condition, provided that the processes have been checked and approved by **TL** on the manufacturer's premises.

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 **TL**, hot-rolled plates, wide flats and sections shall be subject to the delivery conditions stipulated in EN 10163.

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

6. Thickness Tolerances of Steel Plates and Wide Flats

6.1 Scope

6.1.1 These requirements apply to the tolerance on thickness of steel plates and wide flats with widths 600 mm or greater (hereinafter referred to as: product or products) with thicknesses of 5 mm and over covering normal and higher strength hull structural steels according to Section 3 B (UR W11), high strength quenched and tempered steels for welded structure according to Section 3 C (UR W16) and steels for machinery structures according to Türk Loydu Material Rules

The thickness tolerances for products below 5 mm may be specially agreed.

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

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

6.1.3 Class C of ISO 7452 may be applied in lieu of 6.3, in which case the requirements in 6.4 and 6.5 need not be applied. If Class C of ISO 7452 is to be used, the portion of the footnote of ISO 7452, Table 2, which reads “Also a minus side of thickness of 0.3 mm is permitted.” is not to be applied.

Additionally, if ISO 7452 is applied, it is required that the steel mill demonstrate to the satisfaction of the TL that the number of measurements and measurement distribution is appropriate to establish that the mother plates produced are at or above the specified nominal thickness.

6.2 Responsibility

6.2.1 The responsibility for verification and maintenance of the production within the required tolerances rests with the manufacturer. The surveyor may require witnessing some measurements.

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

6.3 Thickness tolerances

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

- Minus tolerance is the lower limit of the acceptable range below the nominal thickness.

- Plus tolerance is the upper limit of the acceptable range above the nominal thickness.

Note:

Nominal thickness is defined by the purchaser at the time of enquiry and order.

6.3.2 The minus tolerance on thickness of normal and higher strength hull structural steels and high strength quenched and tempered steels for welded structure is 0.3 mm irrespective of nominal thickness.

6.3.3 The minus tolerances for products for machinery structures are to be in accordance with Table 3.2.

Table 3.2 Minus tolerances for products for machinery structures

Nominal thickness (t) [mm]	Tolerance [mm]
5 ≤ t < 8	-0.4
8 ≤ t < 15	-0.5
15 ≤ t < 25	-0.6
25 ≤ t < 40	-0.8
t ≥ 40	-1.0

6.3.4 The tolerances on nominal thickness are not applicable to areas repaired by grinding which are to be in accordance with a recognized standard. The IACS Rec.No.12 may be used for this purpose.

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

6.4 Average thickness

6.4.1 The average thickness of a product or products is defined as the arithmetic mean of the measurement made in accordance with the requirements of 6.5.

6.4.2 The average thickness of the normal and higher strength hull structural steels (UR W11) or high strength quenched and tempered steels for welded structures (UR W16) is not to be less than the nominal thickness.

6.5 Thickness measurements

6.5.1 The thickness is to be measured at locations of a product or products as defined in 6.6.

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

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

6.6 Thickness measuring locations

6.6.1 Scope of application

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

6.6.2 Measuring locations

At least two lines among line1, line 2 or line 3 as shown in Figure 3.1a, are to be selected for the thickness measurements and at least three points on each selected line as shown in Figure 3.1a are to be selected for thickness measurement. If more than three points are taken on each line the number of points is to be equal on each line.

Note:
The measurement locations apply to a product rolled directly from one slab or steel ingot even if the product is to be later cut by the manufacturer. Examples of the original measurements relative to later cut products are shown in Figure 3.1b. It is to be noted that the examples shown are not representative of all possible cutting scenarios.

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

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

6.6.3 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.

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

7. Rectification of Surface Defects

7.1 Rectification of surface defects by grinding

Defects which required to be repaired may be removed by grinding.

The repaired areas are to be ground smooth to the adjacent surface of the plate. The surveyor may request that the complete removal of defects is verified by suitable non-destructive examination.

7.2 Rectification of surface defects by welding

Surface defects which cannot be removed as stated in 7.1 may be repaired by chipping or grinding followed by welding subject to the surveyor’s consent and under his supervision.

8. Test Material and Tests

8.1 General

8.1.1 All products are to be presented for testing in the final supply condition in batches or units.

8.1.2 Sampling

The samples required for the preparation of test specimens are to be cut from:

8.1.2.1 The end of the plate or section corresponding to the top position of the ingot, in the case of casting in ingot moulds.

8.1.2.2 Any end of the plate or section, where such product are rolled from blooms or billets manufactured by continuous casting,

8.1.2.3 Both the ends of the coil for plates fabricated in coils.

8.1.2.4 Unless otherwise agreed the test samples are to be taken from the following positions:

8.1.2.4.1 Plates and flats with a width ≥ 600 mm

The test samples are to be taken from one end at a position approximately midway between the axis in the direction of the rolling and the edge of the rolled product (see Figure 3.2). Unless otherwise agreed the tensile test specimens are to be prepared with their longitudinal axes transverse to the final direction of rolling.

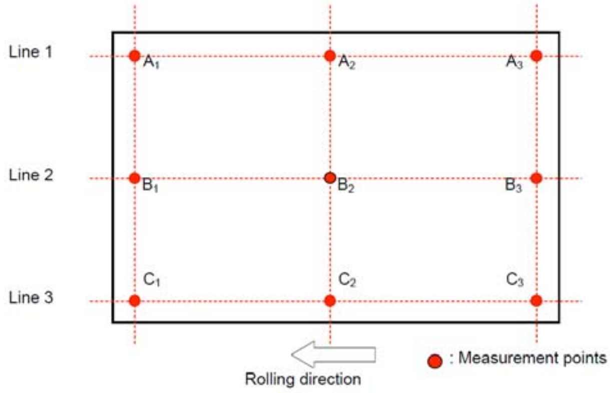


Figure 3.1a - Locations of thickness measuring points for the original steel plates

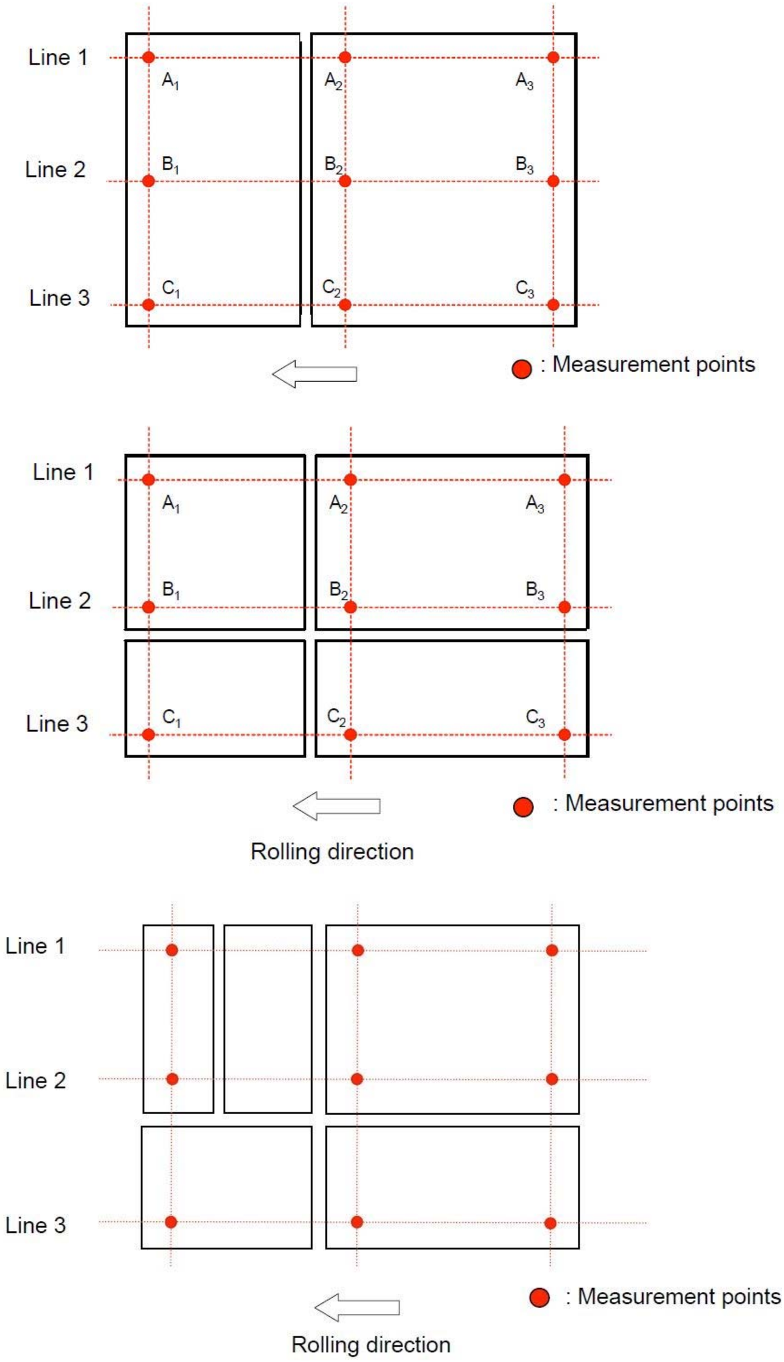


Figure 3.1b - Locations of thickness measuring points for the cut steel products

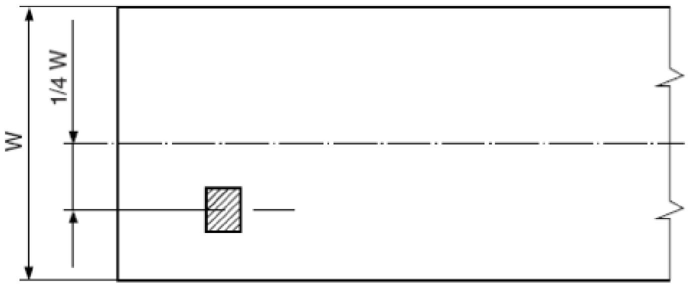


Figure 3.2 Plates and flats

8.1.2.4.2 Flats with a width < 600 mm, bulb flats and other sections

The test samples are to be taken from one end at a position approximately one third from the outer edge (see Figure 3.3, 3.4, 3.5 and 3.6) or in the case of small sections, as near as possible to this position.

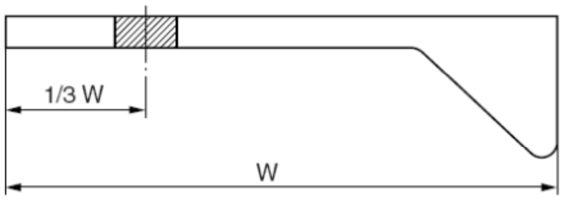


Figure 3.3 Bulb flats

In the case of channels, beams or bulb angles, the test samples may be alternatively be taken from a position approximately one quarter of the width from the web centre line or axis (see Figure 3.5). The tensile test specimen may be prepared with their longitudinal axes either parallel or transverse to the final direction of rolling.

8.1.2.4.3 Bars and other similar products

The test samples are to be taken so that the longitudinal axes of the test specimens are parallel to the direction of rolling and are as near as possible to the following:

- For non-cylindrical sections, at one third of the half diagonal from the outside,

- For cylindrical sections, at one third of the radius from the outside (see Figure 3.7).

8.1.3 Preparation of test specimens

The test specimens are to be cut from the samples with their principal axis parallel (longitudinal test) or perpendicular (transverse test) to the direction of rolling. For the preparation of test specimens and their testing procedures, see Section 2.

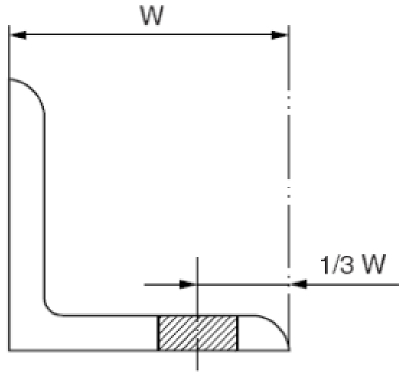


Figure 3.4 Angles

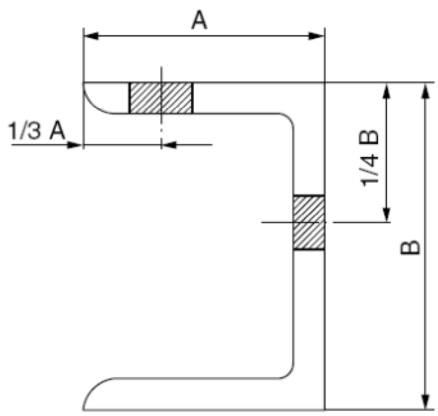


Figure 3.5 Channel

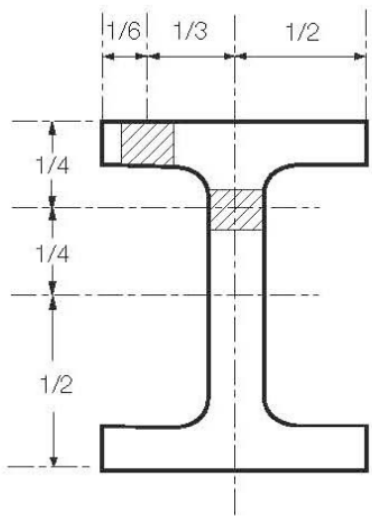


Figure 3.6 H-Section

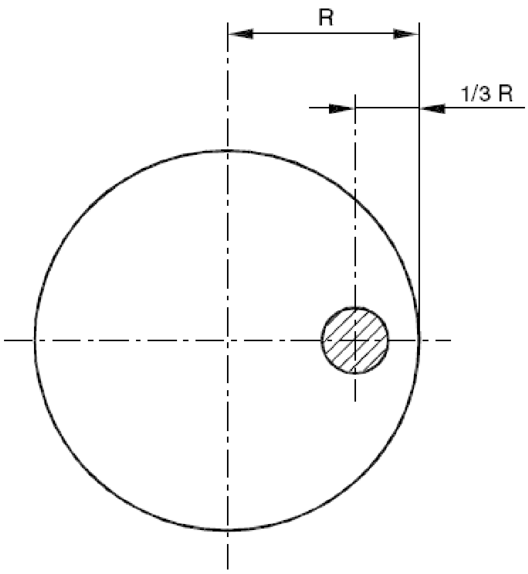


Figure 3.7 Bars

8.1.4 Tensile test

The results of the tensile test are to comply with the values specified in the tables relevant to products.

If during the tensile test there is no marked yield stress R_{eH} , the 0.2% proof stress $R_{p0.2}$, may be taken as an alternative.

8.1.5 Impact test

The average value is to comply with the minimum average value specified in the tables relevant to products and only one individual value may be less than the average required provided that it is not less than 70 % of it.

8.1.6 Retest procedure

For details see Section 1.

For tensile re-test procedure see Section 2, B.3, for Charpy V-notch retest procedure see Section 2, D.1.5.

9. Marking of Products

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

- Steel grade,
- Manufacturer's mark,
- Heat number, manufacturing serial number,
- Specimen number (where necessary).

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

9.2 In the case of shapes and bars weighing < 25 kg or less per 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. Certification

10.1 The Surveyor is to 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 inter crystalline 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 **TL** Rules for Material, and the requirements were satisfied. The name "Türk Loydu" (**TL**) 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 **TL** for testing."

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

B. Normal and Higher Strength Hull Structural Steels

1. Scope

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

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

- For steel plates and 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 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 **TL**. 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 subsection, 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

See A.3.

3. Method of Manufacture

See, A.2.

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 3.3 and 3.4.

For plates and wide flats more than 50 mm thick, slight variations in the prescribed chemical composition may be allowed as approved by **TL**.

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 is to be calculated from the ladle analysis using the following formula and tocomply with the requirements of Table 3.4;

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

4.3.2 The following formula may be used for evaluating weldability instead of the carbon equivalent at the discretion of **TL.**

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

In such cases, the P_{cm} value is to be agreed with **TL**.

5. Condition of Supply

All materials are to be supplied in a condition complying with the appropriate requirements of Tables 3.6 and 3.7.

Table 3.3 Chemical composition and deoxidation practice for normal strength steels

<table>
<tr><th>Grade</th><th>TL-A</th><th>TL-B</th><th>TL-D</th><th>TL-E</th></tr>
<tr><td rowspan="2">Deoxidation practice</td><td>For t ≤ 50 mm
Any method except rimmed steel (1)</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
Fully 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>2.5xC</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 thicness

(1) *Grade **TL**-A sections up to a thickness of 12.5 mm may be accepted in rimmed steel subject to the special approval of **TL**.*

(2) *Max. 0.23 % for sections.*

(3) *When Grade **TL**-B steel is impact tested the minimum manganese content may be reduced to 0.60 %*

(4) *When any grade of steel is supplied in the thermo-mechanically rolled condition variations in the specified chemical composition may be allowed or required by **TL.***

(5) *For Grade **TL**-D steel over 25 mm thick.*

(6) *For Grade **TL**-D steel over 25 mm thick and for Grade **TL**-E steel, the total aluminium content may be determined instead of the acid soluble content. In such cases, the total aluminium content is not be less than 0.020 %. **TL** may also specify a maximum limit for aluminium. Other suitable grain refining elements may also be permitted subject to the special approval of **TL.***

(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 additions of any other element have been made as part of the steel making practice, the content is to be indicated.*

Table 3.4 Chemical composition and deoxidation practice for higher strength steels

Grade (1)	**TL-A 32, TL-D 32, TL-E 32 TL-A 36, TL-D 36, TL-E 36 TL-A 40, TL-D 40, TL-E 40**	**TL-F 32 TL-F 36 TL-F 40**
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)** (Nb, V, Ti: Total 0.12 max.)	0.02-0.05 **(4)** (Nb, V, Ti: Total 0.12 max.)
V	0.05-0.10 **(4)**	0.05-0.10 **(4)**
$Ti_{max.}$	0.02	0.02
$Cu_{max.}$	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. TL-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 determined instead of the acid-soluble content. In such cases the total aluminium content may is to be not less than 0.020 %.*

(4) *The steel is to contain aluminium, niobium, vanadium or other suitable grain refining elements, either singly or in any combination. When used singly the steel is to contain the specified minimum content of the grain refining element. When used in combination, the specified minimum content of 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 allowed or required by* ***TL.***

(6) *When required, the carbon equivalent value is to be calculated from the ladle analysis using the following formula and to comply with the requirements of Table 3.5:*

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

This formula is applicable only to steels which are basically of the carbon-manganese type and gives a general indication of the weldability of the steel.

(7) *Where additions of any other element have been made as part of the steelmaking practice, the content is to be indicated.*

6. Mechanical Properties

6.1 For tensile testing the upper yield strength R_{eH} or, where this is not stipulated, the 0.2 per cent 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 are to comply with the appropriate requirements of Tables 3.8 and 3.9.

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 (See IACS UR W11.12.2). Generally only longitudinal test specimens need be prepared and tested. For special applications, if required by **TL** or the purchaser, transverse specimens are to be tested. The requirements in respect of the transverse test specimens shall be guaranteed by supplier.

The tabulated values are for standard specimens 10 mm x 10 mm. For plate thicknesses less than 10 mm, impact test may be waived at the discretion of **TL** or subsize specimens, as specified in Section 2, may be used:

Test specimen10x7,5 mm: 5/6 of the energy given in the table

Test specimen 10x5 mm: 2/3 of the energy given in the table

Table 3.5 Carbon equivalent for higher strength steels up to 100 mm in thickness produced by TM

Grade	**Carbon equivalent value (%) max. (1)**	
	Thickness of product (t) [mm]	
	t ≤ 50	**50 < t ≤100**
TL-A 32, TL-D 32, TL-E 32, TL-F 32	0.36	0.38
TL-A 36, TL-D 36, TL-E 36, TL-F 36	0.38	0.40
TL-A 40, TL-D 40, TL-E 40, TL-F 40	0.40	0.42

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

Table 3.6 Condition of supply for normal strength steels

Grades	**Thickness [mm]**		**Condition of supply**
TL-A	≤50		Any
	>50	≤100	Normalised, controlled rolled or TM-rolled **(1)**
TL-B	≤50		Any
	>50	≤100	Normalised, controlled rolled or TM-rolled **(1)**
TL-D	≤35		Any
	>35	≤100	Normalised, controlled rolled or TM-rolled **(2)**
TL-E	≤100		Normalised, or TM-rolled **(2)**

(1) *Subject to the special approval of TL, plates in Grade TL-A and TL-B steel may also be supplied in the as-rolled condition.*

(2) *Subject to the special approval of **TL**, sections in Grade TL-D steel may be supplied in the as-rolled condition provided satisfactory results are consistently obtained from notch impact tests. Similarly sections in Grade TL-E steel may be supplied in the as rolled or controlled rolled condition. The frequency of impact tests is to be determined in accordance with 13.2.3 and 13.3.3 respectively.*

Table 3.7 Condition of supply for higher strength steels

Grades	Grain refining elements used	Thickness t [mm]	Condition of supply
TL-A 32 TL-A 36	Nb and/or V	≤ 12.5	Any
		12.5 < t ≤100	Normalised, controlled rolled or TM-rolled **(3)**
	Al alone or with Ti	≤ 20	Any
		20 < t ≤35	Any, but as-rolled subject to special approval of **TL** **(2)**
		35 < t ≤100	Normalised, controlled rolled or TM-rolled **(3)**
TL-A 40	Any	≤ 12.5	Any
		12.5 < t ≤50	Normalised, controlled rolled or TM-rolled
		50 < t ≤100	Normalized ,TM rolled or quenched and tempered
TL-D 32 TL-D 36	Nb and/ or V	≤ 12.5	Any
		12.5 < t ≤100	Normalised, controlled rolled or TM-rolled **(3)**
	Al alone or with Ti	≤ 20	Any
		20 < t ≤25	Any, but as-rolled subject to special approval of **TL** **(2)**
		25 < t ≤100	Normalised, controlled rolled or TM-rolled **(3)**
TL-D 40	Any	≤ 50	Normalised, controlled rolled or TM-rolled
		50 < t ≤100	Normalised, TM rolled or quenched and tempered
TL-E 32 TL-E 36	Any	≤ 50	Normalised or TM rolled **(3)**
		50 < t ≤100	Normalised, TM rolled
TL-E 40	Any	≤ 50	Normalised, TM rolled or quenched and tempered
		≤ 100	Normalised, TM rolled or quenched and tempered
TL-F 32 TL-F 36 TL-F 40	Any	≤ 50	Normalised, TM rolled or quenched and tempered **(4)**
		50 < t ≤ 100	Normalised, TM rolled or quenched and tempered

(1) *These conditions of supply and the requirements for impact tests are summarised in Table 3.11.*

(2) *The frequency of impact tests is to be in accordance with 13.2.3.*

(3) *Subject to the special approval of* ***TL****, sections in Grade TL-A 32, TL-A 36, TL-D 32 and TL-D 36 steels may be supplied in as-rolled condition provided satisfactory results are consistently obtained from notch impact tests. Similarly sections in grade TL-E 32 and TL-E 36 steels may be supplied in as-rolled or controlled rolled condition. The frequency of notch impact tests is to be in accordance with 13.2.3 and 13.2.4 respectively.*

(4) *Subject to special approval of* ***TL****, sections in Grade TL-F 32 and TL-F 36 steels with thickness ≤ 50 may be supplied in controlled rolled condition. The frequency of notch impact tests is to be in accordance with 13.3.3.*

Table 3.8 Mechanical properties for normal strength steels

Grade	Yield strength R_{eH} [N/mm^2] min.	Tensile strength R_m [N/mm^2]	Elongation $L_0 = 5.65 \cdot \sqrt{S_0}$ A_5 [%] min.	Impact test						
				Test temp. [°C]	Average impact energy(KV) [J] min.					
					t ≤ 50 mm		50 < t ≤ 70 mm		70 < t ≤ 100 mm	
					Long. (3)	Transv. (3)	Long. (3)	Transv. (3)	Long. (3)	Transv. (3)
TL-A	235	400-520 **(1)**	22 **(2)**	+20	-	-	34 **(5)**	24 **(5)**	41 **(5)**	27 **(5)**
TL-B				0	27 **(4)**	20 **(4)**	34	24	41	27
TL-D				-20	27	20	34	24	41	27
TL-E				-40	27	20	34	24	41	27

t = Thickness of product [mm]

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

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

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

(3) *See B,6.3.*

(4) *Notch impact tests are generally not required for Grade TL-B steels with thickness of 25 mm or less.*

(5) *Impact tests for Grade TL-A over 50 mm thick are not required when the material is produced using fine grain practice and furnished normalised. TM rolling may be accepted without impact testing at the discretion of **TL**.*

6.4 The average notch impact energy value obtained from one set of three tests is to comply with the requirements given in Tables. 3.8 and 3.9. One individual value may only be below the specified average value provided it is not less than 70 % of that value.

6.5 Notch impact tests are generally not required if the product is less than 6 mm thick.

7. Freedom from Defects

7.1 The steel is to be reasonably free from segregations and non-metallic inclusions. The finished material is to have a workmanlike finish and is to be free from internal and surface defects prejudicial to the use of the material for the intended application.

7.2 The acceptance criteria for surface finish and procedures for the repair of defects, as detailed in Recommendation, No 12, "Guidance for the Surface Finish of Hot Rolled Steel Plates and Wide Flats" are to be observed.

7.3 Repair procedures

7.3.1 Grinding

7.3.1.1 Grinding may be applied provided:

- The nominal product thickness will not be reduced by more than 7 % or 3 mm, whichever is the less,
- Each single ground area does not exceed 0.25 m^2 and
- All ground areas do not exceed 2 % of the total surface in question.

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

7.3.1.2 Ground areas lying opposite each other on both surfaces must not decrease the product thickness by values exceeding the limits as stated under 7.3.1.1.

Table 3.9 Mechanical properties for higher strength steels

Grade	Yield strength R_{eH} [N/mm^2] min.	Tensile strength R_m [N/mm^2]	Elongation $L_0 = 5.65 \cdot \sqrt{S_0}$ A_5 [%] min.	Impact test						
				Test temp. [°C]	Average impact energy (KV) [J] min.					
					t ≤ 50 mm		50 < t ≤ 70 mm		70 < t ≤ 100 mm	
					Long. (2)	Transv. (2)	Long. (2)	Transv. (2)	Long. (2)	Transv. (2)
TL-A 32				0	31**(3)**	22**(3)**	38	26	46	31
TL-D 32	315	440-570	22	-20	31	22	38	26	46	31
TL-E 32			**(1)**	-40	31	22	38	26	46	31
TL-F 32				-60	31	22	38	26	46	31
TL-A 36				0	34**(3)**	24**(3)**	41	27	50	34
TL-D 36	355	490-630	21	-20	34	24	41	27	50	34
TL-E 36			**(1)**	-40	34	24	41	27	50	34
TL-F 36				-60	34	24	41	27	50	34
TL-A 40				0	39	26	46	31	55	37
TL-D 40	390	510-660	20	-20	39	26	46	31	55	37
TL-E 40			**(1)**	-40	39	26	46	31	55	37
TL-F 40				-60	39	26	46	31	55	37

t = Thickness of product [mm]

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

Thickness t [mm]		≤ 5	> 5 ≤ 10	> 10 ≤ 15	> 15 ≤ 20	> 20 ≤ 25	> 25 ≤ 30	> 30 ≤ 40	> 40 ≤ 50
Elogation [%]	TL-A 32,-D 32,-E 32,-F 32	14	16	17	18	19	20	21	22
	TL-A 36,-D 36,-E 36,-F 36	13	15	16	17	18	19	20	21
	TL-A 40,-D 40,-E 40,-F 40	12	14	15	16	17	18	19	20

(2) *See B,6.3.*

(3) *For grades TL-A 32 and TL-A 36 steels a relaxation in the number of impact tests for acceptance purposes may be permitted by special agreement with **TL**, provided that satisfactory results are obtained from occasional check tests.*

7.3.1.3 The defects or unacceptable imperfections are to be removed completely by grinding.

The ground areas must have smooth transitions to the surrounding surfaces of the product. Complete elimination of the defects may be verified by a magnetic particle or dye penetrant test procedure at the surveyor's discretion.

7.3.1.4 Where necessary, the entire surface may be ground to a depth as given by the under thickness tolerances of the product.

7.3.2 Welding repair

Local defects which cannot be repaired by grinding as stated under 7.3.1 may be repaired with the surveyor's consent by chipping and/or grinding followed by welding subject to the following conditions:

7.3.2.1 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.

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

7.3.2.2 The weld preparation must not reduce the thickness of the product below 80% of the nominal thickness. For occasional defects with depths exceeding the 80% limit, special consideration at the surveyor's discretion will be necessary.

7.3.2.3 The repair shall be carried out by qualified welders using an approved procedure for the appropriate steel grade. The electrodes shall be of low hydrogen type and must be dried in accordance with the manufacturer's requirements and protected against rehumidification before and during welding.

7.3.2.4 All weldings are to be of reasonable length and must have at least 3 parallel welding beads. The deposited metal must be sound without any lack of fusion, undercut, cracks and other defects which could impair the workability or use of the product.

Welding is to be performed with one layer of beads in excess, which is subsequently to be ground smooth to the surface level.

7.3.2.5 Products which are to be supplied in a heat treated condition are to be welded prior to the heat treatment; otherwise, a new heat treatment may be required.

Products supplied in the controlled rolled or as-rolled condition may require a suitable heat treatment after welding. However, the post weld heat treatment may be omitted provided the manufacturer has demonstrated by a procedure test that the required properties will be maintained without heat treatment.

7.3.2.6 The finished products are to be presented to the surveyor for acceptance. The soundness of the repair may be verified by ultrasonic, magnetic particle or dye penetrant methods at the surveyor's discretion.

7.3.2.7 For every welding repair the manufacturer must provide the surveyor with a written report and a sketch showing sizes and location of the defects and full details of the repair procedure including the welding consumables, post weld heat treatment and non-destructive testing.

8. Tolerances

Unless otherwise agreed or specially required the thickness tolerances in A.6 (Reference IACS UR W13 "Allowable under thickness tolerances of steel plates and wide flats".) are applicable.

9. Identification of Materials

9.1 The steelmaker is to adopt a system for the identification of ingots, slabs and finished pieces which will enable the material to be traced to its original cast.

9.2 The surveyor is to be given full facilities for so tracing the material when required.

10. Testing and Inspection

10.1 Facilities for inspection

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

10.2 Testing procedure

The prescribed tests and inspections are to be conducted at the place of manufacture prior to dispatch of products. The test specimens and procedures are to comply with the information given in Section 2. Unless otherwise agreed with **TL**, the specimens are to be selected by the Surveyor, marked and tested in his presence.

10.3 Through thickness tensile testing

Where plates and wide flats with thicknesses ranging from 15 to 150 mm are ordered with, through thickness properties, the through thickness tensile test in accordance with H (Reference UR W14 "Steel Plates and Wide Flats with Improved Through Thickness Properties" is to be carried out.

10.4 Non-destructive testing

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

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

10.4.2.1 Electrical welded hollow sections

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

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

- EN ISO 10893-3, acceptance category F5, or EN ISO 10893-11, acceptance category U5

10.4.2.2 Submerged-arc welded hollow sections

The weld seam of hollow sections is to be examined according to acceptance category U4 in accordance with EN ISO 10893-6, image quality class R2.

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

10.5 Surface inspection and dimensions

Surface inspection and verification of dimensions are the responsibility of the steel maker. The acceptance by **TL**'s surveyor shall not absolve the steel maker from this responsibility.

11. Test Material

11.1 Definitions

11.1.1 "Piece" denotes the rolled product from a single slab, billet or ingot if this is rolled directly into plates, sections or bars.

11.1.2 "Batch" denotes a number of similar pieces presented as a group for acceptance tests.

11.2 Test samples

11.2.1 All materials in a batch presented for acceptance tests are to be of the same product form e.g. plates, flats, sections, etc. from the same cast and in the same condition of supply.

11.2.2 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.

11.2.3 The test specimens are not to be separately heat treated in any way.

11.2.4 The removal of test samples is subject to the rules laid down in A.8.1.2.

12. Mechanical Test Specimens

12.1 Tensile test specimens

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

12.2 Impact test specimens

Impact test specimens shall comply with the Charpy V specimen shape and be taken horizontally with the long side of the specimen 2 mm below the rolling surface. They shall be positioned so that their axes are either "longitudinal" or "transverse" to the main direction of rolling as shown in Tables 3.8 and 3.9. The notch is to be cut in a face of the test specimen which was originally perpendicular to the rolled surface. The position of the notch is not 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 are to be taken with their longitudinal axis at a quarter thickness position.

13. Number of Test Specimens

13.1 Number of tensile tests

For each batch presented, except where specially agreed by **TL**, 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 TL-E, TL-E 32, TL-E 36, TL-E 40, TL-F 32, TL-F 36 and TL-F 40), see Tables 3.9 and 3.10

13.2.1 Except where otherwise specially agreed by **TL**, 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. When steel plates except for grade TL-A steel over 50 mm in thickness is supplied in the controlled rolled condition, the frequency of impact test is to be made from a different piece from each 25 tonnes or fraction thereof.

13.2.2 For steel plates of grades TL-A 40 and, TL-D 40 with thickness over 50 mm in normalized or TM condition, one set of impact test specimens is to be taken from each batch of 50 tonnes or fraction thereof. For those in QT condition, one set of impact test specimens is to be taken from each length as heat treated.

13.2.3 When, subject to the special approval of **TL**, 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 TL-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.

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

13.3 Number of impact tests (for Grades TL-E, TL-E 32, TL-E 36, TL-E 40, TL-F 32, TL-F 36 and TL-F 40), see Tables 3.9 and 3.10

13.3.1 For plates supplied in the normalized or TM-rolled condition, one set of specimens is to be taken from each piece. 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 batch of 25 tonnes or fractions thereof.

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

13.3.4 The specimens taken as described in 13.3.2 and 13.3.3 above are to be taken from the thickest piece in each batch.

14. Retest Procedures

14.1 When the tensile test from the first piece selected in accordance with 13.1 falls to meet the requirements, re-test requirements for tensile test are to be in accordance with Section 2.

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

14.3 Re-test requirements for Charpy impact tests are to be in accordance with Section 2.

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

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

Table 3.10 Required condition of supply and number of impact tests for normal strength steels

<table>
<tr><th rowspan="3">Grade</th><th rowspan="3">Deoxidation practice</th><th rowspan="3">Products</th><th colspan="5">Condition of supply (1) (2)
(Test Batches for Impact Tests)</th></tr>
<tr><th colspan="5">Thickness t [mm]</th></tr>
<tr><th>10 – 12.5</th><th>25</th><th>35</th><th>50</th><th>100</th></tr>
<tr><td rowspan="3">TL-A</td><td>Rimmed</td><td>Sections</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)**
CR(50), AR*(50)</td></tr>
<tr><td>Sections</td><td colspan="4">A (-)</td><td>Not applicable</td></tr>
<tr><td rowspan="2">TL-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)
CR(25),AR*(25)</td></tr>
<tr><td>Sections</td><td colspan="2">A (-)</td><td colspan="2">A (50)</td><td>Not applicable</td></tr>
<tr><td rowspan="3">TL-D</td><td>Killed</td><td>Plates, Sections</td><td colspan="2">A (50)</td><td colspan="3">Not applicable</td></tr>
<tr><td rowspan="2">Fully killed and fine grain treated</td><td>Plates</td><td colspan="3">A (50)</td><td>N (50)
CR(50)
TM (50)</td><td>N (50)
TM (50)
CR(25)</td></tr>
<tr><td>Sections</td><td colspan="3">A (50)</td><td>N (50)
CR(50)
TM (50)
AR*(25)</td><td>Not applicable</td></tr>
<tr><td rowspan="2">TL-E</td><td rowspan="2">Fully killed and fine grain treated</td><td>Plates</td><td colspan="5">N (each piece)
TM (each piece)</td></tr>
<tr><td>Sections</td><td colspan="4">N (25)
TM (25)
AR*(15),CR*(15)</td><td>Not applicable</td></tr>
</table>

(1) *Condition of supply:*
A : Any
N : Normalised condition
CR : Controlled rolled condition
TM : Thermo-mechanically rolled condition
AR : As rolled condition subject to special approval of* ***TL***
CR : Controlled rolled condition subject to special approval of* ***TL***

(2) *Number of impact tests:*
One set of 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) *See Table 3.8 (5).*

Table 3.11 Required condition of supply and number of impact tests for higher strength steels

Grade	Deoxidation practice	Grain refining elements	Products	Condition of supply (Batches for Impact Tests) (1) (2) Thickness t [mm] 10 – 12.5	12.5 – 20	20 – 25	25 – 35	35 – 50	50 – 100
TL-A 32 TL-A 36	Fully killed and fine grain treated	Nb and/or V	Plates	A (50)	N (50) CR (50), TM (50)				N (50), CR (50) TM (50)
			Sections	A (50)	N (50), CR (50), TM (50) AR* (25)				Not applicable
		Al only or with Ti	Plates	A(50)		AR*(25)		Not applicable	
						N (50), CR (50), TM (50)			N (50), CR (25), TM (50)
			Sections	A(50)	N (50),CR (50), TM (50),AR* (25)				Not applicable
TL-A 40	Fully killed and fine grain treated	Any	Plates	A (50)	N (50),CR (50) TM (50)				N (50), TM (50) QT (each length as heat treated)
			Sections	A (50)	N (50),CR (50) TM (50)				Not applicable
TL-D 32 TL-D 36	Fully killed and fine grain treated	Nb and/or V	Plates	A (50)	N (50),CR (50), TM (50)				N (50), CR (25), TM (50)
			Sections	A (50)	N (50), CR (50), TM (50) AR* (25)				Not applicable
		Al only or withTi	Plates	A(50)		AR*(25)	Not applicable		
						N (50), CR (50), TM (50)			N (50), CR (25), TM (50)
			Sections	A(50)		N (50),CR (50), TM (50),AR* (25)			Not applicable
TL-D 40	Fully killed and fine grain treated	Any	Plates	N (50), CR (50) TM (50)					N (50), TM (50) QT (each length as heat treated)
			Sections	N (50), CR (50) TM (50)					Not applicable
TL-E 32 TL-E 36	Fully killed and fine grain treated	Any	Plates	N (each piece) TM (each piece)					
			Sections	N (25) TM (25) AR*(15), CR*(15)					Not applicable

Table 3.11 Required condition of supply and number of impact tests for higher strength steels (continued)

Grade	Deoxidation practice	Grain refining elements	Product	Condition of supply (Batches for Impact Tests) (1) (2) — Thickness t [mm]: 10 – 12.5 – 20 – 25 – 35 – 50	50 – 100
TL-E 40	Fully killed and fine grain treated	Any	Plates	N (each piece) TM (each piece) QT (each length as heat treated)	
			Sections	N (25) TM (25) QT (25)	Not applicable
TL-F 32 TL-F 36	Fully killed and fine grain treated	Any	Plates	N (each piece) TM (each piece) QT (each length as heat treated)	
			Sections	N (25),TM (25) QT (25), CR***(15)**	Not applicable
TL-F 40	Fully killed and fine grain treated	Any	Plates	N (each piece) TM (each piece) QT (each length as heat treated)	
			Sections	N (25) TM (25) QT (25)	Not applicable

(1) *Condition of supply:*
A : Any
N : Normalised condition
CR : Controlled rolled condition
TM : Thermo-mechanically rolled condition
QT : Quenched and tempered condition
AR : As rolled condition subject to special approval of* ***TL***
CR : Controlled rolled condition subject to special approval of* ***TL***
(2) *Number of impact tests:*
One set of impact test specimens is to be taken from each test batch or parts thereof, the weight of the test batch being stated in ( ).
For grades TL-A 32 and TL-A 36 steels a relaxation in the number of impact tests may be permitted by special agreement with ***TL*** *provided that satisfactory results are obtained from occasional check tests.*

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

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

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

15. Branding

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

- Identification mark for the grade steel (e.g. TL-A, TL-A 36),

- Steels which have been specially approved by **TL** and which differ from these requirements (see 1.4) are to have the letter "S" after the above identification mark (e.g. TL-A36 S, TL-E S),

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

- Name or initials to identify the steelworks,

- Cast or other number to identify the piece,

- If required by the purchaser, his order number or other identification mark.

15.2 Steel plates that have complied with the requirements for corrosion resistant steel will be identified by adding a corrosion designation to the unified identification mark for the grade of steel.

The corrosion resistant steel is to be designated according to its area of application as follows:

- Lower surface of strength deck and surrounding structures; **RCU**

- Upper surface of inner bottom plating and surrounding structures; **RCB**

- For both strength deck and inner bottom plating; **RCW**

Example of designation:

A36 TM RCB Z35

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

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

15.5 In the event of any material bearing **TL**'s brand failing to comply with the test requirements, the brand is to be unmistakably defaced by the manufacturer.

16. Documentation

16.1 The Surveyor is to be supplied with the number of copies as required by the TL, of the test certificates or shipping statements for all accepted materials. The TL may require separate documents of each grade of steel.

These documents are to contain, in addition to the description, dimensions, etc., of the material, at least the following particulars:

- Purchaser's order number and if known the hull number for which the material isintended.

- Identification of the cast and piece including, where appropriate, the test specimen number.

- Identification of the steelworks.

- Identification of the grade of steel.

- Ladle analysis (for elements specified in Tables 3.3 and 3.4).

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

- Condition of supply when other than as rolled i.e. normalised, controlled rolled or thermomechanically rolled.

- State if rimming steel has been supplied for grade A sections, up to 12,5 mm thick.

- 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 **TL**. 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 authorized agents:

" We hereby certify that the material has been made by an approved process and has been satisfactorily tested in accordance with **TL** Rules".

C. High-Strength Quenched and Tempered Steels for Welded Structures

1. Scope

1.1 These Rules apply to weldable high-strength quenched and tempered steel plates and wide flats up to 70 mm thick. The application of these Rules to products with larger thicknesses are to be specially agreed with **TL**. Product forms other than plates and wide flats, such as section and tubular, may be provided to these rules when specially agreed to by **TL.**

1.2 Steel covered by the scope of these rules are divided into six yield strength levels of 420, 460, 500, 550, 620 and 690 N/mm^2. For each yield strength level three grades D, E and F are specified based on the impact test temperature.

1.3 Steels differing in strength level, mechanical properties, chemical composition, etc. may be subject to special approval of **TL.**

1.4 Special consideration may be given to the supply of those steels in thicknesses up to 50 mm in the TMCP condition subject to approval of **TL.**

2. Approval

The steels are to be approved by **TL**. For this purpose, the steel manufacturer is to send **TL** 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. **TL** 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. Method of Manufacture

The steel is to be manufactured in works approved by **TL** by the basic oxygen, electric furnaces or open hearth process or by another process approved by **TL**. The steel shall be fully killed and fine grain treated.

4. Chemical Composition

The chemical composition is to be determined by the steelmaker in an adequately equipped competently staffed laboratory from each cast or ladle and is to comply with the requirements of the approved specification and limits given in Table 3.12.

Elements used for alloying and fine grain treatment are to be as detailed in the approved specification.

The cold cracking susceptibility P_{cm} for evaluating weldability may be calculated from the ladle analysis in accordance with the following formula:

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

The maximum P_{cm} to be achieved is to be agreed with **TL** and included in the approved specification.

5. Heat Treatment

The steels shall be in the quenched and tempered condition . See also C.1.4.

6. Mechanical Properties

6.1 Tensile test

6.1.1 For each piece as heat treated at least one tensile test specimen is to be taken and tested in accordance with Section 2. For continuous heat treated plates special consideration may be given regarding the number and location of test specimen required.

6.1.2 Test specimens are to be cut with their longitudinal axes transverse to the final direction of rolling, except in the case of section and rolled flats with a finished width of 600 mm or less, where the tensile specimens may be taken in either the longitudinal or transverse direction as agreed by **TL**. Normally flat tensile test specimens are to be prepared in such a manner as to maintain the rolling scale at least at one side. Where the thickness exceeds 40 mm, full thickness specimens may be prepared but when instead a machined round tensile test specimen is used then the axis must be located at a position lying at a distance of t/4 from the surface or as near as possible to this position.

6.1.3 The results of the tests are to comply with the appropriate requirements of Table 3.13. In the case of other product forms where longitudinal tests are agreed, the elongation values are to be 2 percentage units above those listed in Tables 3.13 and 3.14.

Table 3.12 Chemical composition of quenched and tempered steels

Yield strength level R_{eH} [N/mm^2]	Impact Grade	Maximum Content of Elements [%]					
		C	Si	Mn	P	S	N
420 to 690	TL-A	0.21	0.55	1.70	0.035	0.035	0.020
	TL-D	0.20	0.55	1.70	0.030	0.030	0.020
	TL-E	0.20	0.55	1.70	0.030	0.030	0.020
	TL-F	0.18	0.55	1.60	0.025	0.025	0.020

Table 3.13 Mechanical properties for products with 70 mm maximum thickness

Grades	Yield strength (1),(2) R_{eH} min. [N/mm^2]	Tensile strength R_m [N/mm^2]	A_{min} Elongation (3) $(L_0 = 5.65 \cdot \sqrt{S_0})$ [%]		Charpy V notch impact test (4)		
					Test temp. [°C]	Average energy J_{min}	
			Longitudinal	Transverse		Long.	Transv.
TL-A 420 TL-D 420 TL-E 420 TL-F 420	420	530-680	20	18	0 -20 -40 -60	42	28
TL-A 460 TL-D 460 TL-E 460 TL-F 460	460	560-720	19	17	0 -20 -40 -60	46	31
TL-A 500 TL-D 500 TL-E 500 TL-F 500	500	610-770	18	16	0 -20 -40 -60	50	33
TL-A 550 TL-D 550 TL-E 550 TL-F 550	550	670-830	18	16	0 -20 -40 -60	55	37
TL-A 620 TL-D 620 TL-E 620 TL-F 620	620	720-890	17	15	0 -20 -40 -60	62	41
TL-A 690 TL-D 690 TL-E 690 TL-F 690	690	770-940	16	14	0 -20 -40 -60	69	46

(1) *Where the yield strength R_{eH} does not mark in the tensile test, the 0.2 % proof stress $R_{p0.2}$ is applicable.*

(2) *The permissible ratio between yield strength and tensile strength is to be agreed between the manufacturer and* ***TL****.*

(3) *Where flat tensile test specimens 25 mm wide and with a gauge length of 200 mm are used, the minimum requirements in respect of elongation are to be obtained from Table 3.14.*

(4) *For TL-A grade steels, a relaxation in the number of impact tests required for acceptance purposes may be permitted by special agreement with* ***TL*** *provided that satisfactorl results are obtained from occasional check tests.*

Table 3.14 Minimum values in respect of elongation when using specimens 25 mm wide and with a gauge length of 200 mm

Nominal yield strength R_{eH} [N/mm^2]	Elongation A_{200mm} [%]						
	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	10	11	11	12	13	14

6.2 Impact test

From each piece as heat treated at least one set of three V-notch impact test specimens in accordance with Section 2 is to be taken and tested. For continuous heat treated plates special consideration may be given to the number and location of test specimens required. Unless otherwise accepted by **TL,** the V-notch impact test specimens for plates and wide flats over 600 mm are to be taken with their axes transverse to the main rolling direction and the results should comply with the appropriate requirements of Table 3.13. For other product forms the impact tests are to be in the longitudinal direction, the results of the tests are to comply with the appropriate requirements of Table 3.13.

Normally sub-surface test specimens will be taken, however, for material with a thickness in excess of 40 mm, impact tests specimens should be taken at the quarter thickness (t/4) location.

6.3 Retest procedures

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

6.4 Through Thickness Tensile Test

If required by TL, through thickness tensile tests are to be performed accordance with requirement H (UR W14).

7. Tolerances

Unless otherwise agreed or specially required, the thickness tolerances in A.6 are applicable.

8. Identification of Materials

The steelmaker is to adopt a system for the identification of ingots, slabs and finished products, which will enable the material to be traced to its original cast.

9. Inspection

9.1 Facilities for inspection

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

9.2 Freedom from defects

The steel is to be reasonably free from segregation and nonmetallic inclusions. The finished material is to be free from internal or surface defects prejudicial to the use of the materials for the intended application.

9.2.1 Welding repair procedures and the method for reporting repairs are to be approved by **TL.**

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

9.3 Surface inspection and dimensions

Surface inspection and verification of dimensions are the responsibility of the steelmaker, and acceptance by **TL**'s surveyor of material later found to be defective shall not absolve the steelmaker of this responsibility.

9.4 Ultrasonic examination

If required by **TL**, the manufacturer is to perform ultrasonic examination in accordance with an approved standard.

10. Branding

Every finished piece is to be clearly marked by the maker in at least one place with **TL**'s brand and the following particulars:

- Identification mark for the grade of steel (e.g. TL-E 620).

- Name or initials to identify the steelworks.

- Heat number, plate number or equivalent identification mark.

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

11. Documentation

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

- Purchaser's order number and if known the ship number for which the material is intended.

- Identification of the cast and piece.

- Identification of the steelworks.

- Identification of the grade of steel.

- Ladle analysis (elements given in the approved specification).

- Condition of supply with heat treatment temperatures.

Before the test certificates or shipping statements are signed by the Surveyor, the manufacturer is required to furnish him with a written declaration stating that the material has been made by an approved process and that it has been subjected to and has withstood satisfactorily the tests required by the Rules of the TL.

The name of Türk Loydu is to appear on the test certificate. The following form of declaration will be accepted if stamped or printed on each test certificate or shipping statement with the name of the steelworks and initialled for the makers by an authorised official:

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

D. Steels for Boilers and Pressure Vessels

1. Scope

These Rules apply to flat products made from high-temperature ferritic steels, which are intended for the manufacture of boilers, pressure vessels and process equipment.

2. Approved Steel Grades

The materials listed below may be used:

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

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

2.3 Flat products made of TL-steels used for pressure vessels according to Table 3.15 and 3.16. For the 0.2 % proof stress at elevated temperatures, Table 3.17 applies.

2.4 Flat products made of other steels, provided that their suitability for the intended purpose and their properties have been proved to **TL.** 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 **TL** report, but is to be not less than 16 %.

2.4.2 The impact energy is to meet or exceed the requirements of EN 10028-2 and -3 respectively for flat products of the same strength, see Table 3.15. In the case of plates to be used for shell rings and heads, the manufacturer and the steel user is to ensure that the values required for the final condition can be complied with.

2.4.3 Proof of weldability is to be furnished by the manufacturer. Details of preheating, temperature control during welding and heat treatment after welding is to be furnished by the manufacturer.

The yield strength at elevated temperature and, where necessary, the long-time rupture stress properties at elevated temperature is to be verified by the manufacturer if they are different from EN-10028-2, see Table 3.17.

Table 3.15 Mechanical and technological properties of flat products made of TL-steels used for pressure vessels (1)

Steel grade	Normal delivery condition	Yield strength R_{eH} and $R_{p0.2}$ respectvely [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.
TL-P235 W	N	235	360 ÷ 480	25	0	34
TL-P265 W	N	265	410 ÷ 530	23	0	34
TL-P295 W	N	295	460 ÷ 580	22	0	34
TL-P355 W	N	355	510 ÷ 650	21	0	34

(1) *N = Normalized*

Table 3.16 Chemical composition of TL steels used for pressure vessels

Steel grade	Chemical composition [%]							
	C	Si	Mn	P	S	$A\ell_{top}$	Cr	Mo
All	≤ 0.23	≤ 0.55	0.60 - 1.70	≤ 0.025	≤ 0.015	≥ 0.020	≤ 0.30	≤ 0.08

Table 3.17 0.2% Proof stress at elevated temperatures for flat products made of TL steels used for pressurevessels

Steel grade	$R_{p0.2}$ – Yield strength [N/mm^2] min.							
	Temperature [°C]							
	50	100	150	200	250	300	350	400
TL-P235 W	227	214	198	182	167	153	142	133
TL-P265 W	256	241	223	205	188	173	160	150
TL-P295 W	285	268	249	228	209	192	178	167
TL-P355 W	343	323	299	275	252	232	214	202

3. Condition of Supply and Heat Treatment

The products is to 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 if lower minus tolerances are required for technical reasons, this is to be stated in the order.

5. Testing

The following tests are to be performed:

5.1 Testing of chemical composition

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

5.2 Tensile test

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

5.2.1 For sheet and plate, the specimens is to 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,

- Alloy steels with rolled length > 7 m:
  one specimen from each end

5.2.2 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 is to be 300 °C, unless no other temperature is specified in the order.

5.4 Notched bar impact test

All products with thicknesses ≥ 6 mm is to be impact tested using Charpy V-notch specimens at the test temperature of 0 °C. The specimens is to be taken from the products transverse to the direction of rolling. The number of sets (each of 3 specimens) required for this purpose is to be determined in the same way as the number of tensile test specimens prescribed in 5.2.

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

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

5.5 Testing of surface finish and dimensions

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

6. Marking

The manufacturer is to mark the products in the prescribed manner, see EN 10028-1. In the case of plates which are not supplied in bundles, the marking is to 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.

E. Steels for Cargo Tanks of Gas Tankers

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.

With regard to this Section reference is made to the UR W1 of IACS.

1.2 Steels conforming to these rules are to be approved by **TL** for the above-mentioned purpose and design temperature.

To this end, the steels listed under 1.1 above are to be subjected to an approval test by **TL. TL** is to 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 3.18 provided that they satisfy the additional requirements stipulated in these Rules:

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

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

2.2 Fine-grained structural steels with nominal yield strengths above 335 N/mm^2 in accordance with EN 10028-3, -5 and -6.

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

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

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

3. Approval Test

3.1 On the subject of approval of materials, the material manufacturer or tank manufacturer is to provide **TL** with a material specification containing all the particulars needed to evaluate the material. The specification is to 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 is to 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 **TL** 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 3.18 are to apply.

5. Condition of Supply and Heat Treatment

All products are to 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 is to be the nominal thickness prescribed in the order specification.

Table 3.18 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 3.19	0
Normalized, TM rolled and finegrained structural steels with nominal yield strengths above 355 N/mm^2	e.g. according to; EN 10028-3, -5 or -6	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	-45 **(1)**
Nickel alloyd steels containing	Steels according to EN 10028-4	
% 0.5 Nickel	13 Mn Ni 6-3, 11 Mn Ni 5-3	-55
% 1.5 Nickel	15 Ni Mn 6	-60 **(2)**
% 3.5 Nickel	12 Ni 14	-90 **(2)**
% 5 Nickel	X 12 Ni 5	-105 **(2)**
% 9 Nickel	X 7 Ni 9, X 8 Ni 9	-165
Austenitic steels	e.g. steels according to EN 10028-7 1.4306 (AISI 304 L) 1.4404 (AISI 316 L) 1.4541 (AISI 321) 1.4550 (AISI 347)	-165

(1) ***TL*** *reserve the right to approve a lower design temperature (max. -55 °C) if suitable properties are demonstrated during approval testing.*

(2) *A lower design temperature may be approved for steels containing 1.5 %, 3.5 % and 5 % nickel if the steels are quenched and tempered. In these cases, the test temperatures will be specially stipulated by* ***TL****.*

7. Freedom from Defects and Repair of Surface Defects

The provisions of A.5.1 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 is to be preceded by a welding procedure test, and the conditions for welding shall then be established.

8. Requirements Applicable to the Material Properties

8.1 Chemical composition

8.1.1 The chemical composition is to conform to the data in the recognized standard or the material specification authorized by **TL**.

In addition the limiting values for the chemical composition of fine-grained structural steels with nominal yield strength of up to 355/Nmm^2 used in the fabrication of tanks carrying pressure-liquefied ammonia as given in Table 3.19 are to be met.

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

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

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

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 is to 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_5 is to be at least 22 %.

8.3 Impact energy

The required impact energy values specified in Table 3.20 and 3.21 respectively for the steel grade concerned is to 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°C 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 are to 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

The following tests are to be performed:

9.1 Test of chemical composition

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

9.2 Tensile test

All products are to be subjected to the tensile test. For this purpose, specimens is to 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.

Table 3.19 Plates, sections and forgings (1) for cargo tanks, secondary barriers (5) and process pressure vessels for design temperatures below 0ºC and down to -55ºC. Maximum thickness 25 mm (2)

Chemical Composition and Head Treatment:

Carbon-Manganese Steel. Fully killed. Aluminium treated fine grain steel.

Chemical composition (ladle analysis):

C	Mn	Si	S	P
% 0.16 max. **(3)**	% 0.70-1.60	% 0.10-0.50	% 0.035 max.	% 0.035 max.

Alloys and grain refining elements may be generally in accordance with the following.

Ni	Cr	Mo	Cu	Nb	V
% 0.80 max. **(3)**	% 0.25 max.	% 0.08 max.	% 0.35 max.	% 0.05 max.	% 0.10 max.

Normalized or quenched and tempered **(4)**

Tensile and Toughness (Impact) Test Requirements:

Plates	Each "piece" to be tested
Sections	Batch test

Charpy V-Notch Test:

Test temperatures 5 °C below the design temperature or -20°C whichever is lower

Plates	Transverse test pieces. Minimum average energy value E, 27 J.
Sections and forgings **(1)**	Longitudinal test pieces. Minimum average energy value E, 41 J

(1) *The Charpy V-notch and chemistry requirements for forgings may be specially considered.*

(2) *For material more than 25 mm thick, Charpy V-notch test are to be conducted as follows:*

Material thickness [mm]	***Test temperature [°C]***
$25 < t \leq 30$	*10°C below design temperature or -20° whichever is lower*
$30 < t \leq 35$	*15°C below design temperature or -20°C whichever is lower*
$35 < t \leq 40$	*20°C below design temperature*

The impact energy value shall be in accordance with the table for applicable type of test specimen. For material more than 40 mm thick, the Charpy V-notch values should be specially considered.

Material for tanks and parts of tanks which are completely thermally stress relieved after welding may be tested at a temperature 5°C below design temperature or -20°C whichever is lower.

(3) *By special agreement with **TL** the carbon content may be increased to 0.18% maximum provided the design temperature is not lower than -40°C.*

(4) *A controlled rolling procedure may be used as an alternative to normalizing or quenching and tempering, subject to special approval by **TL**.*

(5) *Where the secondary barrier is formed by the deck or shell side platings, the material grade required by this table should be carried into the adjacent deck or side shell platings, where applicable, to a suitable extent.*

Table 3.20 Impact energy requirements for steels used for cargo tanks

<table>
<tr><th rowspan="3">Steel designation</th><th rowspan="3">Product thickness [mm]</th><th colspan="3">Notched bar impact energy</th></tr>
<tr><th rowspan="2">Test temperature [°C]</th><th colspan="2">KV</th></tr>
<tr><th>[J] (1) Long. min.</th><th>[J] (1) Transv. min.</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/mm²</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 °C 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:*

Material thickness [mm]	*Test temperature [°C]*	
25 < t ≤ 30	*10°C*	*Below minimum design temperature but not higher than -20°C*
30 < t ≤ 35	*15°C*	
35 < t ≤ 40	*20°C*	

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°C 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 **TL**.*

(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 3.21 Requirements applicable to specimens of reduced size according to impact energy for standard specimens

Necessary impact energy acc. to Table 3.20 (standard specimens)	**Necessary impact energy KV with specimens measuring**			
	7.5 x 10 mm		**5 x 10 mm**	
Average value [J] min. **(1)**	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	22
(1) *Average value of 3 specimens; figures in brackets are minimum individual values.*				

9.2.1 The number of specimens is to 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 is to 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 is to be taken from each end.

- Sheets taken from hot-rolled wide strip which do not undergo individual heat treatment: one specimen each from the outer end of the coil.

- For plates of austenitic stainless steels one specimen of each heat treatment length. If this is greater than 15 m one specimen is to be taken from each end.

9.2.2 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: 70 N/mm^2.

9.3 Notched bar impact test

9.3.1 All products with thicknesses of ≥ 6 mm are to be subjected to the notched bar impact test performed on Charpy V-notch specimens at the test temperatures specified in Table 3.20 and 3.21 respectively. In the case of plates and wide flats with a width of ≥ 600 mm the specimens are to 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 is to 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 x 10 mm), specimens measuring 7.5 mm x 10 mm or 5 mm x 10 mm should be used wherever possible. These specimens are subject to the requirements stated in Table 3.21.

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 are to be taken from the thickest item from each heat and tested at a temperature of 5°C below the minimum design temperature. The test is only to be performed on products with a thickness of > 16 mm. It is to be conducted in accordance with a recognized standard, e.g. Stahl-Eisen-Prufblatt (Steel-iron test specification). SEP 1325, EN 10274 or ASTM E-208, see also Section 2, D.2.

9.5 Test of resistance to intercrystalline corrosion

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

9.6 Test of surface finish and dimensions

The surface finish and dimensions of all products are to 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 is also to 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 as follows:

Test grid ≤ 200 mm or in lines 100 mm apart

	EN 10160
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 respectively.

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

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

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

2.3 In the light of 2.1 and 2.2 above, suitable steels may be selected e.g. in accordance with EN 10088 relating to stainless steels, where the products are not required to be supplied in accordance with a specification which has been examined by **TL**.

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

3. Condition of Supply and Heat Treatment

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

4. Dimensional Tolerances

Unless otherwise stipulated in the order specification, plates are to be supplied in accordance with A.6. For all other products the values stated in the relevant standards is to apply.

5. General Condition of Products

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

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

6. Requirements Applicable to Material Properties

6.1 Chemical composition

6.1.1 The limit values for the chemical composition stated in the standards or in the specifications approved by **TL** are to 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 is to 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 is to be satisfied.

7. Testing

The following tests are to be performed:

7.1 Testing of chemical composition

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

7.2 Testing of resistance to intercrystalline corrosion

All products are to be tested for resistance to intercrystalline corrosion. For this purpose, at least 2 specimens are to be taken from each heat. The test is to be performed in accordance with EN ISO 3651-2 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 is to be taken from each test batch and tested. A test batch comprises:

- Plates > 20 mm thick: the rolled length

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

- Strip and plates taken there from: 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 **TL** 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 is to be agreed with **TL**.

7.5 Testing of surface finish and dimensions

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

7.6 Testing for use of correct material

The manufacturer shall test the 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 are to be performed, e.g. to ASTM-G48. The scope of these tests will be determined by **TL** from case to case.

G. Clad Steel 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. and D. are to be used as base materials. The stainless steels specified in F. and other materials approved by **TL** 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 is normally to 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 is not to impair either the chemical stability or the bonding of the cladding material. The type of heat treatment is to be notified to **TL.**

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 3.22.

Table 3.22 Minus tolerances in relation to the thickness of the cladding material

Nominal thickness [mm]	Minus tolerance [mm]
2.0 ≤ t < 2.5	-0.20
2.5 ≤ t < 3.0	-0.25
3.0 ≤ t < 3.5	-0.35
3.5 ≤ t < 4.0	-0.45
t ≥ 4.0	-0.50

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

6. Surface Finish

6.1 The cladding materials are to have a smooth surface consistent with their purpose. The surface is to 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 is to comply with A.5. On the cladding material, the total surface area of all defects, with the exception of shallow defects as per 7.1, shall not exceed 20 % of the surface area of the cladding.

7. Repair of Defects

7.1 Shallow defects in the cladding material, e.g. impressions, grooves and scratches, are to 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 is to be subject to the following requirements:

7.3.1 All welds is to be made by qualified welders using a technique approved by **TL**.

7.3.2 The welds are to 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 is to be ground flush with the plate. Welding is to 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 are to be submitted to the Surveyor for final testing, and a suitable non-destructive test technique, e.g. dye penetrant inspection, is to be used to prove that the repairs are free from defects.

7.3.5 For each repair weld the manufacturer is to 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 Properties

The clad steels are to 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 is to attain an elongation A_5 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 are to 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 is to 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 is to be at least 95 %, and the area of isolated points where bonding has not occurred is not to 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:

$$\sigma_{PL} = \frac{\sigma_G \cdot S_G + \sigma_A \cdot S_A}{S_{PL}}$$

σ = Specified minimum value of tensile strength or yield strength or 0.2 % proof stress [N/mm^2],

S = Nominal thickness [mm]

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 is to be verified by tests performed on clad specimens.

8.5 Technological properties

When subjected to the side bend test, the clad plate is to be capable of being bent through 180° over a mandrel with a diameter equal to four times the thickness of the specimen without separation of the cladding material or formation of incipient cracks.

Larger bending mandrel diameters may be agreed for other cladding materials, e.g. aluminium.

8.6 Impact energy

The requirements applicable to the base material are to 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 is to 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 is to determine the chemical composition of each heat of base and cladding material and is to 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 is to be verified for each test batch. For this purpose, those plates may be grouped together into a test batch which have been clad in the same manufacturing cycle with cladding materials originating from the same heat. Under test, the clad side is to 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 is to be left on the test specimen. The gauge marks is to be applied to the base material side.

9.4 Shear test

From each test batch a specimen is to be taken with its axis transverse to the rolling direction and this is to be subjected to the shear test.

The test shall be performed in accordance with a recognized standard, e.g.. ASTM A 264.

9.5 Side bend test

From each test batch a specimen is to be taken with its axis transverse to the rolling direction and this is to be subjected to the side bend test.

9.6 Notched bar impact test

The notched bar impact test is to 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 are to be checked by the manufacturer and the thickness of the cladding is to be measured at the edges and in the middle of the plate. All plates is to 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.

H. Steels with Specified Minimum through Thickness Properties

1. Scope

These rules are supplementary those given in B. and C. for material with a thickness greater than or equal to 15 mm and intended to have a specified minimum ductility in the through thickness or “Z” direction (see Figure 3.8). Products with a thickness less than 15 mm may be included at the discretion of **TL**.

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, Z 25 for normal ship applications and Z 35 for more severe applications.

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

2. Manufacture

All the materials are to be manufactured at works approved by **TL** for “Z” quality steels.

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

3. Chemical Composition

In addition to the requirements of the appropriate steel specification B. and C. the maximum sulphur content is to be 0.008 % determined by the ladle analysis.

4. Test Procedure

In addition to the requirements of the appropriate steel specification B. and C. preparation of specimens and testing procedures are to be as follows.

4.1 Test sampling

For plates and wide flats, one test sample is to be taken close to the longitudinal centreline of one end of each rolled piece representing the batch. See Table 3.23 and Figure 3.9.

4.2 Number of tensile test specimens

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

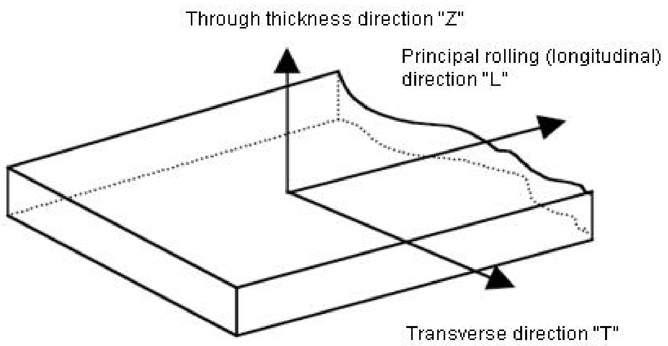


Figure 3.8 Schematic of testing directions

Table 3.23 Batch size dependent on product and sulphur content

Product	S > 0.005%	S ≤ 0.005%
Plates	Each piece (parent plate)	Maximum 50 t of products of the same cast, thickness and heat treatment
Wide flats of nominal thickness ≤ 25 mm	Maximum 10 t of products of the same cast, thickness and heat treatment	
Wide flats of nominal thickness > 25 mm	Maximum 20 t of products of the same cast, thickness and heat treatment	

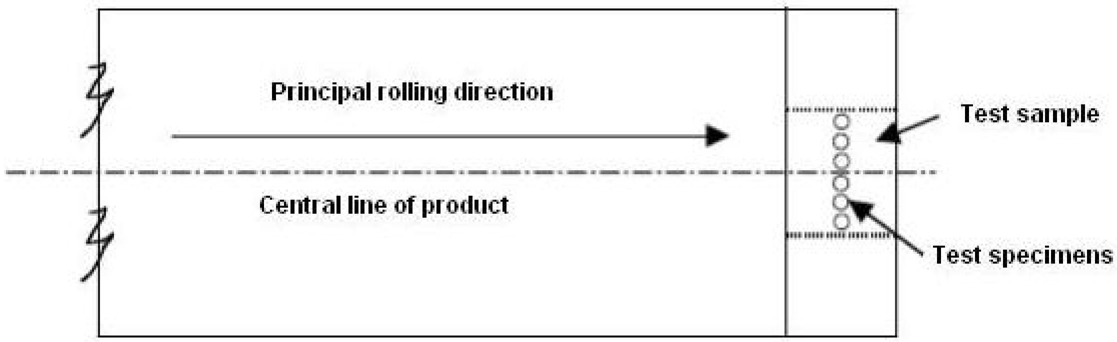


Figure 3.9 Plate and wide flat sampling position

4.3 Tensile test specimen

4.3.1 Cylindrical tensile test specimens are to be used having the following dimensions:

Diameter:

- d = 6 mm for product thickness between 15 mm and 25 mm.
- d = 10 mm for product thickness exceeding 25 mm.

Parallel length: not less than 2 d.

Other dimensions are to be in accordance with recognized standards.

4.3.2 The preparation of specimens are indicated in Figure 3.10 and 3.11.

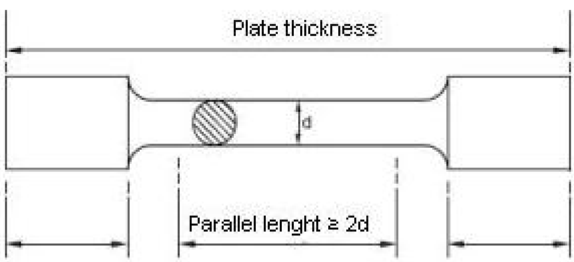


Figure 3.10 Normal test specimen

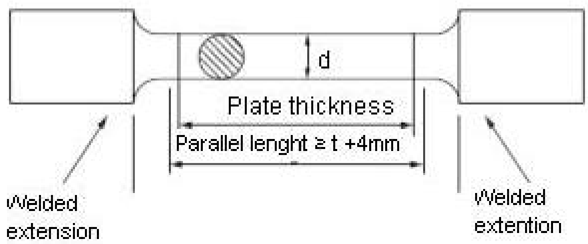


Figure 3.11 Welded test specimen

4.4 Tensile test results

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

The minimum average value for the reduction of area of at least 3 tensile test specimens taken in the through thickness direction must be that shown for the appropriate grade given in Table 3.24. Only one individual value may be below the minimum average but not less than minimum individual value shown for the appropriate grade. See Figure 3.12.

A value less than the minimum individual value is a cause for rejection.

Table 3.24 Reduction of area acceptable values

Grade	Z 25	Z 35
Minimum average	25 %	35 %
Minimum individual	15 %	25 %

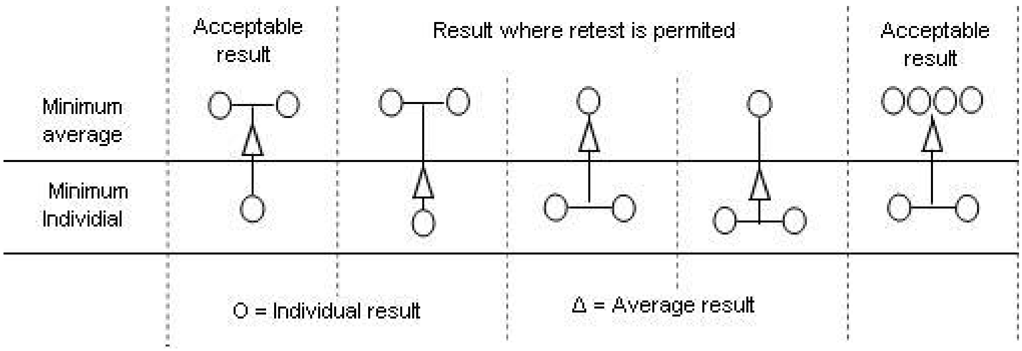


Figure 3.12 Diagram showing acceptance/rejection and retest criteria

5. Retest Procedure

Figure 3.12 shows the three cases where a retest situation is permitted. In these instances three more tensile tests are to be taken from the remaining test sample. The average of all 6 tensile tests is to be greater than the required minimum average with no greater than two results below the minimum average.

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

6. Ultrasonic Tests

Ultrasonic testing is required and is to be performed in accordance with either EN 10160 Level S1/E1 or ASTM A 578/A578M Level C.

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

7. Marking

Products complying with these rules are to be marked in accordance with the appropriate steel requirement B or C and in addition with the notation Z25 or Z35 added to the material grade designation, e.g. TL-E32 Z35.

8. Certification

The following information is required to be included on the certificate in addition to the appropriate steel requirement given in B or C:

- Through thickness reduction in area (%)
- Steel grade with Z25 or Z35 notation.

I. 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 B.

2. Suitable Steels

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

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

– S235: all grades

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

- S275: all grades

- S355: all grades

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

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

and conforming to EN 10025-4 in the grades:

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

2.3 Other steels after their suitability has been determined by **TL**, 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_5 shall be at least 20 % in tests with longitudinal specimens and 18 % in tests with transverse specimens.

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

- 20°C, for products supplied in normalised, normalising rolled or thermo-mechanically rolled condition

0 °C, for products supplied in as rolled condition.

3. Condition of Supply and Heat Treatment

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

4. Dimensions, Dimensional and Geometrical Tolerances

A.6. applies, with the following addition:

For the minus tolerance applicable to the nominal thickness, the values stated Table 3.2 apply to plates, strips and wide flats, unless otherwise specified in the purchase order.

5. Testing and Scope of Tests

The following tests shall be performed:

5.1 Test of chemical composition

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

5.2 Tensile test

5.2.1 The mechanical properties shall be verified by tensile test.

For the purpose of taking specimens, products of the same shape shall be formed according to heat and within the thickness ranges relevant to the yield strength into test batches of not more than 40 t. A tensile test specimen shall be taken from the thickest item in the test batch. In the case of plates and wide flats with a width of ≥ 600 mm, this shall be positioned transverse to the rolling direction. In other products, the test specimen may lie transverse or parallel to the rolling direction.

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

5.3 Notched bar impact test

All products made of fine grain treated steels shall be subjected to notched bar impact tests performed with longitudinal Charpy V-notch specimens at the test temperatures specified in the standards or in 2.3.3.

Where, in the case of plates, individual testing has not been agreed, a set of test specimens shall be taken from the thickest piece in the test batch in accordance with 5.2.1.

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

5.4 Testing of surface finish and dimensions

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

J. Requirements for Use of Extremely Thick Steel Plates on Container Carriers (1)

1. Application of TL-EH47 Steel Plates

1.1. Application

1.1.1 General

1.1.1.1 This subsection is to be complied with for container carriers incorporating extremely thick steel plates in accordance with 1.1.2.1.

1.1.1.2 These Rules give the basic concepts for application of TL-EH47 steel plates 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 TL-EH47 steel plate for other hull structures.

1.1.1.3 Unless otherwise specified in this subsection, Section 3 is to be followed.

1.1.1.4 TL-EH47 steel plates mean the steel plates of specified minimum yield point of 460 N/mm^2. The scope of application is defined under 1.1.2 and 1.1.3.

1.1.2 Thickness

1.1.2.1 This subsection gives the requirements for steel plates with thickness of over 50mm and not greater than 100mm.

1.1.2.2 For steel plates outside of this thickness range, special consideration is to be given by **TL**.

1.2. General

1.2.1 Hull structures (design)

1.2.1.1 HT factor (Material factor of high tensile steel, K) HT factor for the assessment of hull girder strength is to be taken as 0.62.

1.2.1.2 Fatigue assessment

Fatigue assessment on the longitudinal structural members is to be performed in accordance with procedures of **TL**.

1.2.1.3 Details of construction design

Special consideration is to be paid to the details of constructions of structural members where TL-EH47 steel plates are applied such as connections between outfitting and hull structures.

Connections are to be in accordance with procedures of **TL**.

1.2.2 Material specifications

1.2.2.1 Material specifications for TL-EH47 steel plates are defined in Table 3.25 and Table 3.26.

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(1) *This subsection is to be applied to ships contracted for construction on or after 1 January 2014.*

Table 3.25 Conditions of supply, grade and mechanical properties for TL-EH47 steel plates

Supply condition	Grade	Mechanical Properties			Impact test			
		Yield Strength (N/mm^2) min.	Tensile Strength (N/mm^2)	Elongation (%) min	Test Temp. (oC)	Average Impact Energy (J) min.		
						$50 < t \leq 70$	$70 < t \leq 85$	$85 < t \leq 100$
TMCP*	TL-EH47	460	570/720	17	$-40^{o}C$	53	64	75

Note:
t: thickness (mm)
* *Other conditions of supply are to be in accordance with procedures of **TL**.*

Table 3.26 Chemical compositions for TL-EH47 steel plates

Chemical composition	C_{eq}*1	P_{cm}*2
As approved by **TL**	≤ 0.49%	≤ 0.22%

Note:
**1 The carbon equivalent C_{eq} value is to be calculated from the ladle analysis using the following formula.*

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

**2 Cold cracking susceptibility is to be calculated using the following formula.*

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

The extent of testing is to be one set of three specimens taken from each piece defined in B.11.1.

1.2.3 Manufacturing approval test

1.2.3.1 General

Approval test items, test methods and acceptance criteria not specified in this document are to be in accordance with procedures of **TL**.

1.2.3.2 Approval range

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

1.2.3.3 Base Metal test

(a) Charpy V-notch Impact Tests

Generally Charpy V-notch impact testing is to be carried out in accordance with this Section 3.

Test samples are to be taken from the plate corresponding to the top of the ingot, unless otherwise agreed.

In the case of continuous castings, test samples are to be taken from a randomly selected plate.

The location of the test sample is to be at the square cut end of the plate, approximately onequarter width from an edge, as shown Figure 3.13.

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

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

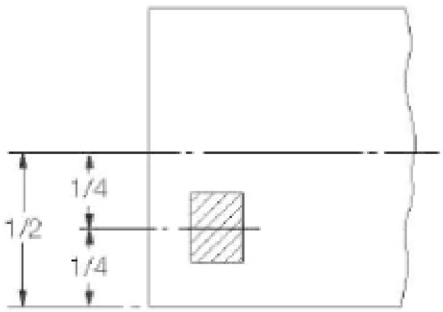

Figure 3.13 Plates and flats

Charpy V-notch impact tests are required from both the quarter and mid thickness locations of the test samples.

One set of 3 Charpy V-notch impact specimens is required for each impact test.

The Charpy V-notch impact test temperature is to be -40°C.

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

The strain aged samples are to be strained to 5% followed by heating to 250°C for 1 hour prior to testing.

Additionally at each location, Charpy V-notch impact tests are to be carried out with appropriate temperature intervals to properly define the full transition range.

(b) Brittle fracture initiation test

Deep notch test or Crack Tip Opening Displacement (CTOD) test is to be carried out and the result is to be reported.

Test method is to be in accordance with **TL**'s practice.

(c) Naval Research Laboratory (NRL) drop weight test

The test method is to comply with ASTM E208 or equivalent method.

Nil Ductility Test Temperature (NDTT) is to be reported for reference.

(d) Brittle crack arrest test

Standard ESSO test described in Annex 2 of J.2 (Safety Measures of Extremely Thick Steel Plates) or other alternative test (e.g. double tension test etc.) is to be carried out in order to obtain the brittle crack arrest toughness for reference.

1.2.3.4 Weldability test

(a) Charpy V-notch Impact Test

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

One set of the specimens transverse to the weld is to be taken with the notch located at the fusion line and at a distance 2, 5 and minimum 20 mm from the fusion line.

The fusion boundary is to be identified by etching the specimens with a suitable reagent.

One additional set of the specimens is to be taken from the root side of the weld with the notch located at the same position and at the same depth as for the face side.

The impact test temperature is -40°C.

Additionally at each location, impact tests are to be carried out with appropriate temperature intervals to properly define the full transition range.

(b) Y- shape weld crack test (Hydrogen crack test)

The test method is to be in accordance with recognized national standards such as KS B 0870, JIS Z 3158 or GB 4675.1.

Acceptance criteria are to be in accordance with **TL**'s practice.

(c) Brittle fracture initiation test

Deep notch test or CTOD test is to be carried out.

Test method and results are to be considered appropriate by **TL**.

1.2.4 Welding works

1.2.4.1 Welder

Welders engaged in TL-EH47 welding work are to possess welder's qualifications specified in procedures of TL.

1.2.4.2 Short bead

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

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

1.2.4.3 Preheating

Preheating is to be 50°C or over when air temperature is 5°C or below.

In the case where Pcm is less than or equal to 0.19, air temperature of 0°C or below may be adopted with approval of **TL**.

1.2.4.4 Welding consumable

Specifications of welding consumables for TL-EH47 steel plates are to be in accordance with Table 3.27.

Consumable tests for butt weld assemblies are to be in accordance with Table 3.28.

Table 3.27 Mechanical properties for deposited metal tests for welding consumables

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.
460	570/720	19	-20	53

Table 3.28 Mechanical properties for butt weld tests for welding consumables

Tensile strength (N/mm^2)	Bend test ratio: D t	Charpy V-notch impact tests		
		Test temperature (°C)	Average energy (J) min.	
			Downhand, horizontal-vertical, overhead	Vertical (upward and downward)
570 - 720	4	- 20	53	53

1.2.4.5 Others

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

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

1.2.5 Welding Procedure Qualification Test

1.2.5.1 General

Approval test items, test methods and acceptance criteria not specified in this document are to be in accordance with procedures of **TL**.

1.2.5.2 Approval range

Chapter 3 Welding Section 12.F is to be followed for approval range.

1.2.5.3 Impact test

Chapter 3 Welding Section 12.F is to be followed for impact test. 64J at -20°C is to be satisfied.

1.2.5.4 Hardness

HV10, as defined in Chapter 3 Welding Section 12.F, is to be not more than 380. Measurement points are to include mid-thickness position in addition to the points required by Chapter 3 Welding Section 12.F.

1.2.5.5 Tensile test

Tensile strength in transverse tensile test is to be not less than 570N/mm^2.

1.2.5.6 Brittle fracture initiation test

Deep notch test or CTOD test may be required.

Test method and acceptance criteria are to be considered appropriate by **TL**.

2. Requirements for Use of Extremely Thick Steel Plates

2.1 Application

2.1.1 General

2.1.1.1 This subsection is to be complied with for container carriers incorporating extremely thick steel plates in accordance with 2.1.2 and 2.1.3.

2.1.1.2 These Rules give measures for identification and prevention of brittle fractures of container carriers to which extremely thick steel plates are applied for longitudinal structural members.

2.1.1.3 The application of the measures specified in 2.2, 2.3 and 2.4 is to be in accordance with Annex 1.

2.1.1.4 Brittle fracture toughness of welded joints is to comply with Section 3, Chapter 3 Welding Section 12.F and Section 3 J.1 (Application of TL-EH47 steel plates) where applicable in addition to the requirements of this subsection.

2.1.2 Steel Grade

2.1.2.1 This subsection is to be applied to container carriers to which any of TL-EH36, TL-EH40 and TL-EH47 steel plates having the thickness specified in 2.1.3 for the longitudinal structure members.

Note:
TL-EH36, TL-EH40 and TL-EH47 means the steel plates having the minimum specified yield points of 355, 390 and 460 N/mm^2, respectively.

2.1.3 Thickness

2.1.3.1 For steel plates with thickness of over 50mm and not greater than 100mm, the measures for prevention of brittle crack initiation and propagation specified in this document are to be taken.

2.1.3.2 For steel plates with thickness exceeding 100mm, appropriate measures for prevention of brittle crack initiation and propagation are to be taken in accordance with **TL**’s decision considering this document.

2.2 Non-Destructive Testing (NDT) during construction (Measure No.1 of Annex 1)

Where NDT during construction is required in Annex 1, the NDT is to be in accordance with 2.2.1 and 2.2.2. Enhanced NDT as specified in 2.4.3.1(e) is to be carried out in accordance with the appropriate standard.

2.2.1 General

2.2.1.1 Ultrasonic testing (UT) in accordance with IACS Rec.20 or **TL**'s requirement is to be carried out on all block-to-block butt joints of all upper flange longitudinal structural members in the cargo hold region. Upper flange longitudinal structural members include the topmost strakes of the inner hull/bulkhead, the sheer strake, main deck, coaming plate, coaming top plate, and all attached longitudinal stiffeners. These members are defined in Figure 3.14.

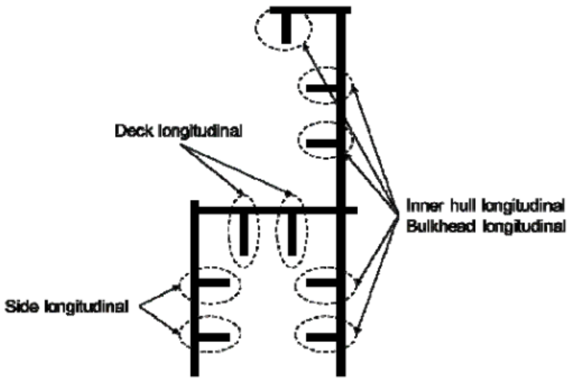

Figure 3.14 Upper Flange Longitudinal Structural Members

2.2.2 Acceptance criteria of UT

2.2.2.1 Acceptance criteria of UT are to be in accordance with IACS Rec.20 or **TL**'s practice.

2.2.2.2 The acceptance criteria may be adjusted under consideration of the appertaining brittle crack initiation prevention procedure and where this is more severe than that found in IACS Rec.20, the UT procedure is to be amended accordingly to a more severe sensitivity.

2.3. Periodic NDT after delivery (Measure No.2 of Annex 1)

Where periodic NDT after delivery is required, the NDT is to be in accordance with 2.3.1, 2.3.2 and 2.3.3.

2.3.1 General

2.3.1.1 The procedure of the NDT is to be in accordance with IACS Rec.20 or **TL**'s requirements.

2.3.2 Timing of UT

2.3.2.1 Where UT is carried out, the frequency of survey is to be in accordance with requirements of **TL**.

2.3.3 Acceptance criteria of UT

2.3.3.1 Where UT is carried out, acceptance criteria of UT are to be in accordance with IACS Rec.20 or **TL**'s practice.

2.4. Brittle crack arrest design (Measure No.3, 4 and 5 of Annex 1)

2.4.1 General

2.4.1.1 Measures for prevention of brittle crack propagation, which is the same meaning as Brittle crack arrest design, are to be taken within the cargo hold region.

2.4.1.2 The approach given in this section generally applies to the block-to-block joints but it should be noted that cracks can initiate and propagate away from such joints. Therefore, appropriate measures should be considered in accordance with 2.4.2.1 (b) (ii).

2.4.1.3 Brittle crack arrest steel is defined as steel plate with measured crack arrest properties, K_{ca} at -10 degree C ≥ 6,000 N/mm$^{3/2}$ or other methods based on the determination of Crack Arrest Temperature (CAT).

Note 1:

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

Note 2:

Where the thickness of the steel exceeds 80 mm the required Kca value or alternative crack arrest parameter for the brittle crack arrest steel plate is to be specifically agreed with ***TL****.*

2.4.2 Functional requirements of brittle crack arrest design

2.4.2.1 The purpose of the brittle crack arrest design is aimed at arresting propagation of a crack at a proper position and to prevent large scale fracture of the hull girder.

(a) The point of a brittle crack initiation is to be considered in the block-to-block butt joints both of hatch side coaming and upper deck.

(b) Both of the following cases are to be considered:

(i) where the brittle crack runs straight along the butt joint, and

(ii) where the brittle crack initiates or deviates away from the butt joint and runs into base metal.

2.4.3 Concept examples of brittle crack arrest design

2.4.3.1 The following are considered to be acceptable examples of brittle crack arrest-design.

The detail design arrangements are to be submitted for approval by **TL**. Other concept designs may be considered and accepted for review by **TL**.

Brittle crack arrest design for 4.2.1(b)(ii):

(a) Brittle crack arresting steel is to be used for the upper deck along the cargo hold region in a way suitable to arrest a brittle crack initiating from the coaming and propagating into the structure below.

Brittle crack arrest design for 4.2.1(b)(i):

(b) Where the block to block butt welds of the hatch side coaming and those of the upper deck are shifted, this shift is to be greater than or equal to 300mm. Brittle crack arrest steel is to be provided for the hatch side coaming.

(c) Where crack arrest holes are provided in way of the block-to-block butt welds at the region where hatch side coaming weld meets the deck weld, the fatigue strength of the lower end of the butt weld is to be assessed. Additional countermeasures are to be taken for the possibility that a running brittle crack may deviate from the weld line into upper deck or hatch side coaming. These countermeasures are to include the application of brittle crack arrest steel in hatch side coaming.

(d) Where Arrest Insert Plates of brittle crack arrest steel or Weld Metal Inserts with high crack arrest toughness properties are provided in way of the block-to-block butt welds at the region where hatch side coaming weld meets the deck weld, additional countermeasures are to be taken for the possibility that a running brittle crack may deviate from the weld line into upper deck or hatch side coaming. These countermeasures are to include the application of brittle crack arrest steel in hatch side coamings.

(e) The application of enhanced NDT particularly time of flight diffraction (TOFD) technique using stricter defect acceptance in lieu of standard UT technique specified in 2.2 can be an alternative to (b), (c) and (d).

Annex 1

Measures for Extremely Thick Steel Plates

The thickness and the yield strength shown in the following table apply to the hatch coaming structure, and are the controlling parameters for the application of countermeasures.

If the as built thickness of the hatch coaming structure is below the values contained in the table, countermeasures are not necessary regardless of the thickness and yield strength of the upper deck.

Yield Strength (kgf/mm^2)	Thickness (mm)	Option	Measures			
			1	2	3+4	5
36	50 < t ≤ 85	-	N.A.	N.A.	N.A.	N.A.
	85 < t ≤ 100	-	X	N.A.	N.A.	N.A.
40	50 < t ≤ 85	-	X	N.A.	N.A.	N.A.
	85 < t ≤ 100	A	X	N.A.	X	X
		B	X*	N.A.**	N.A.	X
47 (FCAW)	50 < t ≤ 100	A	X	N.A.	X	X
		B	X*	N.A.**	N.A.	X
47 (EGW)	50 < t ≤ 100	-	X	N.A.	X	X

Measures:

1 NDT other than visual inspection on all target block joints (during construction) See J.2.2

2 Periodic NDT other than visual inspection on all target block joints (after delivery) See J.2.3.

3 Brittle crack arrest design against straight propagation of brittle crack along weldline to be taken (during construction) See J.2.4.3.1 (b), (c) or (d).

4 Brittle crack arrest design against deviation of brittle crack from weldline (during construction) See J.2.4.3.1 (a).

5 Brittle crack arrest design against propagation of cracks from other weld areas such as fillets and attachment welds. (during construction) See J.2.4.3.1 (a).

Symbols:

(a) "X" means "To be applied".

(b) "N.A." means "Need not to be applied".

(c) Selectable from option "A" and "B".

Note:

*: See J.2.4.3 (e).

: may be required at the discretion of **TL.

Annex 2

Standard ESSO Test

1. Scope

1.1 The ESSO test method is used to estimate the brittle crack arrest toughness value Kca of rolled steel plates for hull of thickness 100 mm or less.

2. Symbols

Table 1 Symbols used and their meanings

Symbol	Unit	Meaning
t_S	mm	Thickness of test specimen
W_S	mm	Width of test specimen
L_S	mm	Length of test specimen
t_r	mm	Thickness of tab plate
W_r	mm	Width of tab plate
L_r	mm	Length of tab plate
L_P	mm	Distance between pins
a	mm	Length of crack projected on surface normal to the line of load
a_a	mm	Maximum crack length at brittle crack arrest position
T	^oC	Temperature of test specimen
dT/da	$^oC/mm$	Temperature gradient of test specimen
σ	N/mm^2	Gross stress in tested part (*load* / W_S .t_S)
K_{ca}	$N/mm^{3/2}$	Brittle crack arrest toughness value

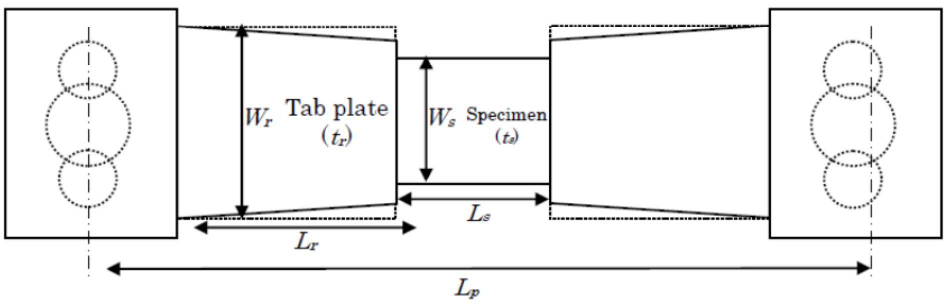

Figure 1 Conceptual view of test specimen, tab and load jig

3. Purpose

3.1 The purpose of this test is to encourage the performance of a standard test for assessment of brittle crack arrest toughness with temperature gradient and to obtain the corresponding brittle crack arrest toughness value K_{ca}.

4. Standard test specimen

4.1 Figure 2 shows the shape and size of the standard test specimen.

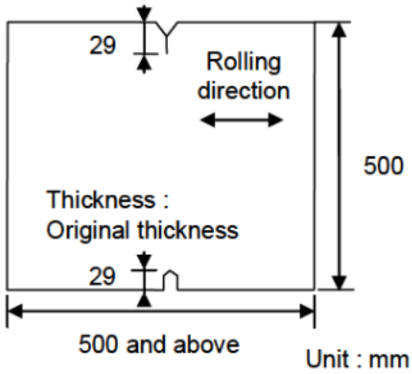

Figure 2 Shape and size of specimen

4.2 The thickness and width of the test specimen are to be in accordance with Table 2.

Table 2 Thickness and width of test specimen

Thickness, t_S	100 mm and below
Width of test specimen, W_S	500 mm

Note:
If the width of the test specimen cannot be made at 500 mm, it may be taken as 600 mm.

4.3 The test specimens are to be taken from the same steel plate.

4.4 Test specimens are to be taken in such a way that the axial direction of the load is parallel to the rolling direction of the steel plate.

4.5 The thickness of the test specimen is to be the same as the thickness of the steel plate to be used in the vessel structure.

5 Test equipment

5.1 The test equipment to be used is to consist of pin load type hydraulic test equipment capable of tensile tests.

5.2 The distance between the pins is to be not less than 2,000 mm. The distance between pins refers to the distance between the centres of the pin diameters.

5.3 Drop weight type or air gun type impact equipment may be used for the impact energy required for generating brittle cracks.

5.4 The wedge is to have an angle greater than the upper notch of the test specimen, and an opening force is to be applied on the notch.

6 Test preparations

6.1 The test piece is to be fixed directly to the pin load jig or by means of weld joint through the tab plate. The overall length of the test specimen and tab plate is to be not less than 3Ws. The thickness and width of the tab plate are to be in accordance with Table 3.

Table 3 Allowable dimensions of tab plate

	Thickness: t_r	Width: W_r
Dimensions of tab plate	$0.8t_s$ (Notes 1 and 2) $\leq t_r \leq 1.5t_s$	$W_s \leq W_r \leq 2W_s$

Note 1: ts : Thickness of test specimen

Note 2: If the tab plate has a thickness smaller than the test specimen, the reflection of stress wave will be on the safer side for the assessment; therefore, considering the actual circumstances for conducting the test, the lower limit of thickness is taken as 0.8ts.

6.2 Thermocouples are to be fitted at 50 mm pitch on the notch extension line of the test specimen.

6.3 If the brittle crack is estimated to deviate from its presumed course, thermocouples are to be fitted at two points separated by 100 mm on the line of load from the notch extension line at the centre of width of the test specimen.

6.4 If dynamic measurements are necessary, strain gauges and crack gauges are to be fitted at specific locations.

6.5 The test specimen is to be fixed to the testing machine together with the tab plate after welding and the pin load jig.

6.6 The impact equipment is to be mounted. The construction of the impact equipment is to be such that the impact energy is correctly transmitted. An appropriate jig is to be arranged to minimize the effect of bending load due to the impact equipment.

7. Test method

7.1 To eliminate the effect of residual stress or correct the angular deformation of tab welding, a preload less than the test load may be applied before cooling.

7.2 Cooling and heating may be implemented from one side on the side opposite the side on which the thermocouple is fitted, or from both sides.

7.3 The temperature gradient is to be controlled in the range of 0.25oC/mm to 0.35oC/mm in the range of width from 0.3Ws to 0.7Ws at the central part of the test specimen.

7.4 When the specific temperature gradient is reached, the temperature is to be maintained for more than 10 minutes, after which the specified test load may then be applied.

7.5 After maintaining the test load for at least 30 seconds, a brittle crack is to be generated by impact. The standard impact energy is taken as 20 to 60 J per 1 mm plate thickness. If the brittle crack initiation characteristics of the base metal are high, and it is difficult to generate a brittle crack, the impact energy may be increased to the upper limit of 120 J per 1 mm plate thickness.

7.6 Loading is stopped when the initiation, propagation, and arrest of crack have been confirmed. Normal temperature is restored, and if necessary, the ligament is broken by gas cutting and forcibly the specimen is broken by using the testing machine. Or, after the ductile crack has been propagated to an adequate length with the testing machine, the ligament is broken by gas cutting.

7.7 After forcing the fracture, photos of the fractured surface and the propagation route are to be taken, and the crack length is to be measured.

8 Test results

8.1 The distance from the top of the test specimen including the notch to the maximum length in the plate thickness direction of the arrested crack tip is to be measured. If the crack surface deviates from the surface normal to the line of load of the test specimen, the projected length on the surface normal to the line of load is to be measured. In this case, if the trace of brittle crack arrest is clearly visible on the fractured surface, the first crack arrest position is taken as the arrest crack position.

8.2 From the results of thermocouple measurement, the temperature distribution curve is to be plotted, and the arrest crack temperature is to be measured corresponding to the arrest crack length.

8.3 The brittle crack arrest toughness value (Kca value) of each test is to be determined by using the following formula:

$$K_{ca} = \sigma\sqrt{\pi a}\sqrt{\left(\frac{2W_S}{\pi a}\right)\tan(\pi a / 2W_S)}$$

9 Report

9.1 The following items are to be reported:

(i) Testing machine specifications; testing machine capacity, distance between pins (Lp) (ii) Load jig dimensions; tab plate thickness (tr), tab plate width (Wr), test specimen length including tab plate (Ls + 2Lr)

(iii) Test specimen dimensions; plate thickness (ts); test specimen width (Ws) and length (Ls)

(iv) Test conditions; preload stress, test stress, temperature distribution (figure or table) impact energy

(v) Test results; crack arrest length (aa), temperature gradient at arrest position, brittle crack arrest toughness (Kca)

(vi) Dynamic measurement results (if measurement is carried out); crack growth rate, strain change

(vii) Test specimen photos; fracture route, fractured surface

9.2 If the conditions below are not satisfied, the test results are to be treated as reference values.

(i) The brittle crack arrest position is to be in the range of the hatched part shown in Figure 3.

In this case, if the brittle crack arrest position is more than 50 mm away from the centre of the test specimen in the longitudinal direction of the test specimen, the temperature of the thermocouple at the ±100 mm position is to be within ±3oC of the thermocouple at the centre.

(ii) The brittle crack should not have a distinct crack bifurcation while it propagates.

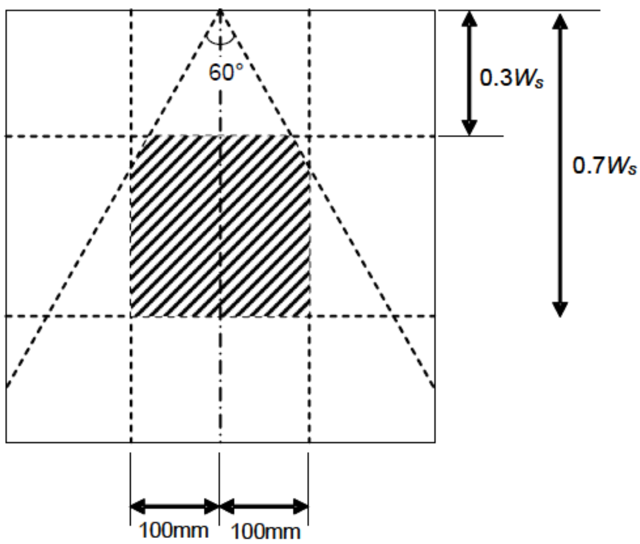

Figure 3 Necessary conditions of arrest crack position

9.3 From effective test results measured at more than 3 points, the linear approximation equation is to be determined on the Arrhenius plot, and Kca at the desired temperature is to be calculated. In this case, data should exist on both sides, that is, the high temperature and low temperature sides around the assessed temperature.

K. Approval of Manufacturing Scheme of Hull Structural Steels

1. Approval of manufacturing scheme of semi finished products for hull structural steels should be according to Appendix A1 (UR W11).

2. Approval of manufacturing scheme of hull structural steels should be according to Appendix A2 (UR W11).

3. Approval scheme for manufacturer of hull structural steels intended for welding with high heat input should according to Appendix B (UR W11).

Appendix A

Manufacturing Approval Scheme of Hull Structural Steels

A1. Manufacturing Approval Scheme of Semi Finished Products for Hull Structural Steels

1. Scope of application

This document specifies, as given in A.3.1, the scheme for the approval of the manufacturing process of semi-finished products such as ingots, slabs, blooms and billets for the structural steels.

The manufacturing approval scheme is valid for verifying the manufacturer's capability to provide satisfactory products stably under effective process and production controls in which is required in A.3.2.

2. Approval application

2.1 Documents to be submitted

The manufacturer has to submit to **TL**, request of approval, proposed approval test program (see 3.1) and general information relevant to:

a) Name and site address of the manufacturer, location of the workshops, general indications relevant to the background, dimension of the works, estimated total annual production of finished products for shipbuilding and for other applications, as deemed useful.

b) Organization and quality:

- Organizational chart
- Staff employed
- Staff employed and organization of the quality control department
- Qualification of the personnel involved in activities related to the quality of the products
- Certification of compliance of the quality system with ISO 9001, if any
- Approval certificates already granted by other classification societies, if any

c) Manufacturing facilities

- Flow chart of the manufacturing process
- Origin and storage of raw materials
- Storage of finished products
- Equipment for systematic control during fabrication

d) Details of inspections and quality control facilities

- Details of system used for identification of materials at the different stages of manufacturing
- Equipment for chemical analyses and relevant calibration procedures
- List of quality control procedures

e) Type of products (ingots, slabs, blooms, billets); types of steel (normal or higher strength), range of thickness and aim material properties as follows:

- Range of chemical composition and aim analyses, including grain refining, micro alloying and residual elements, for the various grades of steel; if the range of chemical composition depends on thickness and supply condition, the different ranges are to be specified, as appropriate
- Aim maximum carbon equivalent according to ııw formula
- Aim maximum P_{cm} content for higher strength grades with low carbon content C < 0.13 %
- Production statistics of the chemical composition and, if available at rolling mills, mechanical properties (R_{eH}, R_m, A% and KV). The statistics are intended to demonstrate the capability to manufacture the steel products in accordance with the requirements.

f) Steelmaking

- Steel making process and capacity of furnace/s or converter/s
- Raw material used
- Deoxidation and alloying practice

- Desulphurisation and vacuum degassing installations, if any
- Casting methods: ingot or continuous casting. In the case of continuous casting, information relevant to type of casting machine, teeming practice, methods to prevent re-oxidation, inclusions and segregation control, presence of electromagnetic stirring, soft reduction, etc., is to be provided as appropriate.
- Ingot or slab size and weight
- Ingot or slab treatment: scarfing and discarding procedures

g) Approval already granted by other Classification Societies and documentation of approval tests performed.

2.2 Documents to be submitted for changing the approval conditions

The manufacturer has to submit to **TL** the documents required in 2.1 together with the request of changing the approval conditions, in the case of the following a) through c):

a) Change of the manufacturing process (steel making process, casting method, steel making plant, caster)

b) Change of the thickness range (dimension)

c) Change of the chemical composition, added element, etc.

However, where the documents are duplicated by the ones at the previous approval for the same type of product, part or all of the documents may be omitted except the approval test program (see 3.1).

3. Approval tests

3.1 Extent of the approval tests

The extent of the test program is specified in 3.6, it may be modified on the basis of the preliminary information submitted by the manufacturer.

In particular a reduction of the indicated number of casts, product thicknesses and types to be tested or complete suppression of the approval tests may be accepted by **TL** taking into account:

a) Approval already granted by other Classification Societies and documentation of approval tests performed.

b) Types of steel to be approved and availability of long term statistic results of chemical properties and of mechanical tests performed on rolled products.

c) Change of the approval conditions.

On the other hand, an increase of the number of casts and thicknesses to be tested may be required in the case of newly developed types of steel or manufacturing processes.

3.2 Approval test program

Where the number of tests differs from those shown in 3.6, the program is to be confirmed by **TL** before the tests are carried out.

3.3 Approval survey

The approval tests are to be witnessed by the Surveyor at the manufacturer's plant and the execution of the plant inspection in operation may be required by the Surveyor during the visit for the approval.

If the testing facilities are not available at the works, the tests are to be carried out at recognized laboratories.

3.4 Selection of the test product

For each type of steel and for each manufacturing process (e.g. steel making, casting), one test product with the maximum thickness and one test product with the minimum thickness to be approved are in general to be selected for each kind of product (ingots, slabs, blooms/billets).

The selection of the casts for the test product is to be based on the typical chemical composition, with particular regard to the specified Ceq or Pcm values and grain refining micro-alloying additions.

3.5 Position of the test samples

The test samples are to be taken, unless otherwise agreed, from the product (slabs, blooms, billets) corresponding to the top of the ingot, or, in the case of continuous casting, a random sample.

3.6 Tests on base material

3.6.1 Type of tests

The tests to be carried out for the approval of the manufacturing process of semi-finished products are:

- Chemical analysis. The analysis is to be complete and is to include micro alloying elements.

- Sulphur prints.

In addition, for initial approval and for any upgrade of the approval, **TL** will require full tests indicated in Appendix A2.3 to be performed at rolling mill on the minimum thickness semi finished product.

In case of a multi-caster work, full tests on finished products shall be carried out for one caster and reduced tests (chemical analysis and sulphur print) for the others. The selection of the caster shall be based on the technical characteristics of the casters to be evaluated on case by case basis to be performed at rolling mill on products manufactured from the minimum thickness semi finished product.

3.6.2 Test specimens and testing procedure

The following tests and procedures apply:

a) Chemical analyses
Both the ladle and product analyses are to be reported. In general the content of the following elements is to be checked: C, Mn, Si, P, S, Ni, Cr, Mo, Al, N, Nb, V, Cu, As, Sn, Ti and, for steel manufactured from electric or open-hearth furnace, Sb and B.

b) Sulphur prints are to be taken from product edges which are perpendicular to the axis of the ingot or slab. These sulphur prints are to be approximately 600 mm long taken from the centre of the edge selected, i.e. on the ingot centreline, and are to include the full product thickness.

4. Results

All the results, which are in any case to comply with the requirements of the Rules, are evaluated for the approval; depending on the results, particular limitations or testing conditions, as deemed appropriate, may be specified in the approval document.

All the information required under Appendix A2.2, applicable to the products submitted to the tests, is to be collected by the manufacturer and put in the dossier which will include all the results of the tests and operation records relevant to steel making, casting and, when applicable, rolling and heat treatment of the test products.

5. Certification

5.1 Approval

Upon satisfactory completion of the survey, approval is granted by **TL**.

On the approval certificate the following information is to be stated:

- Type of products (ingots, slabs, blooms, billets)
- Steelmaking and casting processes
- Thickness range of the semi-finished products
- Types of steel (normal or higher strength)

It is also to be indicated that the individual users of the semi finished products are to be approved for the manufacturing process of the specific grade of rolled steel products they are going to manufacture with those semi finished products.

5.2 List of approved manufacturers

The approved manufacturers are entered in a list containing the types of steel and the main conditions of approval.

6. Renewal of approval

The validity of the approval is to be a maximum of five years.

Renewal can be carried out by an audit and assessment on the result of satisfactory survey during the period **(1)**. Where for operational reasons, the renewal audit falls outside the period of approval, the manufacturer will still be considered as approved if agreement to this audit date is made within the original period of approval, in this instance if successful, the extension of approval will be back dated to the original renewal date.

Manufacturers who have not produced the approved grades and products during the period between renewals may be required to either carry out approval tests or, on the basis of results of production of similar grades of products, at the discretion of **TL**, be reapproved.

7. Reconsideration of the approval

During the period of validity the approval may be reconsidered in the following cases:

a) In service failures, traceable to product quality

b) Non conformity of the product revealed during fabrication and construction

c) Discovered failure of the Manufacturer's quality system

d) Changes brought by the Manufacturer, without preliminary agreement of **TL**, to the extent of the approval defined at the time of the approval

e) Evidence of major non conformities during testing of the products.

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(1) *The provision for renewal of approval is also to be applied to all grades and products which were approved by* ***TL*** *prior to an implementation of revision 4 of UR W11 regardless of the validity of certificate in existing approvals. Such renewal is to be completed within five years after the revision 4 becomes effective.*

A2. Manufacturing Approval Scheme of Hull Structural Steels

1. Scope of application

This document specifies, as given in A.3.1, the scheme for the approval of the manufacturing process of normal and higher strength hull structural steels.

The manufacturing approval scheme is valid for verifying the manufacturer's capability to provide satisfactory products stably under effective process and production controls in operation including programmed rolling, which is required in A.3.2 and A.3.3.

2. Approval application

2.1 Documents to be submitted

The manufacturer has to submit to **TL**, request of approval, proposed approval test program (see 3.1) and general information relevant to:

a) Name and site address of the manufacturer, location of the workshops, general indications relevant to the background, dimension of the works, estimated total annual production of finished products for shipbuilding and for other applications, as deemed useful.

b) Organization and quality:
- Organizational chart
- Staff employed
- Staff employed and organization of the quality control department
- Qualification of the personnel involved in activities related to the quality of the products
- Certification of compliance of the quality system with ISO 9001, if any
- approval certificates already granted by other classification societies, if any

c) Manufacturing facilities
- Flow chart of the manufacturing process
- Origin and storage of raw materials
- Storage of finished products
- Equipment for systematic control during fabrication

d) Details of inspections and quality control facilities
- Details of system used for identification of materials at the different stages of manufacturing
- Equipment for mechanical tests, chemical analyses and metallography and relevant calibration procedures
- Equipment for non destructive examinations
- List of quality control procedures

e) Type of products (plates, sections, coils), grades of steel, range of thickness and aim material properties as follows:
- Range of chemical composition and aim analyses, including grain refining, micro alloying and residual elements, for the various grades of steel; if the range of chemical composition depends on thickness and supply condition, the different ranges are to be specified, as appropriate
- Aim maximum carbon equivalent according to ııw formula
- Aim maximum pcm content for higher strength grades with low carbon content c < 0.13 %
- Production statistics of the chemical composition and mechanical properties (reh, rm, a% and kv). The statistics are intended to demonstrate the capability to manufacture the steel products in accordance with the requirements.

f) Steelmaking
- Steel making process and capacity of furnace/s or converter/s
- Raw material used
- Deoxidation and alloying practice
- Desulphurisation and vacuum degassing installations, if any
- Casting methods: ingot or continuous casting. In the case of continuous casting, information relevant to type of casting machine, teeming practice, methods to prevent re-oxidation, inclusions and segregation control, presence of electromagnetic stirring, soft reduction, etc., is to be provided as appropriate.

- Ingot or slab size and weight
  Ingot or slab treatment: scarfing and discarding procedures

g) Reheating and rolling
- Type of furnace and treatment parameters
- Rolling: reduction ratio of slab/bloom/billet to finished product thickness, rolling and finishing temperatures
- Descaling treatment during rolling
- Capacity of the rolling stands

h) Heat treatment
- Type of furnaces, heat treatment parameters and their relevant records
- Accuracy and calibration of temperature control devices

i) Programmed rolling

For products delivered in the controlled rolling(CR) or thermo-mechanical rolling (TM) condition, the following additional information on the programmed rolling schedules is to be given:
- description of the rolling process
- normalizing temperature, re-crystallization temperature and Ar3 temperature and the
- methods used to determine them
- control standards for typical rolling parameters used for the different thickness and
- grades of steel (temperature and thickness at the beginning and at the end of the
- passes, interval between passes, reduction ratio, temperature range and cooling speed of accelerated cooling, if any) and relevant method of control
- calibration of the control equipment

j) Recommendations for working and welding in particular for products delivered in the CR or TM condition:
- Cold and hot working recommendations if needed in addition to the normal practice used in the shipyards and workshops
- Minimum and maximum heat input if different from the ones usually used in the shipyards and workshops (15 - 50 kj/cm)

k) Where any part of the manufacturing process is assigned to other companies or other manufacturing plants, additional information required by TL is to be included.

l) Approval already granted by other Classification Societies and documentation of approval tests performed.

2.2 Documents to be submitted for changing the approval conditions

The manufacturer has to submit to **TL** the documents required in 2.1 together with the request of changing the approval conditions, in the case of the following a) through e) as applicable:

a) Change of the manufacturing process (steel making, casting, rolling and heat treatment)

b) Change of the maximum thickness (dimension)

c) Change of the chemical composition, added element, etc.

d) Subcontracting the rolling, heat treatment, etc.

e) Use of the slabs, blooms and billets manufactured by companies other than the ones verified in the approval tests.

However, where the documents are duplicated by the ones at the previous approval for the same type of product, part or all of the documents may be omitted except the approval test program (see 3.1).

3. Approval tests

3.1 Extent of the approval tests

The extent of the test program is specified in 3.6 and 3.7; it may be modified on the basis of the preliminary information submitted by the manufacturer.

In particular a reduction of the indicated number of casts, steel plate thicknesses and grades to be tested or complete suppression of the approval tests may be accepted by **TL** taking into account:

a) Approval already granted by other Classification Societies and documentation of approval tests performed

b) Grades of steel to be approved and availability of long term statistic results of chemical and mechanical properties

c) Approval for any grade of steel also covers approval for any lower grade in the same strength level, provided that the aim analyses, method of manufacture and condition of supply are similar.

d) For higher tensile steels, approval of one strength level covers the approval of the strength level immediately below, provided the steelmaking process, deoxidation and fine grain practice, casting method and condition of supply are the same.

e) Change of the approval conditions

On the other hand, an increase of the number of casts and thicknesses to be tested may be required in the case of newly developed types of steel or manufacturing processes.

In case of multi-source slabs or changing of slab manufacturer, the rolled steel manufacturer is required to obtain the approval of the manufacturing process of rolled steels using the slabs from each slab manufacturer and to conduct approval tests in accordance with 3.6 and 3.7. A reduction or complete suppression of the approval tests may considered by **TL** taking into account previous approval as follows:

- The rolled steel manufacturer has already been approved for the manufacturing process using other semi finished products characterized by the same thickness, steel
- grade, grain refining and micro-alloying elements, steel making and casting process;
- The semi finished products manufacturer has been approved for the complete manufacturing process with the same conditions (steelmaking, casting, rolling and heat treatment) for the same steel types.

3.2 Approval test program

Where the number of tests differs from those shown in 3.6 and 3.7, the program is to be confirmed by **TL** before the tests are carried out.

3.3 Approval survey

The approval tests are to be witnessed by the Surveyor at the manufacturer's plant and the execution of the plant inspection in operation may be required by the Surveyor during the visit for the approval.

If the testing facilities are not available at the works, the tests are to be carried out at recognised laboratories.

3.4 Selection of the test product

For each grade of steel and for each manufacturing process (e.g. steel making, casting, rolling and condition of supply), one test product with the maximum thickness (dimension) to be approved is in general to be selected for each kind of product.

In addition, for initial approval, **TL** will require selection of one test product of average thickness.

The selection of the casts for the test product is to be based on the typical chemical composition, with particular regard to the specified Ceq or Pcm values and grain refining micro-alloying additions.

3.5 Position of the test samples

The test samples are to be taken, unless otherwise agreed, from the product (plate, flat, section, bar) corresponding to the top of the ingot, or, in the case of continuous casting, a random sample.

The position of the samples to be taken in the length of the rolled product, "piece" defined in B.11.1.1, (top and/or bottom of the piece) and the direction of the test specimens with respect to the final direction of rolling of the material are indicated in Table A.1.

The position of the samples in the width of the product is to be in compliance with A.8.1.2.4.

3.6 Tests on base material

3.6.1 Type of tests

The tests to be carried out are indicated in the following Table A.1.

Table A.1 Test on base material

Type of test	Position of the samples and direction of the test specimens **(1)**	Remarks			
Tensile test	Top and bottom transverse **(2)**	ReH, Rm, A_5(%), RA(%) are to be reported			
Tensile test (stress relieved)only for TM steels	Top and bottom transverse **(2)**	Stress relieving at 600 °C (2 min/mm with minimum 1 hour)			
Impact tests **(3)** on non aged specimens for grades:	Top and bottom - longitudinal	Testing temperature (°C)			
A, B, A32, A36, A40		+20	0	+20	
D, D32, D36, D40		0	-20	-40	
E, E32, E36, E40		0	-20	-40	-60
F32, F36, F40		-20	-40	-60	-80
A, B, A32, A36, A40	Top - transverse **(4)**	+20	0	-20	
D, D32, D36, D40		0	-20	-40	
E, E32, E36, E40		-20	-40	-60	
F32, F36, F40		-40	-60	-80	
Impact test **(3)** on strain aged specimens **(5)** for grades:	Top - longitudinal	Testing temperature (°C)			
A32, A36, A40		+20	0	-20	
D, D32, D36, D40		0	-20	-40	
E, E32, E36, E40		-20	-40	-60	
F32, F36, F40		-40	-60	-80	
Chemical analyses **(6)**	Top	Complete analyses including micro alloying elements			
Sulphur prints	Top				
Micro examination	Top				
Grain size determination	Top	only for fine grain steels			
Drop weight test **(4)**	Top	only for grades E, E32, E36, E40, F32, F36, F40			
Through thickness tensile tests	Top and bottom	only for grades with improved through thickness properties			

(1) *For hot rolled strips see 3.6.2.*

(2) *Longitudinal direction for sections and plates having width less than 600 mm.*

(3) *One set of 3 Charpy V-notch impact specimens is required for each impact test.*

(4) *Not required for sections and plates having width less than 600 mm.*

(5) *Deformation 5% + 1 hour at 250°C.*

(6) *Besides product analyses, ladle analyses are required.*

3.6.2 Test specimens and testing procedure

The test specimens and testing procedures are to be, as a rule, in accordance with W2 (**TL** Rules, Chapter 2, Section 2).

In particular the following applies:

a) Tensile test

- For plates made from hot rolled strip one additional tensile specimen is to be taken from the middle of the strip constituting the coil.
- For plates having thickness higher than 40 mm, when the capacity of the available testing machine is insufficient to allow the use of test specimens of full thickness, multiple flat specimens, representing collectively the full thickness, can be used.
- Alternatively two round specimens with the axis located at one quarter and at midthickness can be taken.

b) Impact test

- For plates made from hot rolled strip one additional set of impact specimens is to be taken from the middle of the strip constituting the coil.
- For plates having thickness higher than 40 mm one additional set of impact specimens is to be taken with the axis located at mid-thickness.
- İn addition to the determination of the energy value, also the lateral expansion and the percentage crystallinity are to be reported.

c) Chemical analyses

Both the ladle and product analyses are to be reported. The material for the product analyses should be taken from the tensile test specimen. In general the content of the following elements is to be checked: C, Mn, Si, P, S, Ni, Cr, Mo, Al, N, Nb, V, Cu, As, Sn, Ti and, for steel manufactured from electric or open-hearth furnace, Sb and B.

d) Sulphur prints are to be taken from plate edges which are perpendicular to the axis of the ingot or slab. These sulphur prints are to be approximately 600 mm long taken from the centre of the edge selected, i.e. on the ingot centreline, and are to include the full plate thickness.

e) Micrographic examination: the micrographs are to be representative of the full thickness.

For thick products in general at least three examinations are to be made at surface, one quarter and mid-thickness of the product.

All photomicrographs are to be taken at x100 magnification and where ferrite grain size exceeds ASTM 10, additionally at x500 magnification. Ferrite grain size should be determined for each photomicrograph.

f) Drop weight test: the test is to be performed in accordance with ASTM E208. The NDTT is to be determined and photographs of the tested specimens are to be taken and enclosed with the test report.

g) Through thickness tensile test: the test is to be performed in accordance with requirements in H (W14).

The test results are to be in accordance, where applicable, with the requirements specified for the different steel grades in this section (W11).

3.6.3 Other tests

Additional tests such as CTOD test, large scale brittle fracture tests (Double Tension test, ESSO test, Deep Notch test, etc.) or other tests may be required in the case of newly developed type of steel, outside the scope of this section (W11), or when deemed necessary by **TL**.

3.7 Weldability tests

3.7.1 General

Weldability tests are required for plates and are to be carried out on samples of the thickest plate. Tests are required for normal strength grade E and for higher strength steels.

3.7.2 Preparation and welding of the test assemblies

The following tests are in general required:

a) 1 butt weld test assembly welded with a heat input approximately 15 kJ/cm

b) 1 butt weld test assembly welded with a heat input approximately 50 kJ/cm.

The butt weld test assemblies are to be prepared with the weld seam transverse to the plate rolling direction, so that impact specimens will result in the longitudinal direction.

The bevel preparation should be preferably 1/2V or K.

The welding procedure should be as far as possible in accordance with the normal welding practice used at the yards for the type of steel in question.

The welding parameters including consumables designation and diameter, preheating temperatures, interpass temperatures, heat input, number of passes, etc. are to be reported.

3.7.3 Type of tests

From the test assemblies the following test specimens are to be taken:

a) 1 cross weld tensile test

b) a set of 3 Charpy V-notch impact specimens transverse to the weld with the notch located at the fusion line and at a distance 2, 5 and minimum 20 mm from the fusion line.

The fusion boundary is to be identified by etching the specimens with a suitable reagent.

The test temperature is to be the one prescribed for the testing of the steel grade in question.

c) Hardness tests HV 5 across the weldment. The indentations are to be made along a 1 mm transverse line beneath the plate surface on both the face side and the root side of the weld as follows:

- Fusion line
- HAZ: at each 0.7 mm from fusion line into unaffected base material (6 to 7 minimum measurements for each HAZ)

The maximum hardness value should not be higher than 350 HV.

A sketch of the weld joint depicting groove dimensions, number of passes, hardness indentations should be attached to the test report together with photomacrographs of the weld cross section.

3.7.4 Other tests

Additional tests such as cold cracking tests (CTS, Cruciform, Implant, Tekken, Bead-on plate), CTOD, or other tests may be required in the case of newly developed type of steel, outside the scope of this section (W11), or when deemed necessary by **TL**.

4. Results

All the results, which are in any case to comply with the requirements of the Rules, are evaluated for the approval; depending on the results, particular limitations or testing conditions, as deemed appropriate, may be specified in the approval document.

All the information required under Appendix 2.2, applicable to the products submitted to the tests, is to be collected by the manufacturer and put in the dossier which will include all the results of the tests and operation records relevant to steel making, casting, rolling and heat treatment of the test products.

5. Certification

5.1 Approval

Upon satisfactory completion of the survey, approval is granted by **TL**.

5.2 List of approved manufacturers

The approved manufacturers are entered in a list containing the types of steel and the main conditions of approval.

6. Renewal of approval

The validity of the approval is to be a maximum of five years.

Renewal can be carried out by an audit and assessment on the result of satisfactory survey during the period **(1).**

Where for operational reasons, the renewal audit falls outside the period of approval, the manufacturer will still be considered as approved if agreement to this audit date is made within the original period of approval, in this instance if successful, the extension of approval will be back dated to the original renewal date.

Manufacturers who have not produced the approved grades and products during the period between renewals may be required to either carry out approval tests or, on the basis of results of production of similar grades of products, at the discretion of **TL**, be reapproved.

7. Reconsideration of the approval

During the period of validity the approval may be reconsidered in the following cases:

a) In service failures, traceable to product quality

b) Non conformity of the product revealed during fabrication and construction

c) Discovered failure of the Manufacturer's quality system

d) Changes brought by the Manufacturer, without preliminary agreement of TL, to the extent of the approval defined at the time of the approval

e) Evidence of major non conformities during testing of the products.

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(1) *The provision for renewal of approval is also to be applied to all grades and products which were approved by **TL** prior to an implementation of revision 4 of this UR W 11 regardless of the validity of certificate in existing approvals. Such renewal is to be completed within five years after the revision 4 becomes effective.*

Appendix B

Approval scheme for manufacturer of hull structural steels intended for welding with high heat input

1. Scope

This document specifies the weldability confirmation scheme of normal and higher strength hull structural steels stipulated in this section (UR W11) intended for welding with high heat input over 50kJ/cm.

The weldability confirmation scheme is to be generally applied by manufacturer's option and valid for certifying that the steel has satisfactory weldability for high heat input welding concerned under testing conditions.

Demonstration of conformance to the requirements of this document approves a particular steel mill to manufacture grade of steel to the specific chemical composition range, melting practice, and processing practice for which conformance was established. The approval scheme does not apply to qualification of welding procedures to be undertaken by the shipyards.

2. Application of certification

The manufacturer is to submit to **TL**, request of certification, proposed weldability test program (see section 3.2) and technical documents relevant to:

a) Outline of steel plate to be certified

- Grade
- Thickness range
- Deoxidation practice
- Fine grain practice
- Aim range of chemical composition
- Aim maximum ceq and pcm
- Production statistics of mechanical properties (tensile and charpy v-notch impact tests), if any

b) Manufacturing control points to prevent toughness deterioration in heat affected zone when welded with high heat input, relevant to chemical elements, steel making, casting, rolling, heat treatment etc.

c) Welding control points to improve joint properties on strength and toughness, if any.

3. Confirmation tests

3.1 Range of certification

Range of certification for steel grades is to be the following a) through e) unless otherwise agreed by **TL**:

a) Approval tests on the lowest and highest toughness levels cover the intermediate toughness level.

b) Approval tests on normal strength level cover that strength level only.

c) For high tensile steels, approval tests on one strength level cover strength level immediately below.

d) Tests may be carried out separately subject to the same manufacturing process.

e) Certification and documentation of confirmation tests performed by other Classification Society may be accepted at the discretion of **TL**.

3.2 Weldability test program

Extent of the test program is specified in section 3.5 but it may be modified according to the contents of certification. In particular, additional test assemblies and/or test items may be required in the case of newly developed type of steel, welding consumable and welding method, or when deemed necessary by **TL**.

Where the content of tests differs from those specified in section 3.5, the program is to be confirmed by **TL** before the tests are carried out.

3.3 Test plate

Test plate is to be manufactured by a process approved by **TL** in accordance with the requirements of this section (UR W11 Appendix A).

For each manufacturing process route, two test plates with different thickness are to be selected. The thicker plate (t) and thinner plate (less than or equal to t/2) are to be proposed by the manufacturer.

Small changes in manufacturing processing (e.g. within the TMCP process) may be considered for acceptance without testing, at the discretion of **TL**.

3.4 Test assembly

One butt weld assembly welded with heat input over 50kJ/cm is to be generally prepared with the weld axis transverse to the plate rolling direction.

Dimensions of the test assembly are to be amply sufficient to take all the required test specimens specified in section 3.5.

The welding procedures should be as far as possible in accordance with the normal practices applied at shipyards for the test plate concerned.

Welding process, welding position, welding consumable (manufacturer, brand, grade, diameter and shield gas) and welding parameters including bevel preparation, heat input, preheating temperatures, interpass temperatures, number of passes, etc. are to be reported.

3.5 Examinations and tests for the test assembly

The test assembly is to be examined and tested in accordance with the following a) through h) unless otherwise agreed by **TL**.

a) Visual examination

Overall welded surface is to be uniform and free from injurious defects such as cracks, undercuts, overlaps, etc.

b) Macroscopic test

One macroscopic photograph is to be representative of transverse section of the welded joint and is to show absence of cracks, lack of penetration, lack of fusion and other injurious defects.

c) Microscopic test

Along mid-thickness line across transverse section of the weld, one micrograph with x100 magnification is to be taken at each position of the weld metal centreline, fusion line and at a distance 2, 5, 10 and minimum 20 mm from the fusion line. The test result is provided for information purpose only.

d) Hardness test

Along two lines across transverse weld section 1 mm beneath plate surface on both face and root side of the weld, indentations by HV5 are to be made at weld metal centreline, fusion line and each 0.7 mm position from fusion line to unaffected base metal (minimum 6 to 7 measurements for each heat affected zone).

The maximum hardness value should not be higher than 350 HV.

e) Transverse tensile test

Two transverse (cross weld) tensile specimens are to be taken from the test assembly.

Test specimens and testing procedures are to comply with the requirements of UR W2 (**TL** Rules, Chapter 2, Section 2).

The tensile strength is to be not less than the minimum required value for the grade of base metal.

f) Bend test

Two transverse (cross weld) test specimens are to be taken from the test assembly and bent on a mandrel with diameter of quadruple specimen thickness. Bending angle is to be at least 120°. Test specimens are to comply with the requirements of UR W2 (**TL** Rules, Chapter 2, Section 2).

For plate thickness up to 20 mm, one face-bend and one root-bend specimens or two side-bend specimens are to be taken. For plate thickness over 20 mm, two side-bend specimens are to be taken.

After testing, the test specimens shall not reveal any crack nor other open defect in any direction greater than 3 mm.

g) Impact test

Charpy V-notch impact specimens (three specimens for one set) are to be taken within 2 mm below plate surface on face side of the weld with the notch perpendicular to the plate surface.

One set of the specimens transverse to the weld is to be taken with the notch located at the fusion line and at a distance 2, 5 and minimum 20 mm from the fusion line. The fusion boundary is to be identified by etching the specimens with a suitable reagent. The test temperature is to be the one prescribed for the testing of the steel grade in question.

For steel plate with thickness greater than 50 mm or one side welding for plate thickness greater than 20 mm, one additional set of the specimens is to be taken from the root side of the weld with the notch located at each the same position as for the face side.

The average impact energy at the specified test temperature is to comply with the Table 3.8 or 3.9 depending on the steel grade and thickness. Only one individual value may be below the specified average value provided it is not less than 70% of that value.

Additional tests at the different testing temperatures may be required for evaluating the transition temperature curve of absorbed energy and percentage crystallinity at the discretion of **TL**.

h) Other test

Additional tests such as wide-width tensile test, HAZ tensile test, cold cracking tests (CTS, Cruciform, Implant, Tekken, and Bead-on plate), CTOD or other tests should be required at the discretion of **TL** (see section 3.2).

4. Results

The manufacturer is to submit to **TL** the complete test report including all the results and required information relevant to the confirmation tests specified in section 3.

The contents of the test report are to be reviewed and evaluated by **TL** in accordance with this weldability confirmation scheme.

5. Certification

TL issues the certificate where the test report is found to be satisfactory.

The following information is generally required to be included on the certificate:

a) Manufacturer

b) Grade designation with notation of heat input (see section 6)

c) Deoxidation practice

d) Fine grain practice

e) Condition of supply

f) Plate thickness tested

g) Welding process

h) Welding consumable (manufacturer, brand, grade), if desired

i) Actual heat input applied.

6. Grade designation

Upon issuance of the certificate, the notation indicating the value of heat input applied in the confirmation test may be added to the grade designation of the test plate, e.g. “E36-W300” (in the case of heat input 300 kJ/cm applied). The value of this notation is to be not less than 50 and every 10 added.

Appendix C

Procedure for Approval of Corrosion Resistant Steels for Cargo Oil Tanks

1. Scope

1.1 This appendix specifies, as given in A.3, the scheme for the approval of corrosion resistant steels based upon corrosion testing.

1.2 The corrosion testing is to be carried out in addition to the approval testing specified in

Appendix A1 and A2 for the approval of normal and higher strength hull structural steels.

1.3 The corrosion tests and assessment criteria are to be in accordance with the Appendix of the Annex to Performance Standard for Alternative Means of Corrosion Protection for Cargo Oil Tanks of Crude Oil Tankers (MSC.289 (87)).

2. Application for approval

2.1 The manufacturer is to submit to the Society a request for approval, which is to include the following:

a) Corrosion test plan and details of equipment and test environments.

b) Technical data related to product assessment criteria for confirming corrosion resistance.

c) The technical background explaining how the variation in added and controlled elements improves corrosion resistance. The manufacturer will establish a relationship of all the chemical elements which affect the corrosion resistance. The chemical elements added or controlled to achieve the required level of corrosion resistance are to be specifically verified for acceptance. Verification is to be based on the ladle analysis of the steel.

d) The grades, the brand name and maximum thickness of corrosion resistant steel to be approved. Designations for corrosion resistant steels are given in Table 2.1

e) The welding processes and the brand name of the welding consumables to be used for approval.

Table 2.1 Designations for Corrosion Resistant Steels Type of steel Location where steel is Effective Corrosion Resistant Designation

Type of steel	Location where steel is effective	Corrosion Resistant Designation
Rolled steel for hull	For lower surface of strength deck and surrounding structures (ullage space)	RCU
	For upper surface of inner bottom plating and surrounding structures	RCB
	For both strength deck and inner bottom plating	RCW

3. Approval of test plan

3.1 The test program submitted by the manufacturer is to be reviewed by the Society, if found satisfactory, it will be approved and returned to the manufacturer for acceptance prior to tests being carried out. Tests that need to be witnessed by the society Surveyor will be identified.

3.2 Method for selection of test samples is to satisfy the following:

3.2.1 The numbers of test samples is to be in accordance with the requirements of the Appendix of the Annex to Performance Standard for Alternative Means of Corrosion Protection for Cargo Oil Tanks of Crude Oil Tankers (MSC.289 (87)).

3.2.2 The number of casts and test samples selected are to be sufficient to make it possible to confirm the validity of interaction effects and/or the control range (upper limit, lower limit) of the elements which are added or intentionally controlled, for improving the corrosion resistance. Where agreed, this may be supported with data submitted by the manufacturer.

3.2.3 Additional tests may be required by the Society when reviewing the test program against the paragraph 3.2.2

Remarks: Considerations for additional tests may include but not be limited to:

a) When the Society determines that the control range is set by the theoretical analysis of each element based on existing data, the number of corrosion resistance tests conducted in accordance with the Appendix of the Annex to Performance Standard for Alternative Means of Corrosion Protection for Cargo Oil Tanks (MSC.289 (87)) is too few to adequately confirm the validity of the control range of chemical composition;

b) When the Society determines that the data of the corrosion resistance test result obtained for setting the control range of chemical composition varies too widely;

c) When the Society determines that the validity of the corrosion resistance test result for setting the control range of chemical composition is insufficient, or has some flaws; and

d) When the Society's surveyor has not attended the corrosion resistance tests for setting the control range of chemical composition, and the Society determines that additional testing is necessary in order to confirm the validity of the test result data.

Remarks: The chemical composition of the corrosion resistant steel is to be within the range specified for rolled steel for hull. Elements to be added for improving the corrosion resistance and for which content is not specified are to be generally within 1% in total.

4. Carrying out the approval test

4.1 The manufacturer is to carry out the approval test in accordance with the approved test plan.

5. Attendance of the Society's Surveyor for Test

5.1 The Society's Surveyor is to be present, as a rule, when the test samples for the approval test are being identified and for approval tests, see also 3.1.

6. Test Results

6.1 After completion of the approval test, the manufacturer is to produce the report of the approval test and submit it to the Society.

6.2 The Society will give approval for corrosion resistant steel where approval tests are considered by the society to have given satisfactory results based on the data submitted in accordance with the provisions of this Appendix.

6.3 The certificate is to contain the manufacturer's name, the period of validity of the certificate, the grades and thickness of the steel approved, welding methods and welding consumables approved.

7. Assessment Criteria for Results of Corrosion Resistance Tests of Welded Joint

7.1 The results will be assessed by the Classification Society in accordance with the acceptance criteria specified in the Appendix of the Annex to Performance Standard for Alternative Means of Corrosion Protection for Cargo Oil Tanks (MSC.289 (87)).

SECTION 4

STEEL PIPES AND FITTINGS

A. General

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 F.

The scope of these Rules embraces all pipes used in the construction of steam boilers, pressure vessels and systems operating at ambient, high or low temperature.

As regards steel pipes for structural applications, Section 3, B., C. and F. are to be applied respectively.

1.2 As regards production and testing of products:

Section 1, Manufacture, Testing and Certification

Section 2, Mechanical and Technological Testing Procedures

are also to apply.

1.3 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.

1.4 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 up of carbon and carbon-manganese steels is to 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, is to 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 are to be approved by **TL**. Such approval is conditional upon their fulfilling the requirements stated in Section 1, B. and demonstrating this to **TL** 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 is to be subject to preliminary proof in the form of a procedure approval test the extent of which shall be determined by **TL** on a case to case basis.

TL 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 are to be made by basic oxygen steelmaking processes, in an electric furnace or by other methods approved by **TL**. Unless otherwise specified, the steels are to 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.

3.4 All pipes are to 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 is to 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 is not to exceed a value of 1 + 0.1 x seam width (mm).

5. Dimensions, Dimensional and Geometrical Tolerances

The dimensions and the dimensional and geometrical tolerances of the pipes are to comply with the requirements specified in the standards. The relevant standards are to be stated in the order and made known to the Surveyor. The ends of pipes are to be cut off perpendicular to the pipe axis and are to 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 are to be leak proof at the specified test pressures.

7. General Requirements Applicable to the Material Properties

7.1 Chemical composition

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

7.2 Weldability

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

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 is to 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 is to at least meet the values specified in D. for the impact energy at the prescribed test temperature.

7.4 Technological properties

Pipes are to 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 - is to verify the composition of each heat and submit the relevant certificates to the Surveyor. All the elements affecting compliance with the required characteristics is to be specified in the certificates.

A product analysis is to 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 are to 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, each two pipes are to 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 is to be sufficient to take one pipe. Normally, longitudinal test specimens are to 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 is to 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 is to be proved by a hot tensile test performed on one test specimen per heat and per pipe size. The test is to 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 is to be determined in the same way as the tensile test specimens called for in 8.2. The test is to 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 is to be subjected to one of the ring tests specified in Table 4.1 provided that the wall thickness of the pipe does not exceed 40 mm.

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

Table 4.1 Types of ring test

Outside diameter of pipe [mm]	**Nominal wall thickness t [mm]**		
	t < 2	**2 ≤ t ≤16**	**16 < t ≤ 40**
≤ 21.3	ring flattening test **(1) (2)**	ring flattening test **(1) (2)**	-
> 21.3 ≤ 146	ring flattening test **(1) (2)**	ring expanding test **(1) (2)**	ring flattening
> 146	-	ring tensile test **(3)**	ring tensile test **(3)**

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

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 is to 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 is to at least equal the percentages shown in Table 4.2 depending on the material.

Table 4.2 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 is to 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 is to be achieved. Where pipes are made of other steels, the requirements of the other relevant standards are to be achieved.

8.6 Test of surface finish and dimensions

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

8.7 Non-destructive tests

8.7.1 The pipes are to be subjected to nondestructive 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 is to be complied with.

8.7.2 Other test specifications require special approval by **TL**.

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

8.8 Tightness test

8.8.1 All pipes are to be tested for leaks by the manufacturer by applying the internal pressure test or, where **TL** 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 is to 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 is to be able to cover the whole circumference of the pipe. In addition, the method of testing is to conform to a recognized standard (e.g. EN ISO 10893) or to an approved test specification. The efficiency of the method is to be initially demonstrated to **TL**.

8.9 Retests in the event of failure of specimens

If the requirements are not met by specimens subjected to tensile, ring or notched bar impact tests or if, in the notched bar impact test, one individual value falls below 70 % of the stipulated average value, then, before the unit testing quantity is rejected, the procedure for retests described in Section 2 may be applied.

9. Marking

9.1 The manufacturer is to 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 are to be applied with punches. Pipes with sensitive surfaces or small wall thicknesses which may be damaged by punches are to be marked by another method, e.g. by colored imprint, electrical engraving or rubber stamps.

10. Certificates

10.1 For each consignment the manufacturer is to 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 is also to 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 is to 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 is to be given facilities for carrying out a check.

10.4 Where, in exceptional cases, pipes are tested on the premises of a stockiest, the latter is to 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 is to 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 4.3 are to be used.

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

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

2. Heat Treatment

The pipes are to 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 Properties

3.1 Chemical composition

The chemical composition of the pipe steels is to conform to the data given in Table 4.4 or, where appropriate, in the relevant standards or specifications.

3.2 Mechanical properties

The required values of tensile strength, yield strength and elongation specified in Table 4.5 or, where appropriate, in the relevant standards or specifications is to be met under test at room temperature.

3.3 Technological properties

When subjected to the ring tests, the pipes are to 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 4.5.

Table 4.3 Standardized pipe grades

Strength category or pipe grade to Table 4.5	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
TL-R 360	P235 TR2		E 235+N	E 235+N
TL-R 410	P265 TR2	P275 NL1		E275+N
TL-R 490		P355 N	E 355+N	E355+N

(1) *Seamless.*
(2) *Welded.*

Table 4.4 Chemical composition of unalloyed steel pipes

Strength category or pipe grade	Chemical composition [%]					
	C	$Si_{max.}$	$Mn_{max.}$	$P_{max.}$	$S_{max.}$	$Al_{tot.}$
TL-R 360	0.17	0.35	1.20	0.025	0.020	≥ 0.020 **(1)**
TL-R 410	0.21	0.35	1.40			
TL-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.*

Table 4.5 Mechanical and technological properties of unalloyed steel pipes

Strength category or pipe grade	Tensile strength R_m [N/mm²]	Yield strength R_{eH} [N/mm²] min.	Elongation A [%] min.		Impact energy at 0ºC KV (1) [J] min.	
			Long.	Transv.	Long.	Transv.
TL-R 360	360-500	235	25	23	41	27
TL-R 410	410-570	255	21	19		
TL-R 490	490-650	310	19	17		

(1) *For pipes with wall thicknees >10 mm.*

4. Testing

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 TL-R490 are to be examined according to one of the ring tests specified in A.8.5, namely two pipes of one test batch.

Apart from that for fusion-welded pipes a weld seam bend test in accordance with Chapter 3 - Welding 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 is to 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 is to be performed on transverse Charpy V-notch specimens if the outside diameter is ≥200 mm. If the outside diameter is < 200, longitudinal specimens may be used.

4.5 Test of surface finish and dimensions

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

4.6 Non-destructive tests

All pipes are to be subjected by the manufacturer to a non-destructive test over their whole length in accordance with EN ISO10893.

4.6.1 Non-destructive testing of seamless pipes

The pipes are to be subjected to a non-destructive test for detection of longitudinal defects according to EN ISO 10893-10, acceptance category U2, subcategory C or EN ISO 10893-3, acceptance category F2. Areas in way of pipe ends which have not been tested automatically are to be subjected either to a manual or semi-automatic ultrasonic test in accordance with EN ISO 10893-10, acceptance category U2, subcategory C or are to be cut off.

4.6.2 Non-destructive testing of pressure-welded pipes

TL-R 360 and TL-R 410:

The weld seam of pipe grades TL-R 360 and TL-R 410 is to be tested over its entire length according to either EN ISO 10893-2, acceptance category E3 or EN ISO 10893-3, acceptance category F3 or EN ISO 10893-10, acceptance category U3, subcategory C or EN ISO 10893-11, acceptance category U3, if applicable.

Areas in way of pipe ends which have not been tested automatically are to be subjected either to a manual or semi-automatic ultrasonic test in accordance with EN ISO 10893-11, acceptance category U3 or shall be cut off.

TL-R 490:

Pipes of grade TL-R 490 are to be subjected to an ultrasonic test for detection of longitudinal defects according to EN ISO 10893-10, acceptance category U2, subcategory C.

Areas in way of pipe ends which have not been tested automatically, are to be subjected either to a manual or semi-automatic ultrasonic test in accordance with EN ISO 10893-10, acceptance category U2, subcategory C or shall be cut off.

4.6.3 Non-destructive testing of fusion-welded pipes

TL-R 360 and TL-R 410:

The weld seam of SAW pipes of grades TL-R 360 and TL-R 410 is to be tested either according to EN ISO 10893-11, acceptance category U3 or EN ISO 10893-6 image quality class R2.

Areas in way of pipe ends which have not been tested automatically, are to be subjected either to a manual or semi-automatic ultrasonic test in accordance with EN ISO 10893-11, acceptance category U3 or are to be examined by means of radiographic testing according to EN ISO 10893-6, image quality class R2 or are to be cut off.

TL-R 490:

The weld seam of pipes of grade TL-R 490 is to be tested over its entire length according to EN ISO 10893-11, acceptance category U2 or EN ISO 10893-6 image quality class R2.

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

The base material is to be tested according to EN ISO 10893-9, acceptance category U2.

The pipe ends have to be tested in accordance with EN 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 EN ISO 10893-9 or EN ISO 10893-8, acceptance category U2 in each case.

4.7 Tightness test

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

C. Pipes for High Temperature Services

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 4.6.

2. Heat Treatment

Pipes are to be properly heat treated as follows:

2.1 Carbon steel, carbon-manganese steel and 0.3 Mo steel pipes: normalized

2.2 Pipes made of 1 Cr 0.5 Mo and 2.25 Cr 1 Mo steels: quenched and tempered.

Subsequent heat treatment need not be applied to hot formed pipes covered by 2.1 if the hot forming operation ensures 2.1 corresponding structure of sufficient uniformity. Under these conditions, tempering may be sufficient for the alloy pipes covered by 2.2.

3. Requirements Applicable to the Material Properties

3.1 Chemical composition

The chemical composition shall conform to the data given in Table 4.7 or, where appropriate, the relevant standards or specifications.

3.2 Mechanical properties

The required values of tensile strength, yield strength and elongation specified in Table 4.8 or, where appropriate, in the relevant standards or specifications are to 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 4.8.

3.5 High-temperature characteristics

The 0.2 % proof stress at elevated temperatures is to satisfy the requirements specified in Table 4.9 or in the other relevant standards or specifications.

Table 4.6 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
TL-R 360 W	P 235 GH	P 235 GH	PH 23	PH 23
TL-R 410 W	P 265 GH	P 265 GH	PH 26	PH 26
TL-R 460 W	-	-	PH 29	-
TL-R 510 W	20 Mn Nb 6	-	PH 35	PH 35
0.3 Mo	16 Mo 3	16 Mo 3	16 Mo 3	16 Mo 3
1 Cr 0.5 Mo	13 Cr Mo 4-5	-	13 Cr Mo 4-5	13 Cr Mo 4-5
2.25 Cr 1 Mo	10 Cr Mo 9-10	-	11 Cr Mo 9-10	11 Cr Mo 9-10

Table 4.7 Chemical compositions of high- temperature steel grades

Strength category or pipe grade	Chemical composition [%]							
	C	$Si_{max.}$	Mn	$P_{max.}$	$S_{max.}$	Cr	Mo	$Al_{tot.}$
TL-R 360 W	≤ 0.16	0.35	≤ 1.20					
TL-R 410 W	≤ 0.20	0.40	≤ 1.40			≤ 0.30	≤ 0.08	≥ 0.020 **(1)**
TL-R 460 W	≤ 0.22	0.40	≤ 1.40					
TL-R 510 W	≤ 0.23	0.55	0.80-1.50	0.025	0.020			
0.3 Mo	0.12-0.20	0.35	0.40-0.90			-	0.25-0.35	
1 Cr 0.5 Mo	0.10-0.17	0.35	0.40-0.70			0.70-1.15	0.40-0.60	≤ 0.040
2.25 Cr 1 Mo	0.08-0.14	0.50	0.30-0.70			2.00-2.50	0.90-1.10	

(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* $(Al+Ti/2) \geq 0.20\%$.

Table 4.8 Mechanical and technological properties of pipes made of high-temperature steel at room temperature

Strength category or pipe grade	Tensile strength R_m [N/mm²]	Yield strength R_{eH} [N/mm²] min.	Elongation $\left(L_o = 5.65 \cdot \sqrt{S_o}\right)$ A [%] min.		Impact energy KV [J] min.	
			Long.	Transv.	Long.	Transv.
TL-R 360 W	360-500	235	25	23		
TL-R 410 W	410-570	255	21	19		
TL-R 460 W	460-580	270	23	21		
TL-R 510 W	510-650	355	19	17	41	27
0.3 Mo	450-600	270	22	20		
1 Cr 0.5 Mo	440-590	290	22	20		
2.25 Cr 1 Mo	480-630	280	20	18		

3.6 Dimensional tolerances for collectors

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

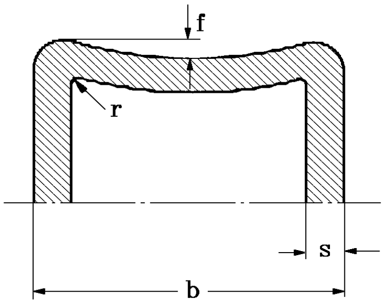
- On the inner or outer clear width: ± 1.0 % where the outer clear width is ≤ 225 mm, or ± 1.5 % where the outer clear width is > 225 mm.

  0 % to + 25 % on the wall thickness

- The lateral curvature of square pipes shall be as shown in Fig. 4.1.

In square pipes, the inner corner radius r in relation to the wall thickness s is to be at least:

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



b [mm]	up to 100	101-200	201-300	301 and over
f [mm]	0.75	1.0	1.5	2.0

Figure 4.1 Tolerance on the lateral curvature of square pipes

4. Testing

The following tests are to be performed:

4.1 Test of chemical composition

The manufacturer is to 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 are to be subjected to the tensile test.

4.3 Technological test

4.3.1 The pipes, namely two pipes of one test batch, is to undergo one of the ring tests specified in Table 4.1 as follows:

For fusion-welded pipes a weld seam bend test in accordance with Chapter 3 - Welding, 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 is to be determined by a high-temperature tensile test.

Table 4.9 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
TL-R 360 W	1.0345	198	187	170	150	132	120	112	108	-
TL-R 410 W	1.0425	226	213	192	171	154	141	134	128	-
TL-R 460 W	-	-	-	235	215	175	155	145	135	-
TL-R 510 W	1.0471	312	292	264	241	219	200	186	174	-
0.3 Mo	1.5415	243	237	224	205	173	159	156	150	146
1 Cr 0.5 Mo	1.7335	264	253	245	236	192	182	174	168	166
2.25 Cr 1 Mo	1.7380	249	241	234	224	219	212	207	193	180

4.6 Test of surface finish and dimensions

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

4.7 Non-destructive tests

All pipes shall be subjected by the manufacturer to a non-destructive test according to EN ISO 10893 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 are to be subjected to a non-destructive test in order to detect longitudinal defects according to EN ISO 10893-10, acceptance category U2, subcategory C.

Areas in way of pipe ends which have not been tested automatically are to be subjected either to a manual or semi-automatic ultrasonic test or shall are to be examined by means of radiographic testing according to the procedures specified above or are to be cut off.

4.7.2 Non-destructive testing of fusion-welded pipes

The weld seam of the pipes is to be tested over its entire length according to either EN ISO 10893-11, acceptance category U2 or EN ISO 10893-6, image quality class R2.

Areas in way of pipe ends which have not been tested automatically are to be subjected either to a manual or semi-automatic ultrasonic test or shall are to be examined by means of radiographic testing according to the procedures specified above or are to be cut off.

The base material is to be tested according to EN ISO 10893-9, acceptance category U2.

The pipe ends have to be tested in accordance with EN 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 EN ISO 10893-9 or EN ISO 10893-8, acceptance category U2 in each case.

4.8 Tightness test

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

D. Pipes for Low Temperature Services

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 4.10.

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

1.3 If the pipes are used for cargo and process equipment on gas tankers, the minimum design temperatures specified in Table 4.11 are applicable.

2. Heat Treatment

Depending on the material, the pipes are to be supplied in one of the heat treated conditions specified in Table 4.12.

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 slagand temper colours on the inner and outer surfaces are to be carefully removed, e.g. by pickling, grinding or sand blasting.

3. Requirements Applicable to the Material Properties

3.1 Chemical composition

The chemical composition of the pipe steels is to conform to the data in Table 4.13 or, where appropriate, to the other relevant standards or specifications.

3.2 Resistance of austenitic pipe grades to intercrystalline corrosion

Austenitic steel pipes shall be resistant to intercrystalline corrosion. Where welding is not followed by further heat treatment (quenching), only those pipe grades may be used which are corrosion-resistant in the welded condition, e.g. steels stabilized with Ti or Nb or steels with carbon contents of C ≤ 0.03 %, see Table 4.13.

3.3 Mechanical properties

The values for tensile strength, yield strength or 0.2 % or 1 % proof stress, and elongation specified in Table 4.14 or, where appropriate, in the other relevant standards or specifications shall be satisfied under test at room temperature.

Table 4.10 Comparably suitable pipe grades of steels for low temperature services according to standards

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 (3) A 312/A 312M-12
TL-R 360 T	P 215 NL P 255 QL			PL 25		
TL-R 390 T	P 265 NL	P 275 NL 1 P 275 NL 2				
TL-R 490 T		P 355 NL 1 P 355 NL 2				
TL-R 0.5 Ni	13 Mn Ni 6-3			13 Mn Ni 6-3		
TL-R 3.5 Ni	12 Ni 14			12 Ni 14		
TL-R 9 Ni	X 10 Ni 9			X 10 Ni Mn 9		
1.4306			X 2 Cr Ni 19-11		X 2 Cr Ni 1810	TP 304 L
1.4404			X 2 Cr Ni Mo 17-13-2		X 2 Cr Ni Mo 17-12	TP 316 L
1.4541			X 6 Cr Ni Ti 18-10		X 6 Cr Ni Ti 18-10	TP 321
1.4550			X 6 Cr Ni Nb 18-10		X 6 Cr Ni Nb 18-10	TP 347
1.4571			X 6 Cr Ni Mo Ti 17-12-2		X 6 Cr Ni Mo Ti 17-12	

(1) *Seamless pipes.*
(2) *Welded pipes.*
(3) *The notched bar impact energies according to Tablo 4.14 are to be demonstrated..*

Table 4.11 Minimum design temperatures

Strength category or pipe grade	Minimum design temperature [° C]
TL-R 360 T TL-R 390 T TL-R 490 T	-55 **(1)**
TL-R 0.5 Ni TL-R 3.5 Ni	-55 -90
TL-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.*	

Table 4.12 Heat treatment of steel pipes tough at sub-zero temperatures

Strength category or pipe grade	Type of heat treatment
TL-R 360 T TL-R 390 T TL-R 490 T	Normalized or quenched and tempered
TL-R 0.5 Ni	Normalized
TL-R 3.5 Ni	Normalized and tempered or quenched and tempered
TL-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

3.4 Technological properties

In the ring tests, the pipes are to 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 4.14 for the pipe grade concerned is to be met at the prescribed test temperatures. This requirement is also applicable to comparable pipe grades conforming to the standards or specifications, irrespective of the values specified therein.

4. Testing

The following tests are to be performed:

4.1 Test of chemical composition

The chemical composition of each heat is to 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 is to 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 is to be performed in accordance with ISO 3651-2 on at least two samples per heat. The test specimens shall are to 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 are to be in the condition in which they are supplied.

Table 4.13 Chemical composition of steel pipes for low temperature services

Strength category or pipe grade	Chemical composition [%]								
	$C_{max.}$	Si	Mn	$P_{max.}$	$S_{max.}$	Cr	Ni	Mo	Other elements
TL-R 360 T	0.16	≤ 0.40	0.40-1.20						
TL-R 390 T	0.16	≤ 0.40	0.50-1.50	0.025	0.020	≤ 0.3	≤ 0.3	≤ 0.08	Al_{met} ≥ 0.015 **(1) (2)**
TL-R 490 T	0.18	0.10-0.50	≥ 0.90						
TL-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)**
TL-R 3.5 Ni	0.15	0.15-0.35	0.30-0.85	0.025	0.010	-	3.25-3.75	-	V ≤ 0.05
TL-R 9 Ni	0.13			0.020			8.5-9.5	≤ 0.10	
1.4306	0.030					17.0-19.0	9.0-12.0	-	-
1.4404	0.030					16.5-18.5	11.0-14.0	2.0-2.5	
1.4541	0.08	≤ 1.00	≤ 2.00	0.040	0.030	17.0-19.0	9.0-12.0	-	Ti ≥ 5x%C ≤ 0.70
1.4550	0.08					17.0-19.0	9.0-12.0	-	Nb ≥ 10x%C ≤ 1.00
1.4571	0.08					16.5-18.5	11.0-14.0	2.0-2.5	Ti ≥ 5x%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 4.14 Mechanical and technological properties of steel pipes for low temperature services

Strength category or pipe grade	Tensile strength R_m [N/mm²]	Yield strength or proof stress R_{eH} or $R_{P0.2}$, $R_{P0.1}$ (1) [N/mm²] min.	Elongation A [%] min.		Impact energy KV (2) [J] min.		
			Long.	Transv.	Test temperature[C°]	Long.	Transv.
TL-R 360 T	360-490	255	25	23	5°C below design temperature, min. -20°C	41 (29)	27 (19)
TL-R 390 T	390-510	275	24	22			
TL-R 490 T	490-630	355	22	20			
TL-R 0.5 Ni	490-610	355	22	20	-60		
TL-R 3.5 Ni	440-620	345	22	20	-95		
TL-R 9 Ni	690-840	510	20	18	-196		
1.4306	480-680	215	40	35	-196		
1.4404	490-690	225	40	35			
1.4541	510-710	235	35	30			
1.4550	510-740	240	35	30			
1.4571	510-710	245	35	30			

(1) *$R_{P0.2}$ or R_{eH} applies to ferritic steels, $R_{P0.1}$ austenitic steels.*
(2) *Average value of 3 specimens; the values in brackets are the indivudual minima.*

4.3 Tensile test

The tensile test is to 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 4.1. 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 4.15 shall be assigned to the constant C in the formula given in A.8.5.2:

Table 4.15

Strength category or pipe grade	Constant C
TL-R 360 T	0.09
TL-R 390 T and TL-R 490 T	0.07
TL-R 0.5 Ni	
TL-R 3.5 Ni	0.08
TL-R 9 Ni	0.06
Austenitic pipes	0.10

4.5 Notched bar impact test

4.5.1 On pipes with wall thicknesses ≥ 6 mm, the notched bar impact test is to 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 are to be taken transverse to the pipe axis. In such cases an additional (transverse) set of specimens are to 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 are to 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 x 10 mm), specimens measuring 7.5 x 10 mm or 5 x 10 mm are to be used. The requirements applicable to these specimens as compared with the standard specimens are shown in Table 4.16.

4.6 Test of surface finish and dimensions

Tests are to be performed in accordance with A.8.6.

4.7 Non-destructive tests

All pipes are to be subjected by the manufacturer to a non-destructive test over their whole length according to EN ISO 10893.

Table 4.16 Impact energy for specimens of reduced size

Required impact energy (1) in Table 4.14 (standard specimens)	Required impact energy KV with specimens measuring			
	7.5 mm x 10 mm		5 mm x 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	22

(1) *Average value of 3 specimens; values in brackets apply to the min. individual value*

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

The pipes are to be subjected to a non-destructive test in order to detect longitudinal defects according to EN ISO 10893-10, acceptance category U2, subcategory C or EN ISO 10893-3 (only for ferromagnetic pipe grades), acceptance category F2.

Areas in way of pipe ends which have not been tested automatically, are to be subjected either to a manual or semi-automatic ultrasonic test according to EN ISO 10893-10, acceptance category U2, subcategory C or shall be cut off.

4.8 Tightness test

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

E. Stainless Steel Pipes

1. Scope

1.1 These Rules are applicable to seamless and welded austenitic and austenitic-ferritic stainless steel pipes to be used for the cargo and processing equipment on chemical tankers and for other lines, vessels and equipment where chemical stability is required. Suitable pipe grades conforming to international or national standards and to established and recognized specifications together with the austenitic pipe grades specified in D., Table 4.13 are appropriate to these applications subject to the following conditions relating to manufacture and testing.

1.2 Pipe grades are to 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 are to 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 Properties

3.1 Chemical composition

The chemical composition of the pipe steels is to conform to recognized standards or specifications.

3.2 Resistance to intercrystalline corrosion

In the condition in which they are supplied, the pipes are to 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 are to be satisfied in tests at room temperature in accordance with the standard or the recognized specification.

3.4 Technological properties

In the ring tests, the pipes are to 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 are to be met at the corresponding temperature level.

3.6 Impact energy

The required impact energy values are to be satisfied in tests at room temperature in accordance with the relevant standard or the recognized specification.

4. Testing

The following tests are to be performed:

4.1 Test of chemical composition

The chemical composition of each heat is to 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 is to be performed on the following pipes:

4.2.1 Pipes for use on chemical tankers irrespective of the type of material

4.2.2 Pipes which do not meet the requirements in respect of stabilization or limited carbon content specified in 3.2

4.2.3 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 is to be performed on specimens of the sample pipes selected in accordance with A.8.2.

4.4 Technological tests

Unless more extensive testing is prescribed in the standards, one of the ring tests specified in A., Table 4.1 is to 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 is to 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 is to 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 are to be subjected by the manufacturer to non-destructive testing over their entire length according to EN ISO 10893.

The pipes are to be subjected to a non-destructive test in order to detect longitudinal defects according to EN ISO 10893-10, acceptance category U2, subcategory C.

Areas in way of pipe ends which have not been tested automatically are to be subjected either to a manual or semi-automatic ultrasonic test according to EN ISO 10893-8, acceptance category U2, subcategory C or are to be cut off.

4.8 Tightness test

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

F. Fittings

1. Scope

These rules are applicable to seamless and welded carbon, carbon manganese, low alloy and alloy steel fittings fabricated from pipes or plates and intended for piping systems or pressure plants.

2. Steel Grades

2.1 Fittings fabricated from pipes are to meet the requirements of A. to E., depending on the applications, with respect to manufacture, chemical composition and mechanical properties. Fittings may be hot or cold formed from sections of pipes.

2.2 Fittings fabricated from plates are to meet the requirements of Section 3, depending on the applications, with respect to manufacture, chemical composition and mechanical properties.

Fittings may be made from sections of plates formed in one or more shells and welded together. The relevant welding process is to be approved.

2.3 Unless otherwise required, the material used for the fabrication of the fittings is to have a work's certificate.

3. Condition of Supply

All fittings are to be in the heat treated or hot working condition specified for the corresponding material.

Fittings in ferritic steel manufactured by hot forming may be delivered in the normalized forming condition in lieu of normalizing, provided that evidence is given of the equivalence of such condition.

Fittings manufactured by cold forming are in general to be submitted to heat treatment after forming.

The heat treatment procedure of welded fittings is to be defined during the approval tests.

4. Mechanical Properties

The mechanical properties of the finished fittings are to comply with the values specified for the original materials (plate or pipe).

5. Testing

5.1 Mechanical and technological tests

The fittings are to be presented for testing in batches homogeneous for cast and in the number of each sample selected in accordance with A.8.2.

A Brinell hardness test HB is to be performed on 10% of the fittings, with a minimum of 3 units, to verify the homogeneity of the batch. The difference in the hardness value may not be greater than 30 units.

Two fittings per batch are to be selected for the mechanical and technological tests stated in A. to E. depending on the application.

The tensile tests are to be performed on the hardest and softest fittings.

5.2 Non-destructive tests

Unless otherwise specified during the approval procedure or in the order, checks with radiographic examination are in general to be performed on welded fittings with outside diameter greater than 75 mm, at the surveyor's discretion.

6. Marking

The requirements specified in A,9 are to be complied with.

7. Certification

The requirements specified in A,10 are to be complied with.

SECTION 5

STEEL FORGINGS

A. General

1. Scope

1.1 These rules are applicable to steel forgings intended for hull and machinery applications such as rudder stocks, pintles, propeller shafts, crankshafts, connecting rods, piston rods, gearing, etc. Where relevant, these rules are also applicable to material for forging stock and to rolled bars intended to be machined into components of simple shape.

1.2 These rules 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 high temperatures.

1.3 Alternatively, forgings which comply with national or proprietary specifications may be accepted provided such specifications give reasonable equivalence to these rules or otherwise specially approved or required by **TL.**

2. Manufacture

2.1 Forgings are to be made at a manufacturer approved by **TL.**

2.2 The steel used in the manufacture of forgings is to be made by a process approved by **TL.**

2.3 Adequate top and bottom discards are to be made to ensure freedom from piping and harmful segregations in the finished forgings.

2.4 The plastic deformation is to be such as to ensure soundness, uniformity of structure and satisfactory mechanical properties after heat treatment.

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

2.5.1 For forgings made from ingots or from forged blooms or billets, 3:1 where $L>D$ and 1.5:1 where $L \leq D$.

2.5.2 For forgings made from rolled products, 4:1 where $L>D$ and 2:1 where $L \leq D$.

2.5.3 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.

2.5.4 For rolled bars, 6:1.

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

2.6 The shaping of forgings or rolled slabs and billets by flame cutting, scarfing or arc-air gouging is to be undertaken in accordance with recognized good practice and, unless otherwise approved, is to be carried out before the final heat treatment.

Preheating is to be employed when necessitated by the composition and/or thickness of the steel. For certain components, subsequent machining of all flame cut surfaces may be required.

2.7 When two or more forgings are joined by welding to form a composite component, the proposed welding procedure specification is to be submitted for approval. Welding procedure tests may be required.

2.8 For crankshafts, where grain flow is required in the most favourable direction having regard to the mode of stressing in service, the proposed method of manufacture may require special approval by TL. In such cases, tests may be required to demonstrate that a satisfactory structure and grain flow are obtained.

3. Quality of Forgings

All forgings are to be free from surface or internal defects which would be prejudicial to their proper application in service.

4. Chemical Composition

4.1 All forgings are to be made from killed steel and the chemical composition is to be appropriate for the type of steel, dimensions and required mechanical properties of the forgings being manufactured.

4.2 The chemical composition of each heat is to be determined by the manufacturer on a sample taken preferably during the pouring of the heat. When multiple heats are tapped into a common ladle, the ladle analysis shall apply.

4.3 The chemical composition is to comply with the overall limits given in Tables 5.2 and 5.3 or, where applicable, the requirements of the approved specification.

4.4 At the option of the manufacturer, suitable grain refining elements such as aluminium, niobium or vanadium may be added. The content of such elements is to be reported.

4.5 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.

4.6 Carbon equivalent (C_{eq}) values, when used in this section, are calculated using the following formula:

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

5. Heat Treatment (Including Surface Hardening and Straightening)

5.1 At an appropriate stage of manufacture, after completion of all hot working operations, forgings are to be suitably heat treated to refine the grain structure and to obtain the required mechanical properties.

5.2 Except as provided in 5.7 and 5.8 forgings are to be supplied in one of the following conditions:

5.2.1 Carbon and carbon-manganese steels

Fully annealed
Normalized
Normalized and tempered
Quenched and tempered

5.2.2 Alloy steels

Quenched and tempered

For all types of steel the tempering temperature is to be not less than 550ºC. Where forgings for gearing are not intended for surface hardening, lower tempering temperature may be allowed.

5.3 Alternatively, alloy steel forgings may be supplied in the normalized and tempered condition, in which case the specified mechanical properties are to be agreed with **TL.**

5.4 Heat treatment is to be carried out in properly constructed furnaces which are efficiently maintained and have adequate means for control and recording of temperature. The furnace dimensions are to be such as to allow the whole furnace charge to be uniformly heated to the necessary temperature. In the case of very large forgings alternative methods of heat treatment will be considered specially by **TL**.

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.

5.5 If for any reasons a forging is heated subsequently for further hot working the forging is to be reheat treated.

5.6 Where it is intended to surface harden forgings, full details of the proposed procedure and specification are to be submitted for approval. For the purpose of this approval, the manufacturer 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 do not impair the soundness and properties of the steel.

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.

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.

5.9 If a forging is locally reheated or any straightening operation is performed after the final heat treatment consideration is to be given to a subsequent stress relieving heat treatment.

5.10 The forge is to maintain records of heat treatment identifying the furnace used, furnace charge, date, temperature and time at temperature. The records are to be presented to the surveyor on request.

6. 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 are to be given in the order documents and are to be made known to the Surveyor.

7. Tightness

Hollow forgings subjected to internal pressure by the operating medium are to be leak proof at the specified test pressure.

8. Mechanical and Technological Properties

8.1 Tensile test

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

8.2 Notched bar impact test

The impact energy values specified for the various steel grades are to 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.

8.3 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 are to be verified by appropriate tests.

9. Testing

9.1 Proof of chemical composition

The manufacturer is to determine the chemical composition of each heat and present a corresponding certificate to the Surveyor. The certificate is to 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 is to be performed.

9.2 Test of mechanical properties and selection of specimens

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

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

9.2.3 Test material, sufficient for the required tests and for possible retest purposes, is to be provided with a cross-sectional area of not less than that part of the forging which it represents. This test material is to be integral with each forging except as provided in 9.2.14

and 9.2.17. Where batch testing is permitted according to 9.2.17, the test material may alternatively be a production part or separately forged. Separately forged test material is to have a reduction ratio similar to that used for the forgings represented.

9.2.4 For the purpose of these requirements a set of tests is to consist of one tensile test specimen and, when required, three Charpy V-notch impact test specimens.

9.2.5 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.

9.2.6 Unless otherwise agreed, the longitudinal axis of test specimens is to be positioned as follows:

- For thickness or diameter up to maximum 50 mm, the axis is to be at the mid-thickness or the center of the cross section.

- For thickness or diameter greater than 50 mm, the axis is to be at one quarter thickness (mid-radius) or 80 mm, whichever is less, below any heat treated surface.

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

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

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

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

Transverse: The longitudinal axis of the specimen traverses the fibre pattern at right angles. Specimens with a longitudinal axis lying in the direction of an additional compression (perpendicular to an expansion) of the fibre pattern (so-called location "in the thickness direction") are not covered by the specimen positions termed "transverse".

9.2.8 Normally, test specimens are to 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. Prior separation is permitted only where the manufacturing process makes this unavoidable. In these circumstances, the forging and the test section are to be heat treated together.

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

- Normalized forgings: one test section from one forging per test batch,

- Quenched and tempered forgings: per test batch one test section from two forgings. With batches of 10 forgings or less, a test section is required from only one forging.

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

9.2.10 Depending on the conditions agreed on placing the order, the test sections are to be taken as follows:

- From a forging (which is then destroyed in its entirety),

- From additional material provided on the forging,

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

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

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

9.2.12 For forgings whose method of manufacture are subject to special approval by TL, the number and position of the test sections shall be specially determined with regard to the method of manufacture.

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

9.2.14 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.

9.2.15 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.

9.2.16 When forgings are to be carburized, sufficient test material is to be provided for both preliminary tests at the forge and for final tests after completion of carburizing.

For this purpose duplicate sets of test material are to be taken from positions as detailed in C.5.1.1, C.5.1.2 and D.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.

This test material is 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 material is to be given a blank carburizing and heat treatment cycle simulating that which subsequently will be applied to the forging.

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

At the discretion of the forgemaster or gear manufacture test samples of larger cross section may be either carburized or blank carburized, but these are to be machined to the required diameter prior to the final quenching and tempering heat treatment.

Alternative procedures for testing of forgings which are to be carburized may be specially agreed with TL.

9.2.17 Normalized forgings with mass up to 1000 kg each and quenched and tempered forgings with mass up to 500 kg each may be batch tested. A batch is to consist of forgings of similar shape and dimensions, made from the same heat of steel, heat treated in the same furnace charge and with a total mass not exceeding 6 tonnes for normalized forgings and 3 tonnes for quenched and tempered forgings, respectively.

Unless otherwise agreed with **TL**, the size of the test batch shall be as detailed in Table 5.1.

Table 5.1 Heat treatment weight of individual forging and number of forgings per test batch

Heat treatment weight of individual forging [kg]	Number of forgings per test batch
up to 15	≤ 300
> 15 to 150	≤ 100
> 150 to 300	≤ 50
> 300 to 1000	≤ 25

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

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

9.2.18 A batch testing procedure may also be used for hot rolled bars. A batch is to consist of either:

- Material from the same rolled ingot or bloom provided that where this is cut into individual lengths, these are all heat treated in the same furnace charge, or
- Bars of the same diameter and heat, heat treated in the same furnace charge and with a total mass not exceeding 2.5 tonnes.

9.2.19 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.

Table 5.2 Chemical composition limits (1) for hull steel forgings (6)

Steel type	C max.	Si max.	Mn	P max.	S max.	Cr	Mo	Ni	Cu(4)	Total residuals
C, C-Mn	0.23 **(2), (3)**	0.45	0.30-1.50	0.035	0.035	0.30 **(4)**	0.15 **(4)**	0.40 **(4)**	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:*

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

(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 5.3 Chemical composition limits (1) for machinery steel forgings

Steel type	C	Si	Mn	P	S	Cr	Mo	Ni	Cu(3)	Total residuals
C, C-Mn	0.65 **(2)**	0.45	0.30-1.50	0.035	0.035	0.30 **(3)**	0.15 **(3)**	0.40 **(3)**	0.30	0.85
Alloy **(4)**	0.45	0.45	0.30-1.00	0.035	0.035	Min. 0.40 **(5)**	Min. 0.15 **(5)**	Min. 0.40 **(5)**	0.30	-

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

(2) *The carbon content of C and C-Mn steel forgings intended for welded construction is to be 0.23 maximum. The carbon content may be increased above this level provided that the carbon equivalent (C_{eq}) is not more than 0.41%.*

(3) *Elements are considered as residual elements unless shown as a minimum.*

(4) *Where alloy steel forgings are intended for welded constructions, the proposed chemical composition is subject to approval by **TL**.*

(5) *One or more of the elements is to comply with the minimum content.*

9.3 Retests in the event of failure of specimens

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

10. Inspection

10.1 Before acceptance, all forgings are to be presented to the surveyor for visual examination. Where appropriate, this is to include the examination of internal surfaces and bores. Unless otherwise agreed the verification of dimensions is the responsibility of the manufacturer.

10.2 When required by the relevant construction rules, or by the approved procedure for welded composite components appropriate non-destructive testing is also to be carried out before acceptance and the results are to be reported by the manufacturer

10.3 When required by the conditions of approval for surface hardened forgings (A.5.6), additional test samples are to be processed at the same time as the forgings which they represent. These test samples are subsequently to be sectioned in order to determine the hardness, shape and depth of the locally hardened zone and which are to comply with the requirements of the approved specification.

10.4 In the event of any forging proving defective during subsequent machining or testing, it is to be rejected notwithstanding any previous certification.

11. Non-Destructive Tests

11.1 Where non-destructive tests are called for, these are to be performed by the manufacturer and/or finishing plant.

11.2 Non-destructive tests are to be performed in accordance with the specifications stated in G.

12. Rectification of Defective Forgings

12.1 Defects may be removed by grinding or chipping and grinding provided the component dimensions are acceptable. The resulting grooves are to have a bottom radius of approximately three times the groove depth and are to be blended into the surrounding surface so as to avoid any sharp contours. Complete elimination of the defective material is to be verified by magnetic particle testing or liquid penetrant testing.

12.2 Repair welding of forgings except crankshaft forgings may be permitted subject to prior approval of **TL**. In such cases, full details of the extent and location of the repair, the proposed welding procedure, heat treatment and subsequent inspection procedures are to be submitted for the approval.

12.3 The forging manufacturer is to maintain records of repairs and subsequent inspections traceable to each forging repaired. The records are to be presented to the surveyor on request.

13. Identification of Forgings

13.1 The manufacturer is to adopt a system of identification, which will enable all finished forgings to be traced to the original cast and the surveyor is to be given full facilities for so tracing the forgings when required.

13.2 Before acceptance, all forgings which have been tested and inspected with satisfactory results are to be clearly marked by the manufacturer with the following details:

- Steel quality,
- Identification number, cast number or other marking which will enable the full history of the forging to be traced,
- Manufacturer's name or trade mark,

- TL’s name,initials or symbol,
- Abbreviated name of the TL's local office,
- Personal stamp of Surveyor responsible for inspection,
- Date of test and test pressure (where applicable).

13.3 Where small forgings are manufactured in large numbers, modified arrangements for identification may be specially agreed with **TL.**

14. Certification

The manufacturer is to provide the required type of inspection certificate giving the following particulars for each forging or batch of forgings which has been accepted:

- Purchaser’s name and order number,
- Description of forgings and steel quality,
- Identification number,
- Steelmaking process, cast number and chemical analysis of ladle sample,
- Results of mechanical tests,
- Results of non-destructive tests, where applicable,
- Details of heat treatment, including temperature and holding times.

B. Forgings for Hull and Machinery Construction

1. Scope

These Rules are applicable to forgings made of unalloyed and low alloy steels intended for the manufacture of components and structural parts in hull and machinery construction, e.g. shafts, piston rods, connecting rods, rudderstocks and heel pintles.

They are also applicable to rolled round bars for the manufacture of shafts, pins, tie-rods and similar components which are given their final shape by machining.

2. Steel Grades

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

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

An initial test of product suitability may be required for this purpose.

3. Condition of supply and heat treatment

3.1 All forgings are to be heat treated properly. Acceptable methods of heat treatment are:

- For carbon and carbon-manganese steels:
  Normalizing,
  Normalizing and tempering (air quenching and tempering),

  Quenching and tempering

- For alloy steels:
  Quenching and tempering

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

4. Chemical composition

4.1 The chemical composition of the forging steels is subject to the limit values in Tables 5.2 and 5.3.

4.2 Where forgings are to be used in welded assemblies, the composition is to be specially determined by reference to the welding method used and is to be submitted to **TL** for approval.

5. Mechanical and technological properties

5.1 Tables 5.6 and 5.7 give the minimum requirements for yield stress, elongation, reduction of area and impact test energy values corresponding to different strength levels but it is not intended that these should necessarily be regarded as specific grades. Where it is proposed to use a steel with a specified minimum tensile strength intermediate to those given, corresponding minimum values for the other properties may be obtained by interpolation.

5.2 Forgings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Tables 5.6 or 5.7 but subject to any additional requirements of the relevant construction Rules.

5.3 The mechanical properties are to comply with the requirements of Tables 5.6 or 5.7 appropriate to the specified minimum tensile strength or, where applicable, the requirements of the approved specification.

5.4 At the discretion of TL hardness tests may be required on the following:

- Gear forgings after completion of heat treatment and prior to machining the gear teeth. The hardness is to be determined at four positions equally spaced around the circumference of the surface where teeth will subsequently be cut. Where the finished diameter of the toothed portion exceeds 2.5 m, the above number of test positions is to be increased to eight. Where the width of a gear wheel rim forging exceeds 1.25 m, the hardness is to be determined at eight positions at each end of the forging.

- Small crankshaft and gear forgings which have been batch tested. In such cases at least one hardness test is to be carried out on each forging.

The results of hardness tests are to be reported and, forinformation purposes, typical Brinell hardness values are given in Table 5.7.

5.5 Hardness tests may also be required on forgings which have been induction hardened, nitrided or carburized. For gear forgings these tests are to be carried out on the teeth after, where applicable, they have been ground to the finished profile. The results of such tests are to comply with the approved specifications (see A.5.6). Where a hardness test is stipulated, the hardness values measured at different points on the forging or on different units within a unit test quantity respectively may not differ by more than the amounts stated in Table 5.5

5.6 Re-test requirements for tensile tests are to be in accordance with Section 2.

5.7 Re-test requirements for Charpy impact tests are to be in accordance with Section 2.

5.8 The additional tests detailed in 5.6 and 5.7 are to be taken, preferably from material adjacent to the original tests, but alternatively from another test position or sample representative of the forging or batch of forgings.

5.9 At the option of the manufacturer, when a forging or a batch of forgings has failed to meet the test requirements, it may be reheat treated and re-submitted for acceptance tests.

5.10 If two test specimens are taken from forgings, the difference between the measured tensile strength values may not exceed the magnitudes stated in Table 5.4.

5.11 The required impact energy values shown in Tables 5.6 and 5.7 in relation to the specified minimum tensile strength shall be met.

Irrespective of this, for heel pintles and rudderstocks an impact energy of at least 27 J are to be attained with longitudinal Charpy V-notch specimens measured at 0°C for ships with ice class symbols ICE-B3 and ICE-B4 and at -20°C for ships with the arctic ice class symbols ARC1 to ARC4. One individual value may be below the average value but shall not be less than 19 J.

For propeller shafts intended for ships with ice class an elongation of at least 22% (tensile specimen L_0=5 d_0) and an impact energy of at least 27 J with longitudinal Charpy V-notch specimens measured at -10°C must be attained.

Table 5.4 Differences permitted between tensile strength values

Minimum tensile strength R_m [N/mm^2]	Difference in hardness Brinell units [N/mm^2]
< 600	70
≥ 600 < 900	100
≥ 900	120

Hardness tests may also be required on forgings which have been induction hardened, nitrided or carburized. For gear forgings these tests are to be carried out on the teeth after, where applicable, they have been ground to the finished profile. The results of such tests are to comply with the approved specifications in A.5.6.

Table 5.5 Differences permitted between hardness values

Minimum tensile strength R_m [N/mm^2]	Difference in hardness Brinell units
< 600	Up to 25
≥ 600 < 900	Up to 35
≥ 900	Up to 42

Table 5.6 Mechanical properties for hull steel forgings

Steel type	Tensile strength 1) R_m min. N/mm^2	Yield stress R_e min. N/mm^2	Elongation A5 min. %		Reduction of area Z min. %		Charpy V- notch 2) 3)		
							Temperature (°C)	Energy (J)	
			Long.	Tang.	Long.	Tang.		Long.	Tang.
C and C-Mn	400	200	26	19	50	35	0	27	18
	440	220	24	18	50	35	0	27	18
	480	240	22	16	45	30	0	27	18
	520	260	21	15	45	30	0	27	18
	560	280	20	14	40	27	0	27	18
	600	300	18	13	40	27	0	27	18
Alloy	550	350	20	14	50	35	0	32	22
	600	400	18	13	50	35	0	32	22
	650	450	17	12	50	35	0	32	22

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

l = longitudinal, t = transverse

3) *Test direction shall follow the requirements of 9.2.5.*

Table 5.7 Mechanical properties for machinery steel forgings 2)

Steel type	Tensile strength 1) R_m min. N/mm^2	Yield stress R_e min.	Elongation A5 min. %		Reduction of area Z min. %		Charpy V-notch 4) 5)		Hardness 3) (Brinell)
			Long.	Tang.	Long.	Tang.	Long.	Tang.	
C and C-Mn	400	200	26	19	50	35	-	-	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	41	24	175-215
	700	420	16	12	45	30	32	22	205-245
	800	480	14	10	40	27	32	22	235-275
	900	630	13	9	40	27	27	18	260-320
	1000	700	12	8	35	24	25	16	290-365
	1100	770	11	7	35	24	21	13	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 propeller shafts intended for ships with ice class notation except the lowest one, Charpy V-notch impact testing is to be carried out for all steel types at –10°C and the average energy value is to be minimum 27 J (longitudinal test). One individual value may be less than 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) *Testing shall be carried out at +20°C.*
5) *Test direction shall follow the requirements of 9.2.5.*

6. Testing

6.1 Mechanical testing

Testing is to be accomplished by tensile tests and notched bar impact tests in accordance with A.9.2. Quenched and tempered forgings grouped into test batches are to be subjected to additional hardness testing.

Hull components such as rudder stocks, pintles etc. General machinery components such as shafting, connecting rods, etc.

One set of tests is to be taken from the end of each forging in a longitudinal direction except that, at the discretion of the manufacture, the alternative directions or positions as shown in Fig. 5.1, 5.3 and 3 may be used. Where a forging exceeds both 4 tonnes in mass and 3m 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.

6.2 Notched bar impact testing of propeller shafts, rudderstocks and heel pintles for ships with ice class symbols is to be carried out with Charpy V-notch specimens. For all other products, the selection of the specimen shape is to be at the manufacturer's discretion.

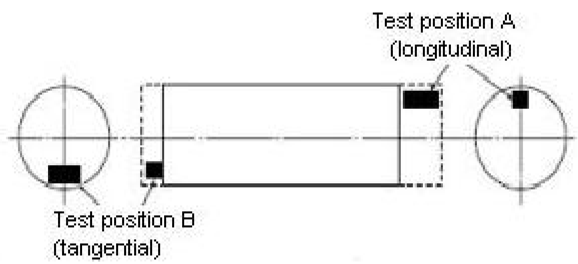


Figure 5.1 Plain shaft

6.3 Non-destructive tests

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

6.4 Test of surface finish and dimensions

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

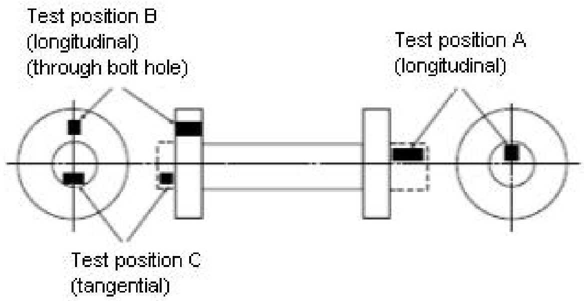


Figure 5.2 Flanged shaft

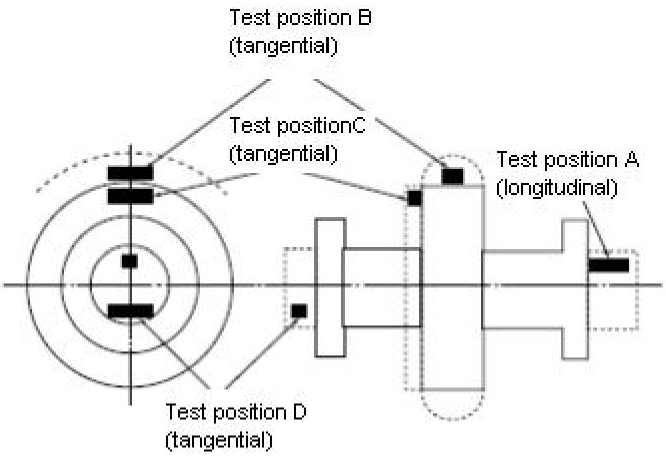


Figure 5.3 Flanged shaft with collar

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. Steel Grades

Only materials which have been approved by **TL** as suitable for the intended application may be used. To this end, the engine manufacturer is to submit to **TL** for approval specifications and/or drawings containing all the data required for evaluating the material, e.g. method of manufacture, chemical composition, heat treatment and mechanical properties. The minimum requirements as per Tables 5.6 and 5.7 are to be satisfied.

3. Requirements Applicable to the Material

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

3.2 The steel is to 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 are to 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. **TL** is to 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 is to 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 are normally to be supplied in quenched and tempered condition. However, crankshafts and their components which are made of carbon and carbon-manganese steels may also be normalized or normalized and tempered. Where crankshafts are to be surface-hardened, the nature of the heat treatment is to be stated in the manufacturer's specification.

5. Testing

5.1 Tensile test

The mechanical properties are to be verified by tensile test. Test specimens are to be taken for this purpose in accordance with 5.1.1 to 5.1.5.

5.1.1 Crankwebs:

One set of tests is to be taken from each forging in a tangential direction.

5.1.2 Solid open die forged crankshafts:

One set of tests is to be taken in a longitudinal direction from the driving shaft end of each forging (test position A in Fig. 5.4).

Where the mass (as heat treated but excluding test material) exceeds 3 tonnes tests in a longitudinal direction are to be taken from each end (test positions A and B in Fig. 5.4). Where, however, the crankthrows are formed by machining or flame cutting, the second set of tests is to be taken in a tangential direction from material removed from the crankthrow at the end opposite the driving shaft end (test position C in Fig. 5.84).

5.1.3 Where the throws are machined or flame cut from a preforged crankshaft, a second set of test specimens are to be taken in the transverse direction from the material removed from the throw furthest from the driven side, see Fig. 5.4.

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

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 in accordance with Table 5.1. For quenched and tempered crankshafts, two tensile test specimens are to be taken from each test batch; for normalized shafts, one specimen is sufficient.

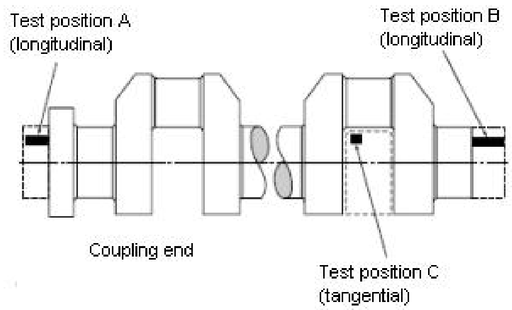


Fig. 5.4 Location of test specimens in crankshaft

5.1.5 Transverse test specimens are to be taken from forged throws. Unless otherwise agreed with **TL**, at least one specimen is to be taken from each forging.

5.1.6 Where two test specimens are taken from large crankshafts, the difference between the measured tensile strength values may not exceed the magnitudes stated in B.5.3.

5.1.7 For closed die crankshaft forgings and crankshaft forgings where the method of manufacture has been specially approved in accordance with A.2.8 , the number and position of test specimens is to be agreed with TL having regard to the method of manufacture employed.

5.2 Notched bar impact test

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

5.1.1 to 5.1.5 for tensile test specimens.

5.3 Hardness test

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

The method of hardness testing and the position of the hardness testing impressions on the forgings are to be agreed with **TL.**

Table 5.8 Suitable steel grades for gears

Steel grade	Standard
42 Cr Mo 4	EN 10083-1
16 Mn Cr 5	EN 10084
20 Mn Cr 5	
18 Cr Ni Mo 7-6	

5.3.2 The differences in the hardness values measured at different points on the forging or on different units within a test batch may not exceed the magnitudes stated in B. 5.5.

5.4 Test of surface finish and dimensions

The crankshaft manufacturer is to test the surface finish and dimensions of the crankshafts and give the measurement records to the Surveyor. He is also to 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 are to be subjected to non-destructive testing according to the scope stipulated in G.

D. Forgings for Gears

1. Scope

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

2. Steel Grades

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

2.1 Quenched and tempered steels conforming to EN 10083-1, case hardening steels conforming to EN 10084 and nitriding steels conforming to EN 10085, provided that proof has been furnished of the suitability of the individual grade of steel for the intended purpose. Table 5.8 contains a selection of suitable steel grades.

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

2.3 Steels conforming to particular material specifications provided that **TL** has authorized their use. To this end, the gear manufacturer is to submit the corresponding specifications for approval. These specifications is to 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 is to be submitted to **TL** for approval. The characteristics of the welds are first to be demonstrated by a welding procedure specification test.

4. Heat Treatment

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

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

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

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

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

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

5. Dimensions, Dimensional and Geometrical Tolerances

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

6. Requirements Applicable to the Material

6.1 Chemical composition

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

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

6.2 Mechanical and technological properties

For quenched and tempered steels, the minimum required values for the yield strength, elongation and reduction in area specified in Tables 5.6 and 5.7 is to be met in relation to the prescribed minimum tensile strength.

For case-hardening steels, the requirements specified in Table 5.9 apply to specimens which have undergone heat treatment together with the forging (coupons).

Table 5.9 Required values for mechanical and technological properties of specimens made of coupons

Steel grade	Sample dia. Φ [mm]	Yield strength R_{eH} [N/mm^2] min	Tensile strength R_m [N/mm^2]	Elongation A (1) [%] min.		Reduction in area Z (1) [%] min.		Impact energy KU (1) [J] min.		Impact energy KV (1) [J] min.	
				ℓ	t, *tr*	ℓ	t,- *tr*	ℓ	t,- *tr*	ℓ	t,- *tr*
16 Mn Cr 5	30	590	780-1080	10	8	40	27	24	18	22	16
20 Mn Cr 5		690	980-1280	8	6	35	27	20	15	18	13
18 Cr Ni Mo 7-6		785	1080-1320	8	6	35	27	20	15	18	13
16 Mn Cr 5	63	440	640-940	11	9	40	27	24	18	22	16
20 Mn Cr 5		540	780-1080	10	8	35	27	24	18	22	16
18 Cr Ni Mo 7-6		685	980-1280	8	6	35	27	20	15	18	13

(1) *Orientation of specimen axis ℓ = longitudinal, t= tangential, tr = 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 are to be performed:

7.1 Test of chemical composition

The material manufacturer is to 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 are to be verified by tensile test. Test specimens are to be taken as follows:

7.2.1 Pinions

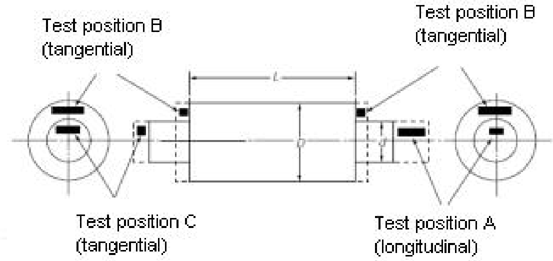
Where the finished machined diameter of the toothed portion exceeds 200mm one set of tests is to be taken from each forging in a tangential direction adjacent to the toothed portion (test position B in Fig. 5.5). Where the dimensions preclude the preparation of tests from this position, tests in a tangential direction are to be taken from the end of the journal (test position C in Fig. 5.5). If however, the journal diameter is 200mm or less the tests are to be taken in a longitudinal direction (test position A in Fig. 5.5). Where the finished length of the toothed portion exceed 1.25 m, one set of tests is to be taken from each end.

7.2.2 Small pinions

Where the finished diameter of the toothed portion is 200mm or less one set of tests is to be taken in a longitudinal direction (test position A in Fig. 5.5).

7.2.3 Gear wheels

One set of tests is to be taken from each forging in a tangential direction (test position A or B in Fig. 5.6).



L = Length of tooth system

D = Diameter of tooth system

d_1, d_2 = Diameter of bearing journal

Fig 5.5 Pinion

7.2.4 Gear wheel rims (made by expanding)

One set of tests is to be taken from each forging in a tangential direction (test position A or B in Fig. 5.7). Where the finished diameter exceeds 2.5 m or the mass (as heat treated excluding test material) exceeds 3 tonnes, two sets of tests are to be taken from diametrically opposite positions(test positions A and B in Fig. 5.7). The mechanical properties for longitudinal test are to be applied.

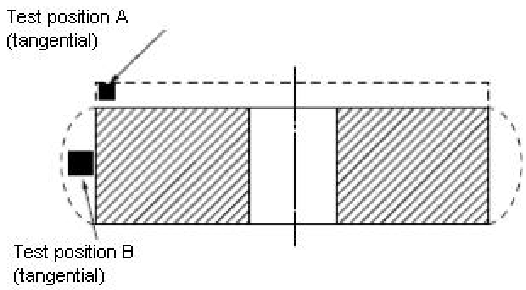


Fig 5.6 Gear wheel

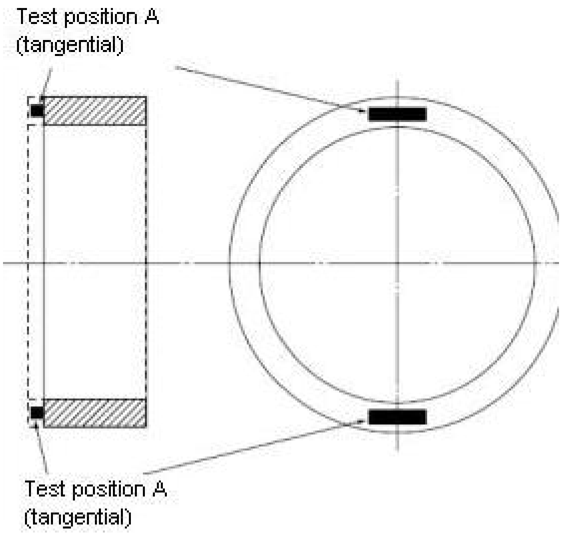


Fig. 5.7 Wheel rim

7.2.5 Pinion sleeves

One set of tests is to be taken from each forging in a tangential direction (test position A or B in Fig. 5.8). Where the finished length exceeds 1.25 m one set of tests is to be taken from each end.

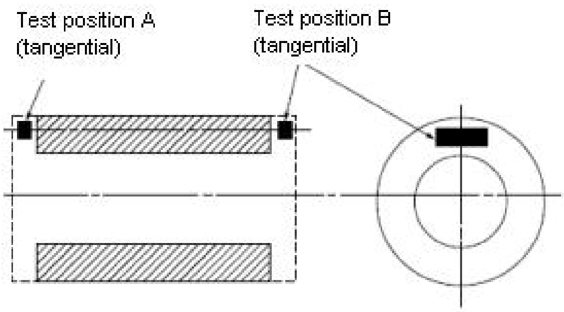


Fig. 5.8 Hollow pinion

7.3 Tensile test on case-hardening steels

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

0.25 x diameter of tooth system ‹Coupling end

63 mm diameter.

If the diameter of the test specimen is less than 63 mm, in agreement with the surveyor a test specimen with standardized dimensions may be used (e.g. 30 mm diameter according to EN 10084).

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

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

7.4 Strength differences in the forging

Where two test specimens are taken from large forgings, the difference between the measured tensile strength values may not exceed the magnitudes specified in B.5.3.

7.5 Notched bar impact test

Each forging or unit test quantity, as applicable, is to be subjected to the notched bar impact test. The number of sets of specimens (each comprising 3 specimens), the positions in the forgings or test sections from which the specimens are taken and their heat treatment are subject to the provisions of 7.2 and 7.3, as appropriate. The test may be carried out on Charpy V- or Charpy U-notch samples as chosen by the manufacturer.

7.6 Hardness test

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

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

7.6.3 The differences in the values measured at the prescribed points on a forging or on different units within a test batch may not exceed the magnitudes specified in B.5.5.

7.7 Test of surface finish and dimensions

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

7.8 Batchwise testing

Forgings with similar dimensions up to a weight in heat-treated condition of 300 kg which originate from the same heat and form part of the same heat treatment batch may be grouped into test batches in accordance with Table 5.1. Two test sections are to be taken from each test batch for the tensile test and the notched bar impact test. Every forging is to be subjected to a hardness test.

7.9 Non-destructive tests

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

7.9.2 The entire tooth system of gear parts with surface-hardened teeth is to be tested for cracks using the magnetic particle or dye penetrant method.

The welds of gear wheels built up of separate parts are to be subjected to non-destructive testing of the scope specified at the time of the process approval.

The tests are to be performed in compliance with G.

E. Forgings for Boilers, Pressure Vessels and Systems

1. Scope

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.

2. Steel Grades

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 EN 10222-5.

2.5 Steel flanges conforming to EN 1092-1.

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 are additionally to satisfy the following minimum requirements.

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

2.6.2 The impact energy is to have the characteristic minimum values for the respective steel grades as specified by **TL**; however, it is to 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 are to 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 **TL** has approved the method.

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

4. Requirements Applicable to the Material

4.1 General requirements

The chemical composition, mechanical properties, and impact energy and hardness values of the steel are to 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 are to 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 are to 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 are to be selected, e.g. steels stabilized with Ti or Nb or steels with carbon contents of C ≤ 0.03%.

5. Testing

The forgings are to be presented for testing in finished condition (condition of supply) and are to undergo the following tests.

5.1 Tensile testing

5.1.1 The mechanical properties are to 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 Table 5.1.

For normalized forgings, one specimen is to be taken from each test batch, while for forgings in other heat-treated conditions, 2 specimens are to 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 are to 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 is to be taken from every forging.

5.2 Notched bar impact test

The forgings are to be subjected to the notched bar impact test. The number of sets of test specimens (3 Charpy V-notch specimens per set) is to 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 is to be performed on each forging.

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

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

5.3.3 In the case of parts not mentioned in paragraphs 5.3.1 and 5.3.2, at least 20% of each test batch is to be tested.

5.4 Test of surface finish and dimensions

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

5.5 Test for use of correct material

Alloy steel forgings are to 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 are to be subjected by the manufacturer to an ultrasonic test and, where necessary, a supplementary test for surface cracks. The tests are to be performed in compliance with G.

5.7 Testing of resistance to intercrystalline corrosion

The manufacturer is to check the resistance to inter-crystalline 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 is to 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 for Low Temperature Services

1. Scope

1.1 These Rules are applicable to steel forgings for low temperature services 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 Section 3, E.8.1.1, Table 3.17 for chemical composition and in Section 3, E.8.2.2 for mechanical properties are to be observed. The required values for impact energy given in Section 3, E.8.3 is also to 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. Steel Grades

The following grades of steel may be used within the minimum design temperature limits specified in Table 5.10 provided that they satisfy the requirements of 5.

2.1 Standardized steels conforming to Table 5.10.

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 are to 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 5.10 Approved grades of forging steels for low temperature services

Type of steel	Approved minimum design temperature	Steel grade or Material No.	Standard
Weldable fine-grained structural steels	-20°C **(1)**	P 285 NH	EN 10222-4
		P 285 QH	
		P 355 N	
		P 355 QH	
%0.5 nickel steel	-55°C	13 Mn Ni 6-3	EN 10222-3
%2.25 nickel steel	-65°C	-	EN 10222-3
%3.5 nickel steel	-90°C	12 Ni 14	
%5 nickel steel	-105°C	12 Ni 19	
	-165°C **(2)**	X 12 Ni 5	
%9 nickel steel	-165°C	X 8 Ni 9	
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 is to conform to the data contained in the relevant standards or approved specifications.

5.2 Weldability

Steels conforming to these Rules are to be weldable by established workshop methods.

5.3 Impact energy at low temperatures

The required impact energy values specified in Table 5.11 for the grade of steel concerned are to 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%.

6. Testing

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

Table 5.11 Required impact energy values for steel forgings for low temperature services

Type of steel	Test temperature	Impact Energy KV [J] (1) min.	
		Longitudinal	Transverse
Weldable fine-grained structural steels and%0.5 nickel steel	5°C 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.*

6.1 Tensile test

6.1.1 The mechanical properties are to 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 Table 5.1.

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

6.1.2 For the batchwise testing, the hardest and softest forgings in each batch are to 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 is to be taken from every forging.

6.2 Notched bar impact test

The forgings are to be subjected to the notched bar impact test using Charpy V-notch specimens. The number of sets of test specimens (3 specimens per set) are to be determined in the same way as the number of tensile test specimens. The tests are to be performed at the test temperatures specified in Table 5.11.

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 is to be performed on every forging.

6.3.2 Flanges with standardized dimensions are to 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 is to be tested.

6.4 Test of surface finish and dimensions

The manufacturer is to 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 are to 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 are to be subjected by the manufacturer to an ultrasonic test and, where necessary, a supplementary test for surface cracks. The test shall be performed in compliance with G.

6.7 Test of resistance to intercrystalline corrosion

The manufacturer is to 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 is to be carried out in the following conditions:

- Steels containing C ≤ 0.03% and stabilized steels: after sensitizing heat treatment (700 °C, 30 min, quenching in water)

- All other steels: in the condition of supply. At least two specimens from each heat shall be tested in accordance with a recognized standard (e.g. ISO 3651-2).

G. Non-destructive Testing of Forged Components

1. Scope

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

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

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

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

1.3 Taking into account the prescriptions in 1.2 in these Rules the following testing methods are described, see Table 5.12.

Table 5.12 Test methods

Testing of	Method	Short name(2)
External condition	Visual testing	VT
	Magnetic particle testing **(1)**	MT
	Penetrant testing	PT
Internal condition	Ultrasonic testing	UT

(1) *Only for forged components made of ferritic steel grades.*
(2) *Definition according to ISO 9712.*

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

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

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

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

For classifying in inspection zones the following principles are decisive:

- The operation loads to be expected,

- The effects of the defects on the reliability of the component,

- Possible risk of damage if the component fails,

- Freedom of defects and surface condition after the final machining.

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

1.6 For forgings where in I. for magnetic particle testing and in J. for ultrasonic testing no classifying in inspection zones is indicated, the manufacturer or customer is to prescribe the inspection zones in a test specification taking into consideration the principles in 1.5 and shall be make them known to the **TL** Surveyor.

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

2. Testing

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

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

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

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

Details for this issue are to be prescribed in a test specification and to be made known to **TL.**

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

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

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

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

3. Visual Testing (VT)

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

3.2 For the acceptance test the forged components are to be presented to the Surveyor in final machined condition.

If necessary an inspection of forged components in raw condition or in premachined condition by the **T**L Surveyor can be agreed on.

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

3.4 The Surveyor certifies the visual inspection on the **TL** acceptance test certificate, e.g. the following text can be typed in the test certificate:

"The aforementioned forged components were visually tested. The prescribed requirements are fulfilled."

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

4. Magnetic Particle Testing (MT)

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

4.2 The roughness of the machined test areas shall not exceed an average roughness of R_a = 12.5 μm for premachined surface, and R_a = 6.3 μm for final machined surface.

4.3 Contact points visible on the surface are to be ground and to be retested by yoke magnetization if they will not be removed by the following machining.

It is not allowed to employ prods on final machined surfaces.

The testing of final machined forged components is to preferably be performed with stationary test appliances.

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

4.5 The indications of magnetic particle testing are to be evaluated depending on the specific inspection zone I to IV concerning their size and number in accordance with Table 5.13. The reference area for this is to be a rectangle with 148 mm x 105 mm (size DIN A6) and shall be placed on the specific most unfavourable area for each case (area with the highest number of indications).

4.6 Concerning the evaluation it shall be differentiated between isolated and aligned indications. These terms are explained in Fig 5.9.

4.7 All indications exceeding the registration levels indicated in Table 5.13 are to be reported.

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

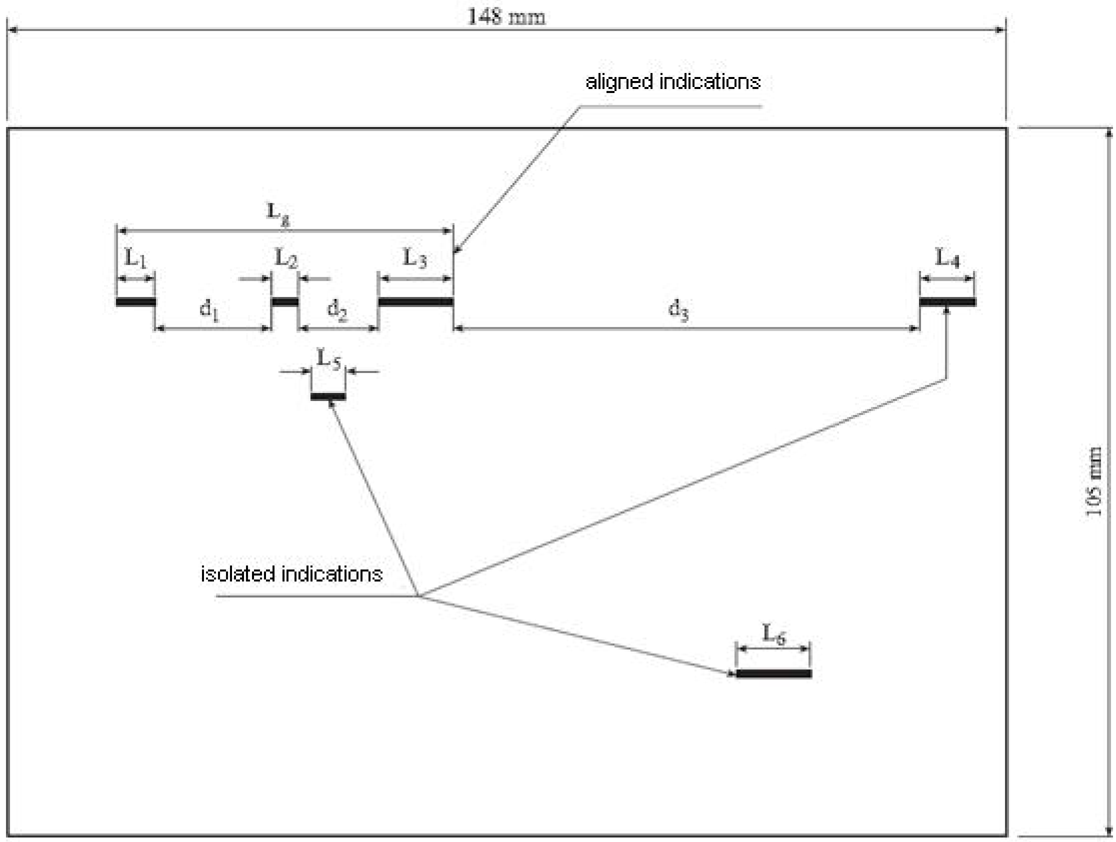
4.8 For the circumferential surfaces of grooves and oil bore holes of crankshafts indications of every type in zone I are not allowed.

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

Table 5.13 Acceptance criteria for magnetic particle testing according to EN 10228-1

Parameter for evaluation	Acceptance limits for inspection zone			
	IV	III	II	I
	appropriate class of quality according to EN 10228-1			
	1	2	3 (1)	4 (2) (3)
Recording level: length of indications [mm]	≥ 5	≥ 2	≥ 2	≥ 1
max. allowed length L_g of aligned or isolated indications L_n [mm]	20	8	4	2
max. allowed cumulative length of indications L_k [mm]	75	36	24	5
max. allowed number of indications on the reference area	15	10	7	5

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



Reference area = 148 mm × 105 mm (d.h. A6-Format)

$d_1 < 5\ L_1$; $d_2 < 5\ L_2$; $d_3 > 5\ L_3$

L_1, L_2 and L_3 = Individual lengths of aligned indications

L_g = Aligned total length of L_1, L_2 and L_3

L_4, L_5 and L_6 = Lengths of isolated indications (L_n)

$L_g + L_4 + L_5 + L_6$ = Cumulative length of indications on the reference area (L_k)

Number of indications on the reference area = 4 (identified as L_g, L_4, L_5, L_6)

Figure 5.9 Reference area and type of indications for magnetic particle testing (MT) according to EN 10228-1

4.10 Repair of defects

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

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

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

5. Penetrant Testing (PT)

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

5.2 Penetrant testing is to be performed on forged components made of austenitic or austenitic-ferritic steel grades. It may be performed on forged components made of ferritic steel grades in addition to magnetic particle testing (MT); nevertheless the results of the magnetic particle tests are decisive concerning the acceptance criteria.

5.3 The manufacturer is to prepare a test instruction which shall contain at least the following information:

- Details of the forged component including the material grade,
- Standards and specifications to be applied,
- Description of the test method,
- Employed testing agent system,
- Qualification of the inspection personnel,
- Surface areas to be tested,
- Required surface condition,
- Test criteria,
- Type of testing report.

5.4 Unless otherwise agreed the testing is to be performed on the final machined forged component and is to be performed in the presence of the Surveyor.

6. Ultrasonic Testing (UT)

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

6.2 For premachined surfaces the average value of the roughness shall be $R_a \leq 25$ μm. It is recommended to agree on the appropriate class of quality for the surface roughness according to Table 5.14.

6.3 The tests may be performed according to ISO 16810, EN 10228-3, SEP 1923 and/or other equivalent and recognized standards, manufacturer or customer specifications.

6.4 Unless no other recording levels were agreed on, all indications exceeding a disc shaped reflector with diameter of 2 mm is to be registered and evaluated and reported concerning their position, size, number and acceptability.

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

Attenuations of the back wall echo with ≥ 4 dB are to be recorded in the testing report in dB.

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

6.7 Indications exceeding the limiting values contained in Table 5.15 or 5.16 are to be regarded as defects and in the first instance result in rejection of the forged component by the Surveyor. If the tests are performed in accordance with a manufacturer or customer specification approved by **TL** then the limiting values indicated there are decisive and the procedure is accordingly.

Table 5.14 Recommendations for the surface quality

Surface quality	**Class of quality and roughness R_a [μm]**			
	1	**2**	**3**	**4**
	≤ 25	≤ 12.5	≤ 12.5	≤ 6.3
Machined	x	x	x	x
Machined and heat treated	x	x	x	
Forged	x			
Note: *"x" indicates the class of quality which can be achieved with the prescribed roughness.*				

Table 5.15 Acceptance criteria for ultrasonic testing of forged components

Forged component	**Zone**	**Size of the max. allowable KSR (1)** [mm]	**Max. allowable length of indications (3)** [mm]	**Min. distance between two indications (3)** [mm]	**Total of all indication lengths [mm] per "m" component length**
Propeller shafts	I **(2)**	-			
Intermediate shafts	II **(2)**	outside : 2	10	10	0.05 · d
Thrust shafts		inside: 4	15	10	0.10 · d
Rudder stocks and pintles	III **(2)**	outside : 3	10	10	0.15 · d
Piston rods **(4)**		insider: 6	15	10	0.20 · d
Connecting rods **(5)**	I	-			
Piston rods	II	2	10	10	0.05 · d
Cross heads	III	4	10	10	0.15 · d (s) **(5)**

(1) *KSR = disc shaped reflector.*

(2) *The classifying in inspection zones is depicted in Figure 5.15 to 5.20.*

(3) *For accumulations of 2 or more isolated indications to be recorded the minimum distance between 2 adjacent indications shall be at least of length of the major indication.*
This applies to distances in axial as well as in thickness direction.
Isolated indications with smaller distance are to be regarded as aligned indication.

(4) *Piston rods with shaft diameter larger than 150 mm.*

(5) *For rectangular cross-section "d" corresponds to the smallest side length "s".*

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

Table 5.16 Acceptance criteria for ultrasonic testing of crank shafts

Zone (2)	Size of the max. allowable KSR (1) [mm]	Max. allowable length of indications [mm]	Min. distance between two indications (3) [mm]	Max. number of isolated indications (3) (4) [-]	Total of all indication length [mm] (4) per pin or journal, or per web or flange, respectively
I	-	-	-	-	-
II	2	10	10	$0.01 \cdot d(D) \cdot \frac{1}{mm}$	0.20 · d (D)
III	4	15	10	$0.02 \cdot d(D) \cdot \frac{1}{mm}$	0.40 · d (D)

(1) *KSR = Disc shaped reflector.*

(2) *The classifying in inspection zones is depicted in Fig. 5.21.*

(3) *For accumulations of 2 or more isolated indications to be recorded the minimum distance between 2 adjacent indications shall be at least of length of major indication.*

This applies to distance in axial as well as in thickness direction.

Isolated indications with smaller distance are to be regarded as aligned indication.

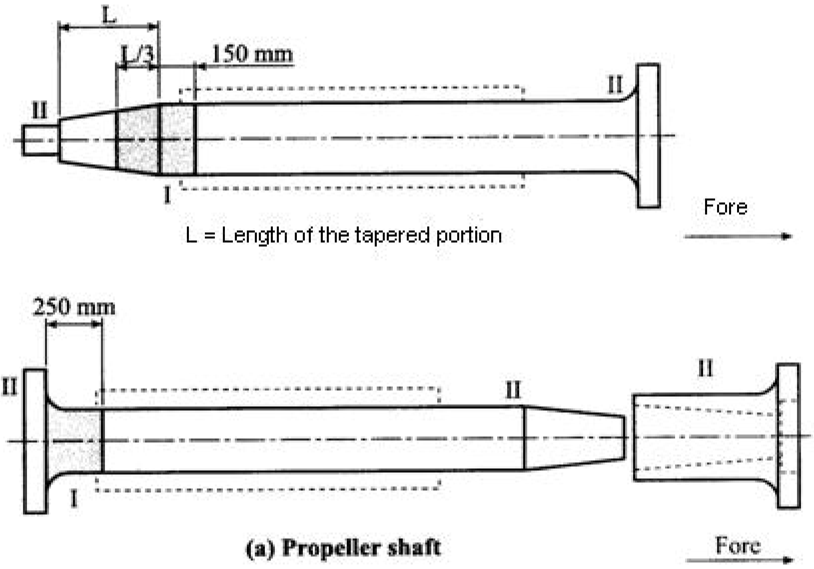
(4) *Related to be diameter of crank pin "d" or to the diameter of main journal "D", respectively.*

H. List of Forged Components for which Non-destructive Tests are Required

Name of the forged component	Test method to be employed		
	VT	MT	UT
Structural parts concerning the hull:			
rudder stocks and pintles	X	X	X **(1)**
Parts for diesel engines:			
- Crank shafts	X	X	X **(3)**
- Connecting rods	X	X	X **(2)**
- Piston rods	X	X	X **(2)**
- Crossheads	X	X	X
- Piston crowns	X	X **(2)**	X
- Cylinder covers	X	X **(2)**	X
- Piston pins	X	X **(2)**	
- Tie rods	X	X **(2)**	
- Bolts > M50 for:			
- Main bearing	X	X **(2)**	
- Connecting rod bearing	X	X **(2)**	
- Cross heads	X	X **(2)**	
- Cylinder covers	X	X **(2)**	
- Camshaft drive gear wheels and chain wheels	X	X **(2)**	
Main shafting and gears:			
- Propeller shafts	X	X	X **(1)**
- Intermediate shafts	X		X **(1)**
- Thrust shafts	X	X	X **(1)**
- 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 ≥ M 50	X	X **(6)**	
- Bolts for superheated steam pipelines	X	X **(6)**	

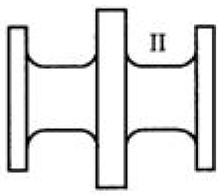
(1) *For diameters ≥ 250 mm.*
(2) *For diesel engines with cylinder diameter > 400 mm.*
(3) *For batchwise testing of small crankshafts ultrasonic testing of the prematerial is sufficient. Small crankshafts are those with gross weights not exceeding 500 kg.*
(4) *For diameter of the gearing or of the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

I. Classifying of Inspection Zones for Magnetic Particle Testing (MT)



(a) Propeller shaft

(b) Intermediate shaft

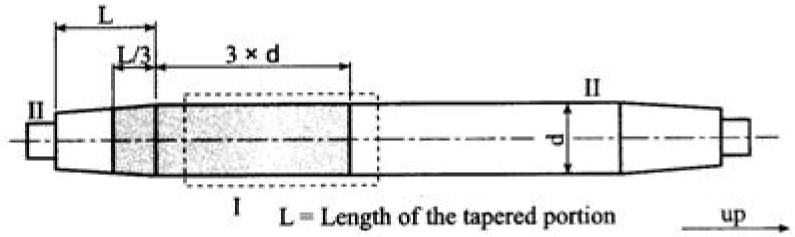


(c) Thrust shaft

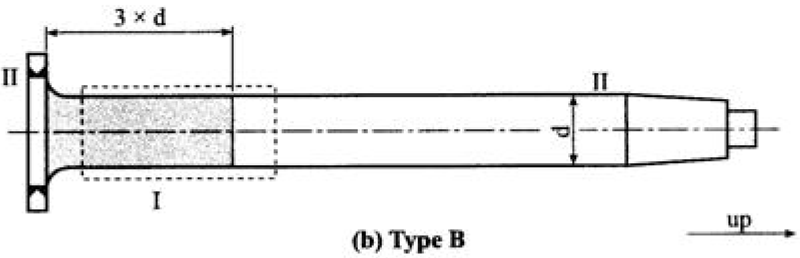
Note:

- *For principles for classifying in inspection zones I to IV see G.1.5.*
- *Acceptance criteria are contained in G. Table 5.13.*

Fig. 5.10 Inspection zones for magnetic particle testing of shafts



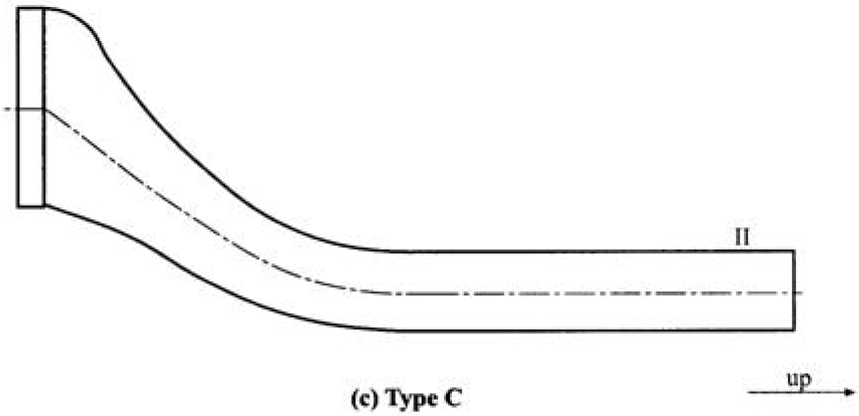
(a) Type A



(b) Type B

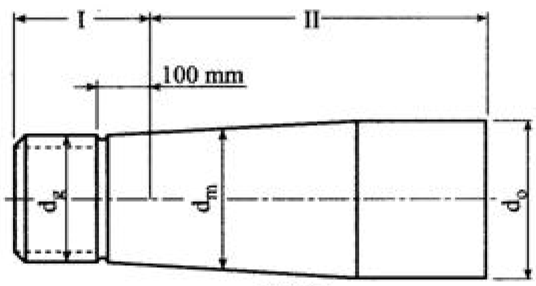
Note

Welded areas are to be regarded as zone I



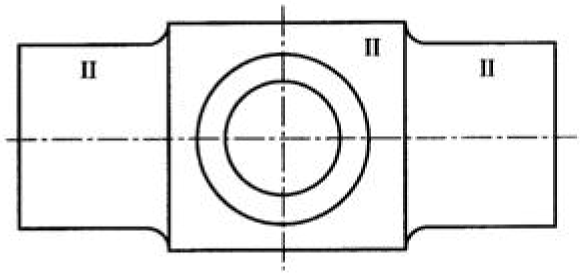
(c) Type C

Rudder stock

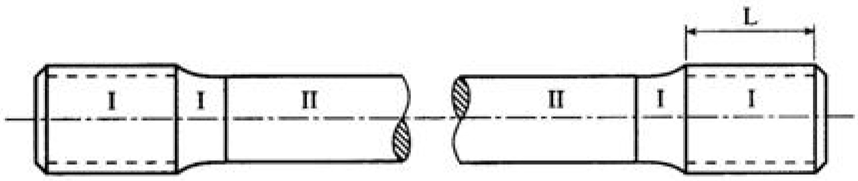


Pintle

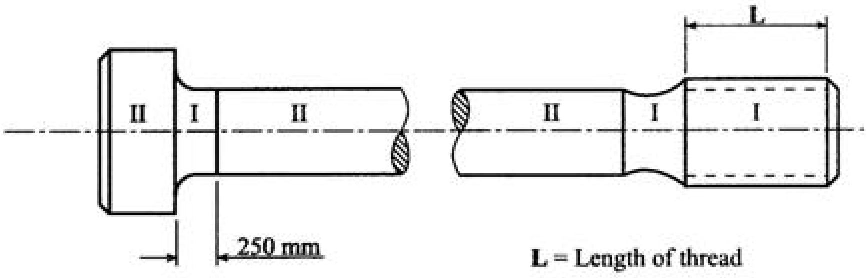
Fig. 5.11 Inspection zones for magnetic particle testing of rudder stocks and accessories



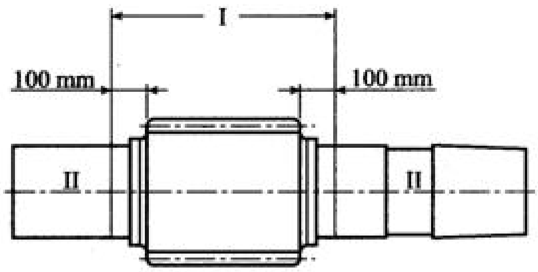
Cross head



Tie rods for diesel engines

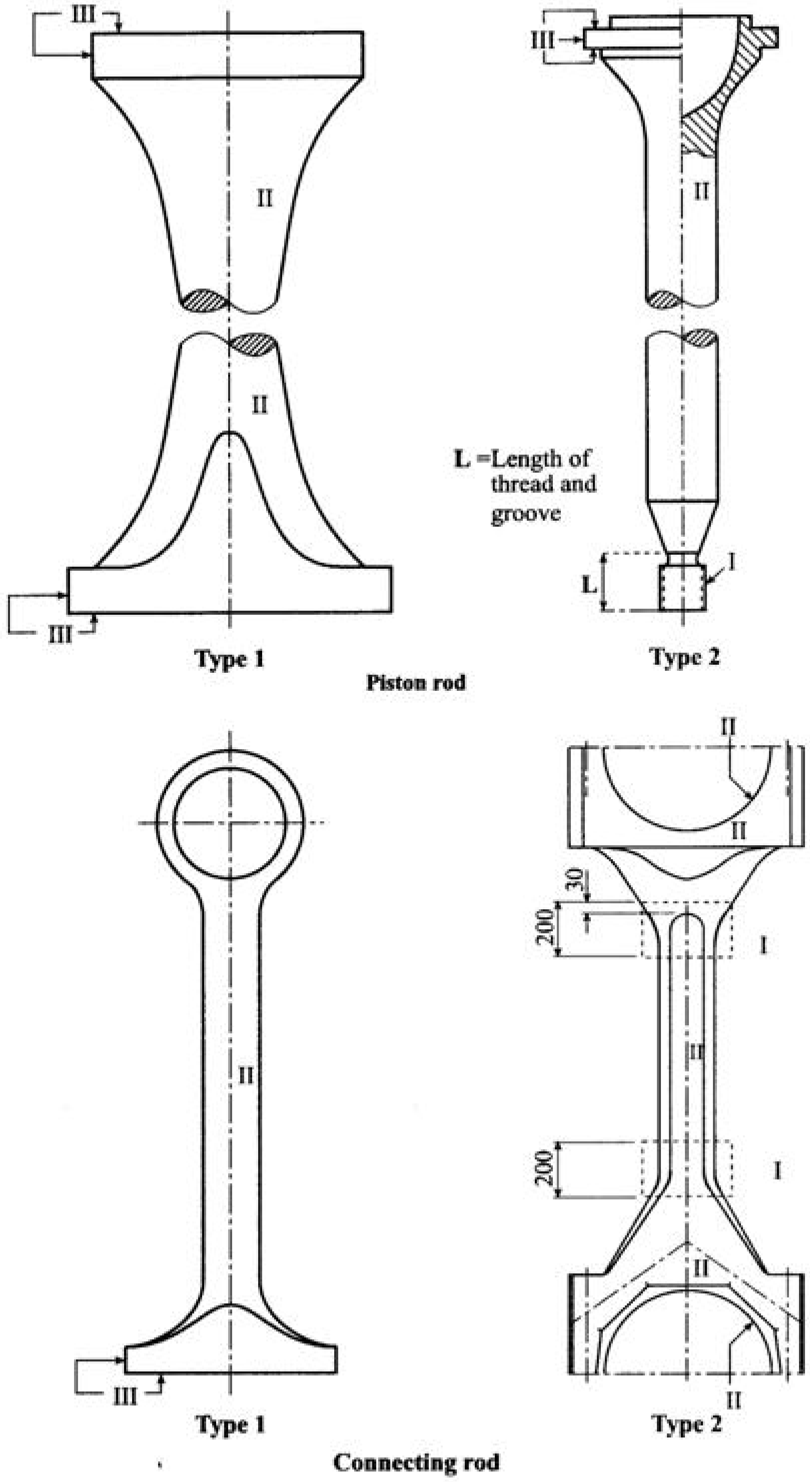


Bolts for connecting rods



Pinion shaft

Fig. 5.12 Inspection zones for magnetic particle testing of machinery components

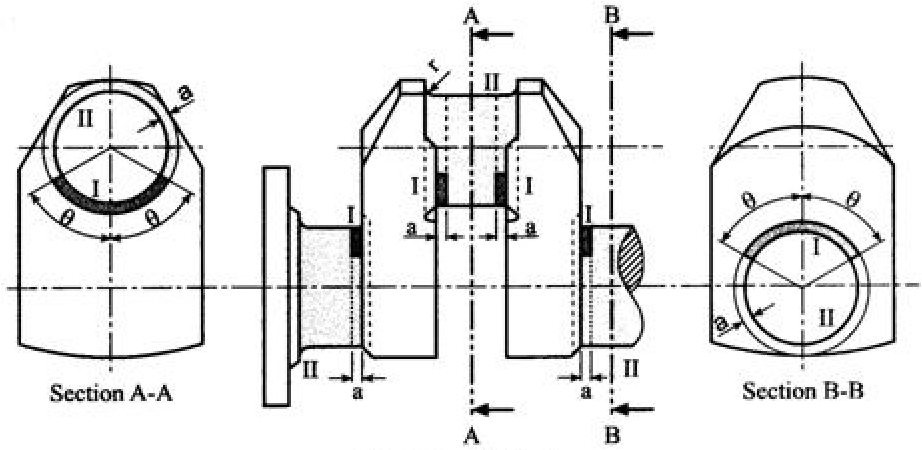


Note :

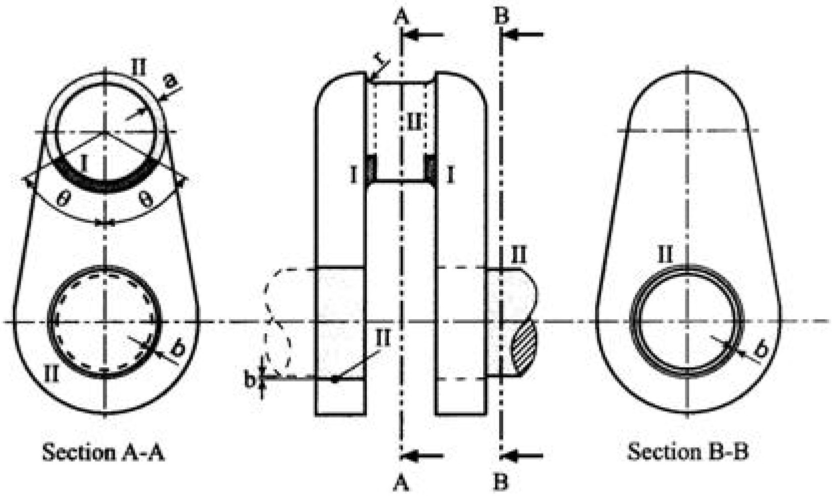
Threads, oil bore holes and their radii are to be regarded as zone I in the regime of 2 · d_B

d_B *= Bore hole diameter.*

Fig. 5.13 Inspection zones for magnetic particle testing of machinery components



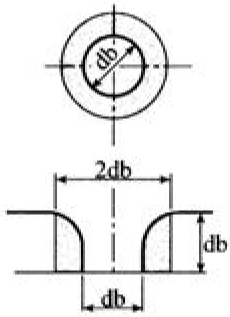
(a) Solid crankshaft



(b) Semi built-up crankshaft

Note

1. *Areas of 2 · db around lubricant bore holes of crank pin or journal are to be regarded as zone 1 (sketch to the right).*



db = Diameter of oil bore hole

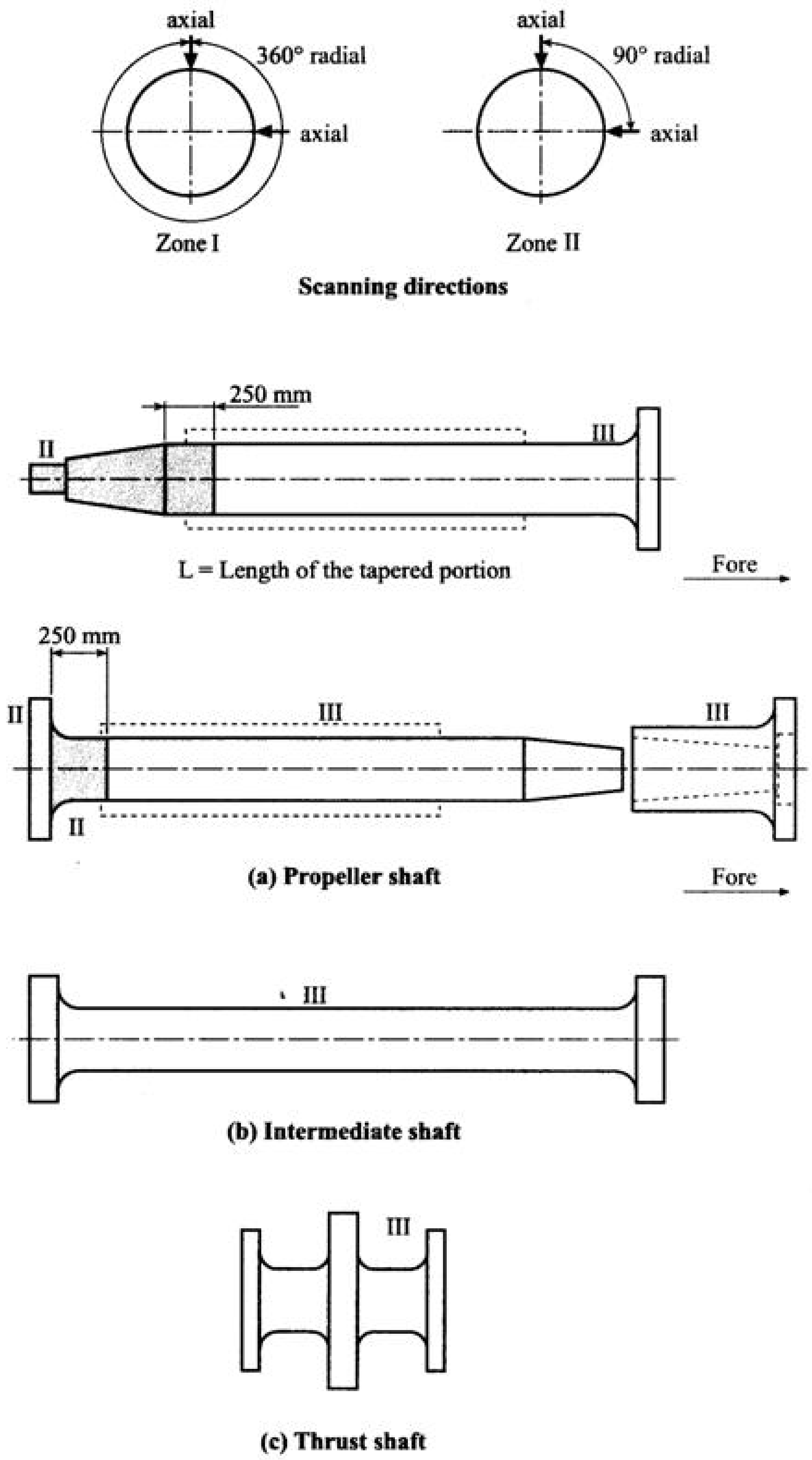
2. *Explanations to the upper figures:*
   θ = 60°
   a = 1,5 · r
   b = 0,05 · d (Peripheral area of the shrinkage fit)
   as well as
   r = Radius of the groove
   d = Pin or journal diameter

3. *Identification of the zones:*
   : Zone I
   : Zone II

4. *The above mentional classifying applies accordingly to forged throws.*

Fig. 5.14 Inspection zones for magnetic particle testing of crank shafts

J. Classifying of Inspection Zones for Ultrasonic Testing (UT)



Note

1. *UT in premachined rotation symmetric condition before machining the taper and threading.*
2. *For hollow shafts: 360° radial scanning applies to Zone II.*
3. *Circumferences of the bolt holes in the flanges are to be treated as Zone II..*

Fig. 5.15 Inspection zones for ultrasonic testing of shafts

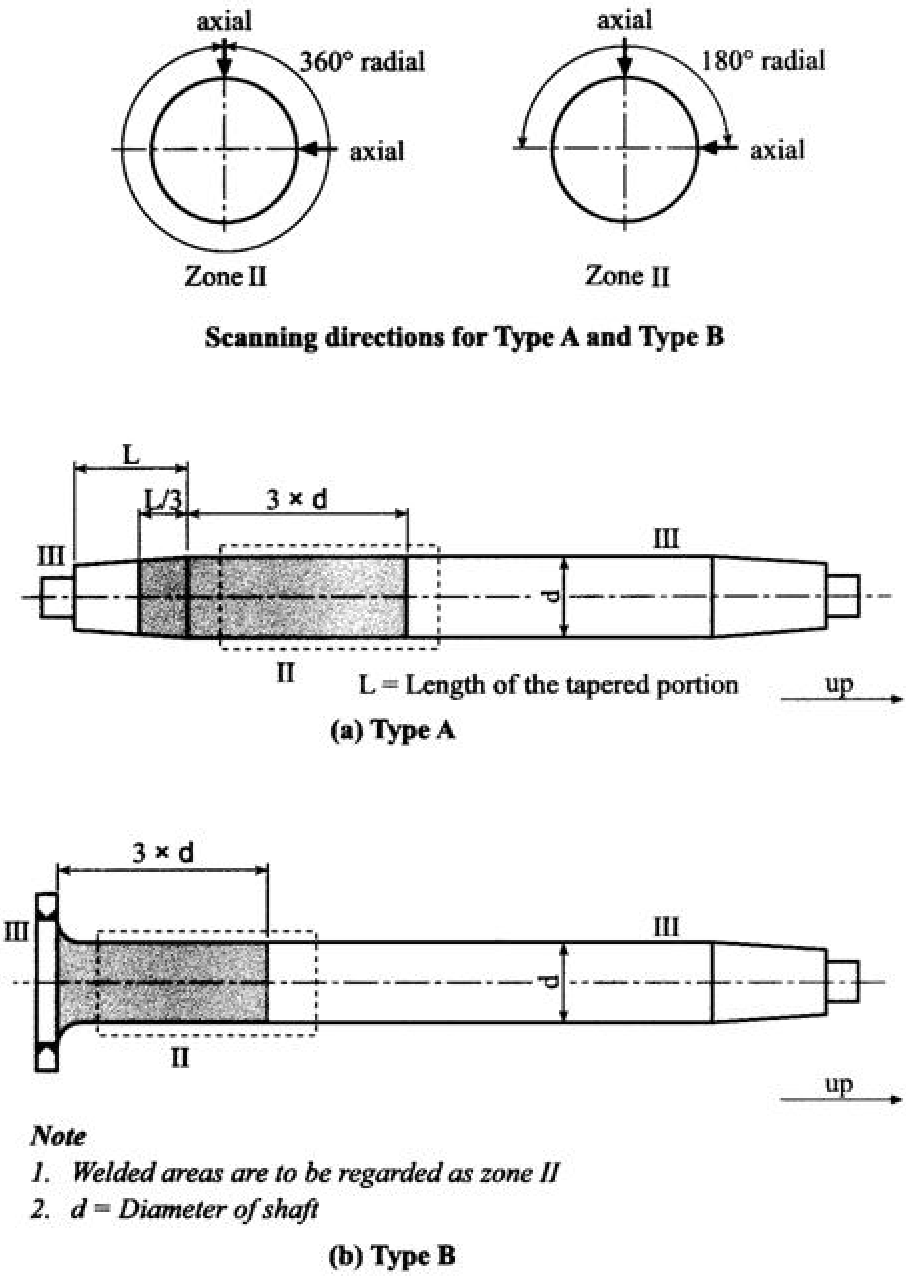
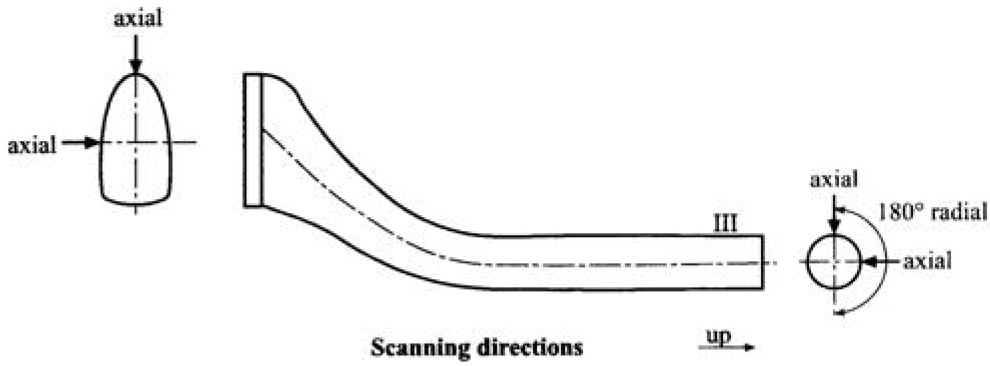
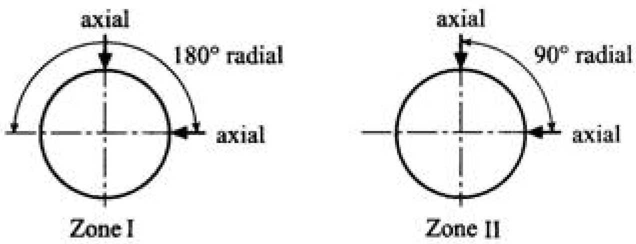


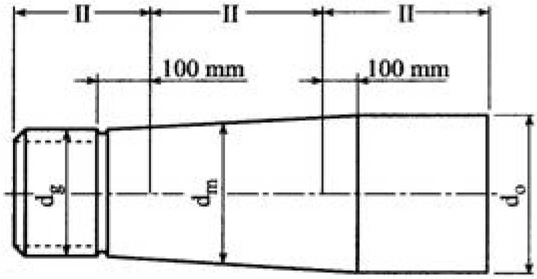
Fig. 5.16 Inspection zones for ultrasonic testing of rudder stocks and accessories



Scanning directions



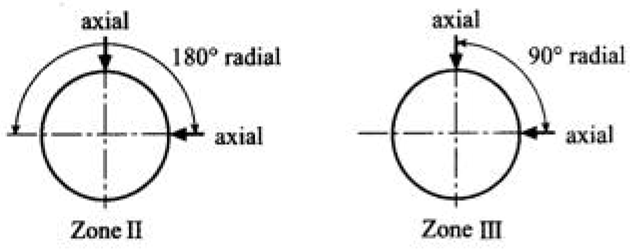
Scanning directions



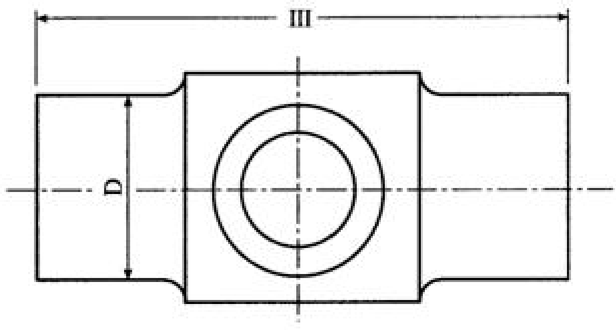
Pintle

Note
Testing in premachined rotation symmetric condition before machining the taper and threading

Fig. 5.17 Inspection zones for ultrasonic testing of rudder stocks and accessories



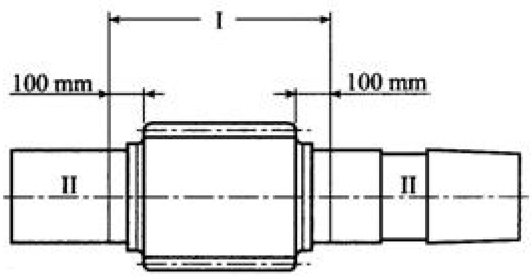
Scanning directions



Cross head

Note

In the core zone with diameter D/3 the lower requirements according to table 3.14 do apply.

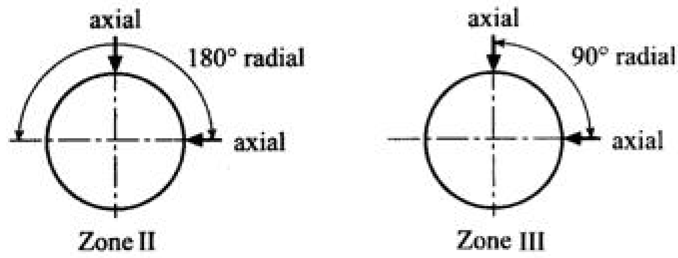


Pinion shafts

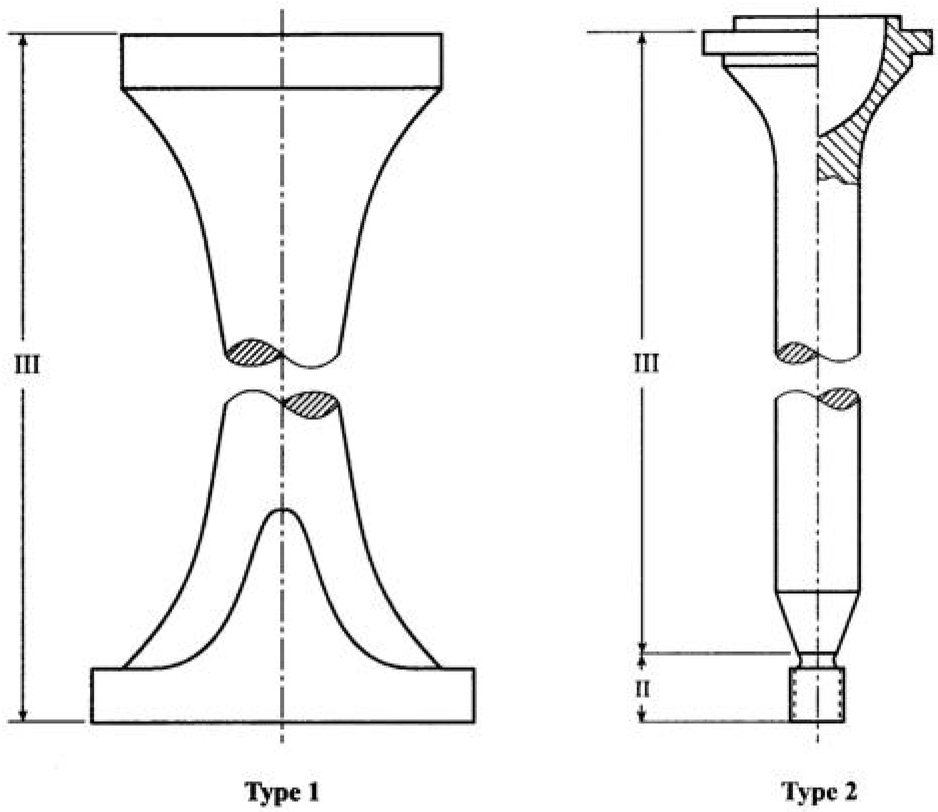
Note

1. *UT of pinion shafts with D ≥ 200 mm, in premachined condition before machinering the gear tooth*
2. *For zone I 360° radial and 90° axial scanning direction applies*

Fig 5.18 Inspection zones for ultrasonic testing of machinery components



Scanning directions



Piston rod

Fig. 5.19 Inspection zones for ultrasonic testing of machinery components

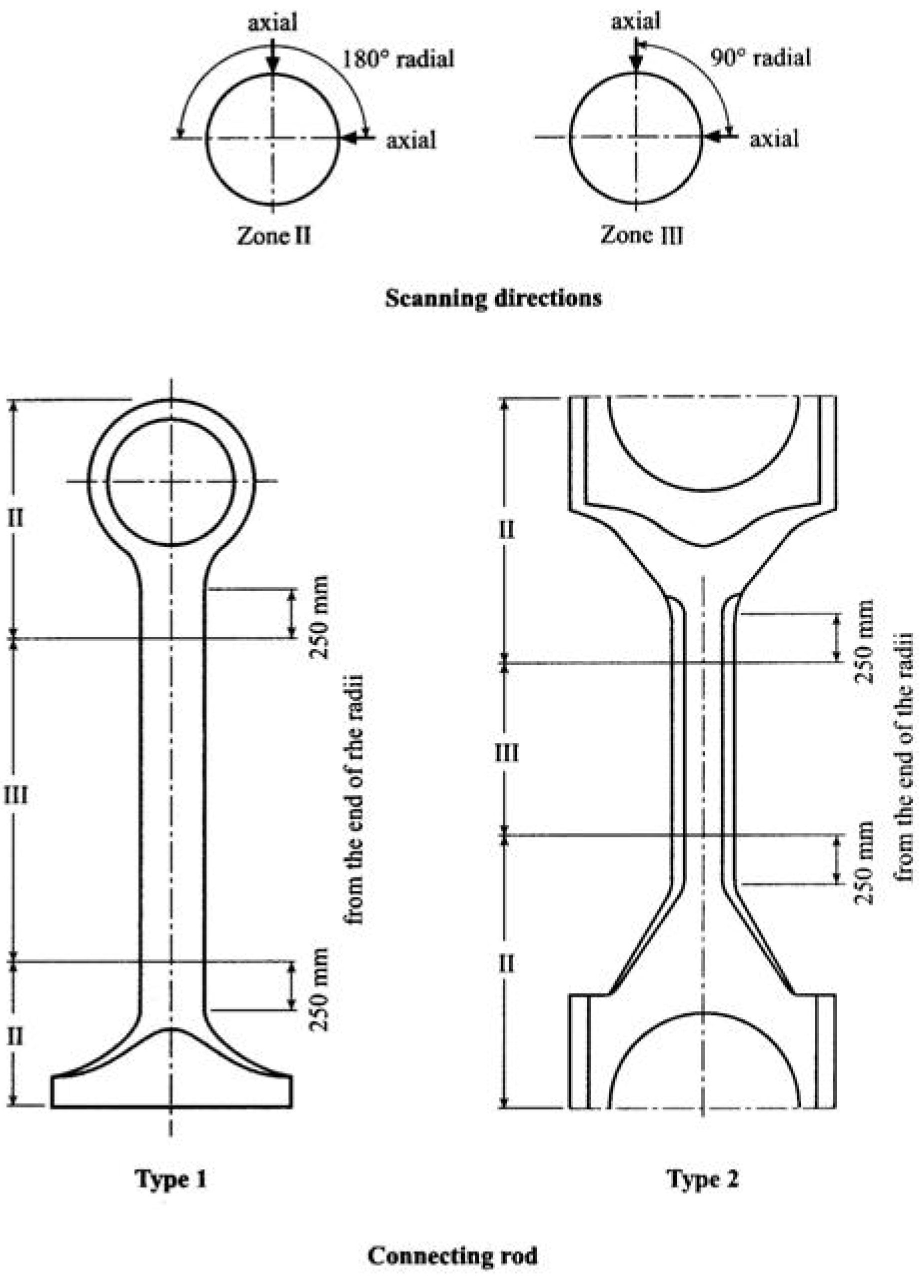
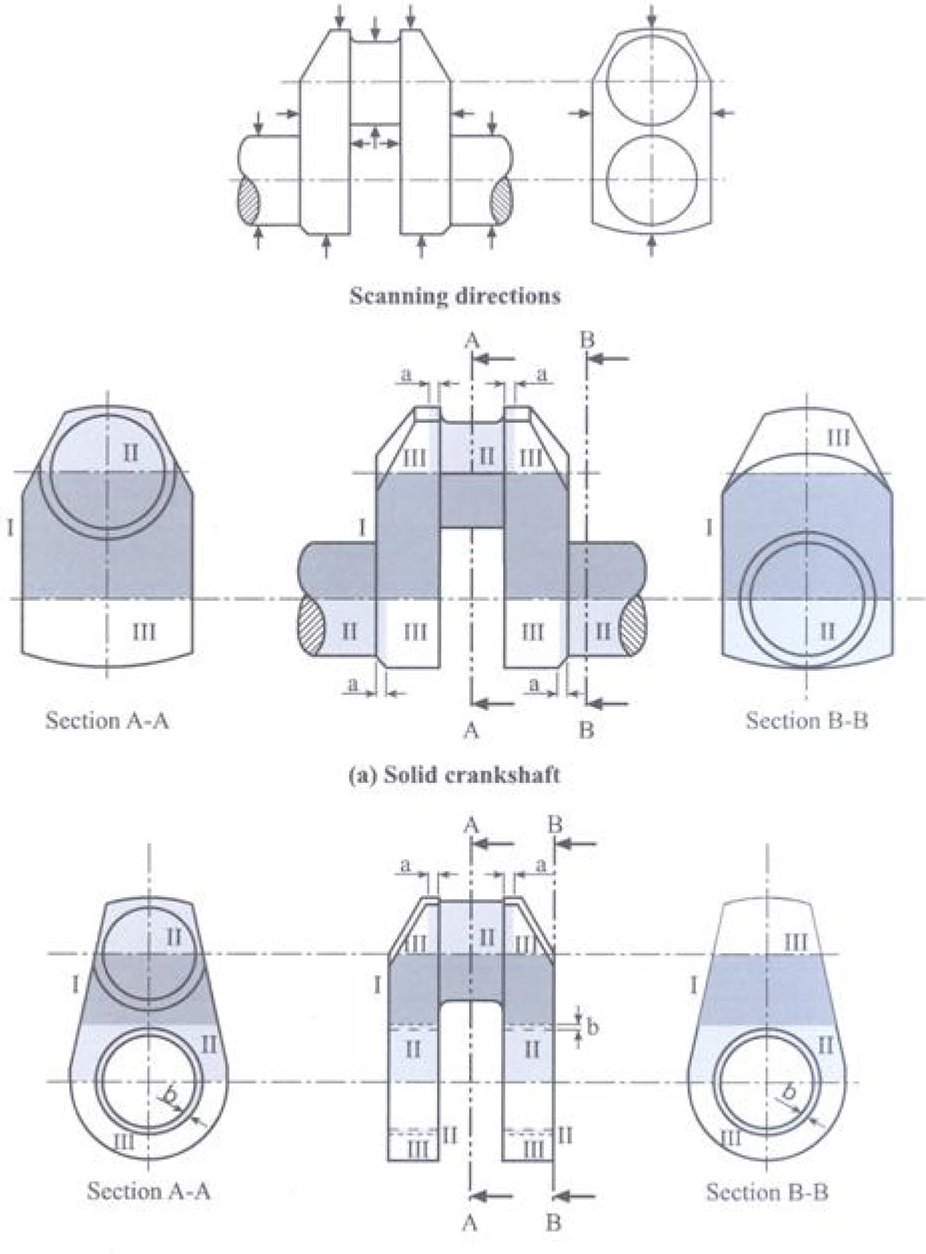


Fig. 5.20 Inspection zones for ultrasonic testing of machinery components



(b) Semi built-up crankshaft

Note

1. *Explanations to the upper figures:*
   a = 0,1 d or 25 mm, whichever greater
   b = 0,05 d or 25 mm, whichever greater (position of shrinkage fit)
   d = Pin or journal diameter.

2. *Core areas of crank pins and/or journals within a radius of 0,25 d between the webs are to be regarded as zor*

3. *Identification of the zones:*

   : Zone I *: Zone II* *: Zone III*

Fig. 5.21 Inspection zones for ultrasonic testing of crankshafts

SECTION 6

STEEL CASTINGS

A. General

1. Scope

1.1 These rules are applicable to steel castings intended for hull and machinery applications such as stern frames, rudder frames, crankshafts, turbine casings, bedplates, etc.

1.2 These rules are applicable only to steel castings where the design and acceptance tests are related to mechanical properties at ambient temperature. For other applications, additional requirements may be necessary, especially when the castings are intended for services at low or elevated temperatures.

1.3 Alternatively, castings which comply with national or proprietary specifications may be accepted provided such specifications give reasonable equivalence to these rules or otherwise specially approved or required by **TL.**

1.4 Specific rules are not given for alloy steel castings and where the use of such materials is proposed full details of the chemical composition, heat treatment, mechanical properties; testing, inspections and rectification are to be submitted for approval of **TL**.

2. Manufacture

2.1 Castings are to be made at a manufacturer approved by **TL.**

2.2 The steel is to be manufactured by a process approved by **TL.**

2.3 All flame cutting, scarfing or arc-air gouging to remove surplus metal is to be undertaken in accordance with recognised good practice and is to be carried out before the final heat treatment. Preheating is to be employed when necessitated by the chemical composition and/or thickness of the castings. If necessary, the affected areas are to be either machined or ground smooth.

2.4 For certain components including steel castings subjected to surface hardening process, the proposed method of manufacture may require special approval by **TL.**

2.5 When two or more castings are joined by welding to form a composite component, the proposed welding procedure is to be submitted for approval. Welding procedure qualification tests may be required.

3. Quality of Castings

All castings are to be free from surface or internal defects, which would be prejudicial to their proper application in service. The surface finish is to be in accordance with good practice and any specific requirements of the approved plan.

4. Chemical Composition

4.1 All castings are to be made from killed steel and chemical composition is to be appropriate for the type of steel and mechanical properties specified for the castings.

4.2 The chemical composition of each heat is to be determined by the manufacturer on a sample taken preferably during the pouring of the heat. When multiple heats are tapped into a common ladle, the ladle analysis shall apply.

4.3 For carbon and carbon-manganese steel castings the chemical composition is to comply with the overall limits given in Table 6.1 or, where applicable, the requirements of the approved specification.

4.4 Unless otherwise required suitable grain refining elements such as aluminium may be used at the discretion of the manufacturer. The content of such elements is to be reported.

Table 6.1 Chemical composition limits for hull and machinery steel castings [%]

Steel type	Application	C (max.)	Si (max.)	Mn	S (max.)	P (max.)	Residual elements (max.)				Total residuals (max.)
							Cu	Cr	Ni	Mo	
C, C-Mn	Castings for non-welded construction	0.40**(1)**	0.60	0.50-1.60	0.040	0.040	0.30	0.30	0.40	0.15	0.80
	Castings for welded construction	0.23	0.60	1.60 max.	0.015	0.020	0.30	0.30	0.40	0.15	0.80

(1) *For welded structures for machinery application* $C \leq 0.23$ *or* $C_{eq} \leq 0.49$

5. Heat Treatment (Including Straightening)

5.1 Castings are to be supplied in one of the following conditions:

Fully annealed
Normalized
Normalized and tempered
Quenched and tempered

The tempering temperature is to be not less than 550ºC.

5.2 Castings for components such as crankshafts and engine bedplates, where dimensional stability and freedom from internal stresses are important, are to be given a stress relief heat treatment. This is to be carried out at a temperature of not less than 550ºC followed by furnace cooling to 300ºC or lower.

5.3 Heat treatment is to be carried out in properly constructed furnaces which are efficiently maintained and have adequate means for control and recording of temperature. The furnace dimensions are to be such as to allow the whole casting to be uniformly heated to the necessary temperature. In the case of very large castings alternative methods for heat treatment will be specially considered by **TL**. 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.

5.4 If a casting is locally reheated or any straightening operation is performed after the final heat treatment, a subsequent stress relieving heat treatment may be required in order to avoid the possibility of harmful residual stresses.

5.5 The foundry is to maintain records of heat treatment identifying the furnace used furnace charge, date, temperature and time at temperature. The records are to be presented to the surveyor on request.

6. 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 are to be made known to the Surveyor.

7. Tightness

All castings which are subjected to internal pressure by the operating medium or for which special proof of impermeability is required are to be leak proof at the specified test pressures after being machined.

8. Mechanical and Technological Properties

8.1 Tensile test

The tensile characteristics indicated in the Tables. contained in this Section or, where applicable, in the relevant standards or specifications are to be verified by tensile test.

8.2 Notch bar impact test

The impact energy specified for the various grades of cast steel is to 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.

8.3 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 are, where necessary, to be proved by appropriate tests.

9. Testing

9.1 Proof of chemical composition

The manufacturer is to determine the chemical composition of each heat or, where necessary, of each ladle and present corresponding certificates to the Surveyor. Should there be any doubt as to the chemical composition of the products; a product analysis is to be performed.

9.2 Mechanical Tests and Mechanical Properties

9.2.1 Mechanical Tests

Test material, sufficient for the required tests and for possible retest purposes is to be provided for each casting or batch of castings.

9.2.1.1 At least one test sample is to be provided for each casting. Unless otherwise agreed these test samples are to be either integrally cast or gated to the castings and are to have a thickness of not less than 30 mm.

9.2.1.2 The tests are to be performed on a heat-by heat basis. Castings from each heat that undergo the same heat treatment are to be grouped into test batches of up to 4 500 kg. Residual quantities of up to 1250 kg are to be allocated to the preceding test batch. Parts with unit weights > 1000 kg are to be tested individually.

Where the casting is of complex design or where the finished mass exceeds 10 tonnes, two test samples are to be provided. Where large castings are made from two or more casts, which are not mixed in a ladle prior to pouring, two or more test samples are to be provided corresponding to the number of casts involved. These are to be integrally cast at locations as widely separated as possible.

9.2.1.3 For castings where the method of manufacture has been specially approved by **TL** in accordance with 2.4, the number and position of test samples is to be agreed with the TL having regard to the method of manufacture employed.

9.2.1.4 As an alternative to 9.2.1.1 , where a number of small castings of about the same size, each of which is under 1000 kg in mass, are made from one cast and heat treated in the same furnace charge, a batch testing procedure may be adopted using separately cast test samples of suitable dimensions. At least one test sample is to be provided for each batch of castings.

9.2.1.5 The test samples are not to be detached from the casting until the specified heat treatment has been completed and they have been properly identified.

9.2.1.6 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.

9.2.2 Mechanical Properties

9.2.2.1 Table 6.4 gives the minimum requirements for yield stress, elongation and reduction of area corresponding to different strength levels. Where it is proposed to use a steel with a specified minimum tensile strength intermediate to those given, corresponding minimum values for the other properties may be obtained by interpolation.

9.2.2.2 Castings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Table 6.4 but subject to any additional requirements of the relevant construction Rules.

9.2.2.3 The mechanical properties are to comply with the requirements of Table 6.4 appropriate to the specified minimum tensile strength or, where applicable, the requirements of the approved specification.

9.2.2.4 Re-test requirements for tensile tests are to be in accordance with Section 2 (see 9.3)

9.2.2.5 The additional tests detailed in 9.2.2.4 are to be taken, preferably from the same, but alternatively from another, test sample representative of the casting or batch of castings.

9.2.2.6 At the option of the manufacturer, when a casting or batch of castings has failed to meet the test requirements, it may be reheat treated and re-submitted for acceptance tests.

9.3 Retests in the event of failure of specimens

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, 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**.**

10. Inspection

10.1 All castings are to be cleaned and adequately prepared for examination; suitable methods include pickling, caustic cleaning, wire brushing, local grinding, shot or sand blasting. The surface are not to be hammered, peened or treated in any way which may obscure defects.

10.2 Before acceptance all castings are to be presented to the surveyor for visual examination. Where applicable, this is to include the examination of internal surfaces. Unless otherwise agreed, the verification of dimensions is the responsibility of the manufacturer.

10.3 When required by the relevant construction Rules, or by the approved procedure for welded composite components, appropriate non-destructive testing is also to be carried out before acceptance and the results are to be reported by the manufacturer. The extent of testing and acceptance criteria is to be agreed with **TL.**

10.4 When required by the relevant construction Rules castings are to be pressure tested before final acceptance. These tests are to be carried out in the presence of the surveyor and are to be to their satisfaction.

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.

11. Non-Destructive Tests

11.1 Where non-destructive tests are required, these are to be performed by the manufacturer of the castings and/or the finishing plant.

11.2 Non-destructive tests are to be performed in accordance with the specifications stated in G. to J.

12. Rectification of Defective Castings

12.1 General

12.1.1 The approval of **TL** is to be obtained where steel castings from which defects were removed are to be used with or without weld repair.

Procedure of removal of defect and weld repair is to be in accordance with IACS Recommendation No. 69.

12.1.2 Where the defective area is to be repaired by welding, the excavation is to be suitably shaped to allow good access for welding. The resulting grooves are to be subsequently ground smooth and complete elimination of the defective material is to be verified by MT or PT.

12.1.3 Shallow grooves or depressions resulting from the removal of defects may be accepted provided that they will cause no appreciable reduction in the strength of the casting. The resulting grooves or depressions are to be subsequently ground smooth and complete elimination of the defective material is to be verified by MT or PT. Small surface irregularities sealed by welding are to be treated as weld repairs.

12.1.4 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.

12.2 Weld repairs

When it has been agreed that a casting can be repaired by welding, the following requirements apply:

12.2.1 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.

12.2.2 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.

12.2.3 Welding is to be done under cover in positions free from draughts and adverse weather conditions by qualified welders with adequate supervision. As far as possible, all welding is to be carried out in the down hand (flat) position.

12.2.4 The welding consumables used are to be of an appropriate composition, giving a weld deposit with mechanical properties similar and in no way inferior to those of the parent castings. Welding procedure tests are to be carried out by the manufacturer to demonstrate that satisfactory mechanical properties can be obtained after heat treatment.

12.2.5 After welding has been completed the castings are to be given either a suitable heat treatment in accordance with the requirements of 5.1 or a stress relieving heat treatment at a temperature of not less than 550 ºC.

The type of heat treatment employed will be dependent on the chemical composition of the casting and the dimensions, position and nature of the repairs.

12.2.6 Subject to prior agreement of **TL**, special consideration may be given to the omission of post weld heat treatment or to the acceptance of local stress-relieving heat treatment where the repaired area is small and machining of the casting has reached an advanced stage.

12.2.7 On completion of heat treatment the weld repairs and adjacent material are to be ground smooth and examined by magnetic particle or liquid penetrant testing. Supplementary examination by ultrasonic or radiography may also be required depending on the dimensions and nature of the original defect. Satisfactory results are to be obtained from all forms of non-destructive testing used.

13. Identification of Castings

13.1 The manufacturer is to adopt a system of identification, which will enable all finished castings to be traced to the original cast and the surveyor is to be given full facilities for so tracing the castings when required.

13.2 Before acceptance, all castings which have been tested and inspected with satisfactory results are to be clearly marked by the manufacturer with the following details:

- Steel quality.
- Identification number, cast number or other marking which will enable the full history of the casting to be traced.
- Manufacturer's name or trade mark.
- TL's name, initials or symbol.
- Abbreviated name of the TL's local office.

- Personal stamp of Surveyors responsible for inspection.

- Where applicable, test pressure.

13.3 Where small castings are manufactured in large numbers, modified arrangements for identification may be specially agreed with **TL.**

14. Certification

The manufacturer is to provide the required type of inspection certificate giving the following particulars for each castings or batch of castings which has been accepted:

- Purchaser's name and order number,

- Description of castingss and steel quality,

- Identification number,

- Steelmaking process, cast number and chemical analysis of ladle sample,

- Results of mechanical tests,

- Results of non-destructive tests, where applicable,

- Details of heat treatment, including temperature and holding times,

- Where applicable, test pressure.

B. Steel Castings for Hull and Machinery Construction

1. Scope

These Rules are applicable to castings made of unalloyed and alloyed grades of cast steel which are intended for the manufacture of components and structural parts in hull and machinery construction e.g. diesel engine components (excluding crankshafts), gears, couplings, and also stem and stern posts, stern tubes, shaft struts, rudder bearings and anchors.

2. Cast Steel Grades

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

2.1 General-purpose cast steels conforming to EN 10293.

2.2 General-purpose cast steels with enhanced weldability and toughness conforming to EN 10293.

2.3 Quenched and tempered cast steels conforming to EN 10293.

2.4 Other grades of cast steel with minimum impact energy values conforming to other standards or material specifications, provided that they are equivalent to the grades described in 2.1 to 2.3 and their suitability has been confirmed by **TL**. An initial test of product suitability may be required for this purpose

3. Condition of Supply and Heat Treatment

3.1 All castings are to be properly heat treated.

Acceptable methods of heat treatment are:

- Normalizing,

- Normalizing and tempering,

- Quenching and tempering.

3.2 Where castings are subject to special requirements with regard to their geometrical and dimensional stability or to the absence of internal stresses, e.g. diesel engine bedplates, stem and stern post parts, additional stress-relieving heat treatment is required. For carbon and carbon-manganese steels, the heat treatment is to be performed at a temperature of at least 550°C followed by cooling in the furnace to below 300°C. For quenched and tempered steel castings, the heat treatment temperature is to be specially determined. The stress-relieving heat treatment may be dispensed with in the case of quenched and tempered steel castings where tempering is followed by a cooling rate of up to 15 °C/h.

4. Chemical Composition

4.1 Carbon and carbon-manganese steel castings including the grades of cast steel described in 2.1 and 2.4 are subject to the limits for the chemical composition of the heat specified in Table 6.1.

Where necessary, the manufacturer may add grain refining elements, e. g. aluminium.

4.2 For grades of cast steel conforming to 2.2 and 2.3 the limits for the chemical composition specified in the standards are applicable.

4.3 For cast alloy steels conforming to 2.4 the limits for the chemical composition specified in the recognized standards or material specifications is to apply.

4.4 Where the weldability of the casting is subject to special requirements, the carbon equivalent is to be calculated according to the following formula:

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

5. Mechanical and Technological Properties

5.1 For grades of cast steel conforming to 2.1 to 2.3, the requirements specified in the respective standards is to apply, see Table 6.2 (grades of cast steel conforming to EN 10293) and Table 6.3 (grades of cast steel conforming to EN 10293).

5.2 Other grades of cast steel as per 2.4 is to have the characteristic properties of the respective grade according to the standard or the specification. In addition, the minimum requirements specified in Table 6.4 are applicable to castings made of C and CMn cast steels.

5.3 The cast steels shown in Table 6.4 may be supplied with any minimum tensile strength within the limits specified in the table. The values graduated in steps of 40 N/mm^2 do not represent the minimum tensile strengths of particular grades of cast steel but are intended to provide means of determining the required mechanical characteristics by interpolation in relation to specified minimum tensile strengths.

5.4 Impact energy

All grades of cast steel are to meet the energy impact values prescribed for the grade in question.

6. Testing

6.1 Tensile test

The mechanical properties shall be verified by tensile test. The test specimens are to be prepared in accordance with A.9.2.1.2.

6.2 Notched bar impact test

Notched bar impact testing is to be performed on each test batch or, where applicable, each casting. The test specimens are to be prepared in accordance with A.9.2.1.2. The type of specimen is governed by the relevant standard or specification.

6.3 Non-destructive tests

6.3.1 In case non-destructive tests are prescribed for castings they are to be performed in accordance with G. to J.

6.3.2 Where castings are welded together, the welds are to be subjected to magnetic particle and ultrasonic or radiographic inspection. The extent of the inspection is to be as specified on the approval drawing or will be determined at the time of approval of the welding procedure.

6.4 Tightness test

Castings subjected to internal pressure, e.g. stern tubes, are to be subjected to a hydraulic pressure test. The test is to be performed with the casting in machined condition. The test pressure is to be 1.5 times of the service pressure and for stern tubes uniformly 2 bars. The test pressure is to be kept for at least 10 min.

Table 6.2 Mechanical properties of cast steels conforming to EN 10293

Grade of cast steel	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 KV (1) KV [J] (2) min.	
					t ≤ 30 mm(3)	t > 30mm(3)
GS-38	200	380	25	40	35	35
GS-45	230	450	22	31	27	27
GS-52	260	520	18	25	27	22
GS-60	300	600	15	21	27	20

(1) *Testing temperature = Room temperature*

For castings for welded structures in shipbuilding the requirements according to Table 6.3 do apply.

(2) *Average value of 3 tests*

(3) *t = Sample thickness*

Table 6.3 Mechanical properties of cast steels conforming to EN 10293

Grade of cast steel	Heat-treated condition (5)	Wall thickness [mm]	Yield strength R_{eH} (1) [N/mm^2] min.	Tensile strength R_m [N/mm^2]	Elongation A [%] min.	Impact energy KV [J] (2) min.	Transition temp. T_u [27J] (4)
GS-16 Mn 5	N	up to 50	260	430 - 600	25	65	-25°C
		over 50 to 100	230	430 - 600	25	45	-15°C
GS-20 Mn 5	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) **(3)**	480 - 630	20	35	0°C
		over 160	(240) **(3)**	450 - 600	20	27	RT
GS-20 Mn 5	QT	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) **(3)**	500 - 650	22	40	-10°C
		over 160	(260) **(3)**	480 - 630	22	30	RT

(1) *If there is no marked yield strength, the 0.2 % proof stress applies.*

(2) *Average value of 3 tests at room temperature (individual value at least 70 %).*

(3) *The values in brackets are only an approximate indication of the minimum yield strength in the casting.*

(4) *Requirements for welded structures for shipbuilding.*

(5) *N = Denotes normalizing*

QT = Denotes quenching and tempering

Table 6.4 Mechanical properties of cast steels conforming to B.2.4

Grade of steel	Minimum tensile strength (1) (2) R_m [N/mm²]	Yield strength R_{eH} [N/mm²] min.	Elongation A [%] min.	Reduction in area Z [%] min.	Impact energy (3)	
					KV [J] min.	KU [J] min.
Ordinary quality C-and CMn cast steel	400	200	25	40	25	25
	440	220	22	30	20	22
	480	240	20	27	18	20
	520	260	18	25	15	17
	560	280	15	20	12	15
	600	300	13	20	10	12
Special quality C and CMn cast steel	400	200	28	45	32	30
	440	220	26	45	28	27
	480	240	24	40	25	25
	520	260	22	40	20	22
	560	280	20	35	18	20
	600	300	18	35	15	17

(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/mm² in case of the ordinary qualities and 120 N/mm² in the case of the special qualities.*

(3) *Average value of 3 tests (individual value not less than 70 %).*

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. Cast Steel Grades

Only grades of cast steel which have been approved by **TL** as suitable for the intended application may be used. To this end, the engine manufacturer is to submit to **TL** 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.2.4 and, for special quality steel castings, Table 6.4 are to be satisfied as a minimum requirement.

3.2 The cast steel is to 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 is to be approved by **TL**. The details of the approval test are established by **TL** from case to case.

4.2 All castings are to be in a heat treated condition appropriate to the grade of steel. The following processes are acceptable:

- Normalizing,
- Normalizing and tempering,
- Quenching and tempering.

Where possible, heat treatment is to be carried out after preliminary machining. If this is not possible, additional stress-relieving heat treatment is to be performed after preliminary machining with the minimum possible cutting allowance.

4.3 Defects are normally to be removed by grinding, gouging and/or machining. Care is to be taken to ensure that the required minimum cross sections are preserved.

The removal of defects by welding requires the consent of **TL** 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 are to be verified by tensile test. For preparing the tensile specimens, test samples are to be cast integrally with the casting at a point stipulated in the specification. Each casting is to be tested individually.

5.2 Notched bar impact test

Notched bar impact specimens are to be taken from every casting and tested. The location of the specimens is to be as described in 5.1. The specimen shape prescribed in the specification (Charpy V-notch or Charpy U-notch specimen) is to be used.

5.3 Non-destructive tests

Crank shafts and connecting rods are to 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

These Rules are applicable to castings made from unalloyed and alloyed grades of cast steel and used for the manufacture of valve and pump housings, endplates, flanges, nozzles and pipe fittings.

2. Cast Steel Grades

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 6.5 and the mechanical properties are stated in Table 6.6.

2.2 Ferritic grades of cast steel GS-38 and GS-45 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.

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 items 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 is to satisfy the following minimum requirements:

- The elongation A shall have the characteristic minimum elongation values of the steel grade as specified by **TL**, but is to be not less than 15 %.

Table 6.5 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	0.60	0.50 - 1.20	0.030	0.020 **(1)**		
GP280GH	0.18 - 0.25**(2)**	0.60	0.80 - 1.20 **(2)**	0.030	0.020 **(1)**		
G20Mo5	0.15 - 0.23	0.60	0.50 - 1.00	0.025	0.020 **(1)**		0.40 - 0.60
G17CrMo 5-5	0.15 - 0.20	0.60	0.50 - 1.00	0.020	0.020 **(1)**	1.00 - 1.50	0.45 - 0.65
G17 CrMo 9-10	0.13 - 0.20	0.60	0.50 - 0.90	0.020	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 % 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 6.6 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			Notched 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	100	240	420-600	22	40
GP280GH	N	100	280	480-640	22	27
	QT	100	280	480-640	22	35
G20Mo5	QT	100	245	440-590	22	27
G17 CrMo5-5	QT	100	315	490-690	20	27
G17 CrMo9-10	QT	100	400	590-740	18	40

(1) *N = Denotes normalizing*
QT = Denotes quenching and tempering
(2) *Testing temperature = Room temperature (individual value not less than 70 %)*

- The impact energy is to 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 are to be verified by the manufacturer, specifying the guide values for the chemical composition.

Proof of weldability is to be furnished by the manufacturer.

3. Heat treatment and Condition of Supply

All steel castings shall be supplied in a heat-treated condition appropriate to the grade of cast steel.

4. External and Internal Condition

The requirements pertaining to the external and internal condition are specified in TRD 103. For this purpose, the cast steel is to be classed into quality levels according to the intended working temperature and pressure, see the Technical Rules for Steam Boilers TRD 103 and "AD-Merkblatt" W5.

5. Requirements Applicable to the Material

5.1 General requirements

With regard to the chemical composition, mechanical and technological properties, required impact energy

5.2 Weldability

Grades of cast steel conforming to these Rules are to 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 are to be presented for testing in finished condition (condition of supply) and are to undergo the following tests.

6.1 Tensile test

The mechanical properties are to be verified by tensile test. The tests are to be performed on a heat-by-heat basis, parts undergoing the same heat treatment being grouped into test batches in accordance with A.9.2.1.2. A tensile specimen is to 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) is to 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 is to 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 is not to exceed 30 HB).

6.4 Non-destructive tests

The manufacturer is to ensure by non-destructive tests on his products that the requirements are pertaining to the external and internal condition according to 4. are met. Unless otherwise agreed, the scope of testing is to conform to TRD 103 or AD data sheet W5, whichever is appropriate. Valves and fittings are subject to TRD 110.

E. Steel Castings for Low Temperature Services

1. Scope

These rules are applicable to steel castings which are to be used for cargo and processing equipment on gas tankers at design temperatures below 0 °C, e.g. flanges, valve parts, weld-on and socket-welding pieces.

2. Cast Steel Grades

The grades of cast steel stated in Table 6.7 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 6.8 and the mechanical properties are stated in Table 6.9.

2.2 Other grades of cast steel

Other grades of cast steel conforming to other standards or material specifications, provided that they are comparable to the grades of cast steel described in 2.1, that they meet the requirements of 3. to 5. and that proof has been furnished of their suitability for the intended application. An initial test of product suitability may be required for this purpose.

3. Heat Treatment and Condition of Supply

All steel castings are to be supplied in a heat-treated condition appropriate to the grade of cast steel, see Table 6.9.

Table 6.7 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)**	G17 Mn 5	EN 10213
	-40°C**(1)**	G20 Mn 5	EN 10213
1.5 % cast nickel steel	-40°C**(1)**	GS-10 Ni 6	SEW 685
2.25 % cast nickel steel	-65°C	G9-Ni 10	EN 10213
3.5 % cast nickel steel	-90°C	G9 Ni 14	EN 10213
Austenitic grades of cast steel	-165°C	1.4308 **(2)**	EN 10213
		1.4408	EN 10213
		1.4581 **(3)**	EN 10213

(1) *A minimum design temperature down to - 55 °C is possible if this is verified by an approval test.*
(2) *In addition EN 10283 does apply.*
(3) *Unsuitable for carriage of ammonia.*

Table 6.8 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	0.60	1.00 - 1.60	0.020	0.020 **(1)**	-
G20Mn5	0.17 - 0.23	0.60	1.00 - 1.60	0.020	0.020 **(1)**	maks. 0.80
G9Ni10	0.06 - 0.12	0.60	0.50 - 0.80	0.020	0.015	2.00 - 3.00
G9Ni14	0.06 - 0.12	0.60	0.50 - 0.80	0.020	0.015	3.00 - 4.00

(1) *For castings having a standard wall thickness of < 28 mm, 0.030 % S is permissible.*

Table 6.9 Mechanical properties of the commonly used grades of cast steel conforming to EN 10213

Grades 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	300	500-650	22	27	-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 6.11 is to be complied with.*

4. External and Internal Condition

The external and internal condition shall be subject to quality levels in accordance with Table 6.10 depending on the minimum design temperature.

If the evaluation is carried out according to other standards, the requirements are to be equivalent to those specified in Table 6.10

Table 6.10 Assignment of quality levels

Minimum design temperature t	Quality level according to: (1) (2) (3) (4)
≥ -105°C	SM4, LM4, AM4 **(1)**, SP4, CP3, LP4, AP4 **(2)**, UV4 **(3)**, RV4 **(4)**
< -105°C	SM3, LM3, AM3 **(1)**, SP3, CP3, LP3, AP3 **(2)**, UV3 **(3)**, RV3 **(4)**
Welding edges **(5)**	SM 01 **(1)** CP 01 **(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.*

5. Requirements Applicable to the Material

5.1 General requirements

The chemical composition and the mechanical properties are subject to the requirements specified in the standards or the approved specifications (see Tables 6.8 and 6.9).

5.2 Weldability

Grades of cast steel conforming to these rules are to be weldable by established workshop methods.

5.3 Impact energy at low temperatures

The required impact energy values specified in Table 6.11 for the relevant grades of cast steel are to be met at the test temperatures stated in the table, using Charpy V-notch specimens.

6. Testing

The castings are to be presented for testing in finished condition (condition of supply) and are to undergo the following tests.

6.1 Tensile test

The mechanical properties are to be verified by tensile test. The tests are to be performed on a heat-by-heat basis, parts undergoing the same heat treatment being grouped into test batches. A tensile specimen is to be taken from each test batch and tested. Castings with unit weights > 1 000 kg are to be tested individually.

6.2 Notched bar impact test

The castings are to be subjected to the notched bar impact test in compliance with the prescribed test temperature according to Table 6.11. The number of sets of test specimens (3 Charpy V-notch specimens per set) is to 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 are to be subjected to a comparative hardness test. The result of the hardness test is to 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 is to ensure by non-destructive tests on his products that the requirements are pertaining to the external and internal condition according to 4. are met.

Table 6.11 Required impact energy values at low temperatures

Grade of cast steel	Notched bar impact test	
	Test temp. [ºC]	**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 6.13.*

F. Stainless Steel Castings

1. Scope

These Rules are applicable to steel castings made from austenitic and austenitic-ferritic grades of steel which are intended for use in cargo and processing equipment for chemical tankers and other equipment for which chemical stability in relation to the cargo or the operating fluid is required. These Rules also apply to sleeves and bushes for propeller shafts and rudder stocks.

The Rules are also applicable in conjunction with E. for austenitic grades of cast steel which are designed for use in cargo and processing systems for gas tankers.

2. Cast Steel Grades

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 6.12 and the mechanical properties are given in Table 6.13.

2.2 Other stainless steels conforming to other standards or specifications after their suitability has been established by **TL**. An initial test of product suitability on the manufacturer's premises may be required for this purpose.

3. Selection of Grades of Cast Steel

3.1 As regards their chemical resistance, the grades of steel are to 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.

3.2 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., are to apply.

4. Heat Treatment and Condition of Supply

All steel castings are to be supplied in a heat-treated condition appropriate to the grade of cast steel, i.e. the grades specified in Table 6.13 shall be solution-annealed and quenched in water.

Table 6.12 Chemical composition (%) of suitable grades of cast steel in dependence on EN 10213 and EN 10283

Designation		C max.	Si max.	Mn max.	P max.	S max.	Cr	Mo	Ni	Cu	Other elements
Grade of cast steel	**Material no**										
GX2CrNi19-11 **(1)**	**1.4309 (1)**	0.030	1.50	2.00	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	1.50	1.50	0.040	0.030	18.00 to 20.00		8.00 to 11.00		-
GX5CrNiNb19-11 **(1)**	**1.4552 (1)**	0.07	1.50	1.50	0.040	0.030	18.00 to 20.00		9.00 to 12.00		Nb:8·C, max.1.00
GX2CrNiMo19-11-2 **(1)**	**1.4409 (1)**	0.030	1.50	2.00	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	1.50	1.50	0.040	0.030	18.00 to 20.00	2.00 to 2.50	9.00 to 12.00		-
GX5CrNiMoNb19-11-2 **(1)**	**1.4581 (1)**	0.07	1.50	1.50	0.040	0.030	18.00 to 20.00	2.00 to 2.50	9.00 to 12.00		Nb:8·C max. 1.00
GX2NiCrMo28-20-2 **(1)**	**1.4458 (1)**	0.030	1.00	2.00	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	**1.4470**	0.030	1.00	2.00	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	**1.4517**	0.030	1.00	1.50	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)**	0.030	1.00	1.00	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 temperatures, narrower limits may be specified for some elements by agreement between foundry and customer.*

(2) *For this grade of steel a minimum value for the "pitting factor" PI = Cr + 3.3 Mo + 16 N $\geq$ 40 may be called for.*

Table 6.13 Mechanical properties of suitable grades of cast steel

Designation	Material No.	Heat treatment + AT (1) °C	Thick-ness [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 %)*

5. External and Internal Condition

Requirements to the external and internal condition are to be agreed on by the customer and the manufacturer. Requirements to welding edges and special rim zones are to be agreed on separately. In case no agreements were made G.3. does apply.

6. Requirements Applicable to the Material

6.1 Chemical composition

6.1.1 The limits stated in Table 6.12 and/or the specifications approved by **TL** are applicable.

6.1.2 For steel castings for the cargo and processing equipment of chemical tankers, the composition is to 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 is to 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 are to be complied with. The manufacturer is to prove the weldability of the material if requested to do so.

6.1.3 If compliance with a minimum value for the aggregate effective chromium value W is required for a particular application, this is calculated as follows:

$$W\ [\%] = [\%]\ Cr + 3.3 \cdot [\%]\ Mo$$

Note :
This formula is applicable for austenitic cast steel which has a molybdenum content of < 3 %.

6.2 Resistance to intercrystalline corrosion

Austenitic grades of cast steel are to 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 are to 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 6.13 or in the approved specifications are applicable.

7. Testing

The castings are to be presented for testing in finished condition (condition of supply) and are to undergo the following tests:

7.1 Tensile test

The mechanical properties are to be verified by tensile test. The tests are to be performed on a heat-by-heat basis, parts undergoing the same heat treatment being grouped into test batches. A tensile specimen is to 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 are to be subjected to the notched bar impact test. The number of sets of test specimens (3 Charpy V-notch specimens per set) is to 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 are to 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 are to be tested in accordance with Iron and Steel Test Specification SEP 1877, Method I, or an equivalent method. The test shall be confirmed by the manufacturer by means of a certificate.

7.4 Non-destructive testing

The manufacturer is to ensure by non-destructive tests on his products that the requirements are pertaining to the external and internal condition according to 5. are met.

G. Non-destructive Testing of Cast Steel Components

1. Scope

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

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

1.3 These Rules apply for the following testing methods defined according to ISO 9712, see Table 6.14.

1.4 Methods and testing, criteria indicated in G. are to be employed by the foundries, companies performing the further processing and the **TL** Surveyors.

1.5 For testing, the cast steel components are to be classified in inspection zones with different requirements for the severity levels.

For classifying one or several of the following principles is/are decisive:

- The operating loads to be expected,
- The effects of the defects on the reliability of the component,
- Possible risk of damage if the component fails,
- Required welding security for the welding edges,
- Freedom of defects and surface condition after machining.

For the most important cast steel components of the hull structure and of the propulsion plant the inspection zones are prescribed in I. and J.

Table 6.14 Test methods

Testing of (1)	Symbol
Visual testing	VT
Magnetic particle testing	MT
Penetrant testing	PT
Ultrasonic testing	UT
Radiography testing	RT

(1) *For testing of stainless austenitic cast steel only the methods VT, PT and RT are applicable.*

2. Testing

2.1 After the inspector of the internal or external inspection body in charge of testing has performed the prescribed tests, the cast steel components are to be presented to the **TL** Surveyor for visual testing.

2.2 Concerning the tests it is to be differentiated between pre-testing and acceptance testing. With pretests, where decisions concerning the testability and the employability of the cast steel component are made, they are in general the business of the foundry. Acceptance tests are to be performed preferably on the final machined cast steel component after the heat treatment appropriate for the required properties has been performed. The Surveyor is to be informed in time about the intended tests. It is up to the discretion of the Surveyor to attend the tests.

2.3 The tests are to be performed for the zones described in the specification or in the test plan. In case the results indicate that further defects are present in the cast steel component, the test scope is to be extended according to agreement with the Surveyor.

2.4 The cast steel components for which testing is prescribed are listed in H. Concerning the test scope and the severity level requirements for specific hull structural parts and for machinery parts test instructions are prescribed in I. and J. which shall be observed in addition to the manufacturer specifications.

3. Classifying in Severity Levels

3.1 The classifying in severity levels for the inner and outer condition is performed in accordance with the criteria indicated in the tables for the specific test methods. Table 6.15 sums up the various severity levels.

3.2 The selection of severity levels is to be agreed upon in accordance with EN 1559-1 and EN 1559-2 within the order.

As a rule this is business of the customer, in doing so the inspection zones are to be specified in accordance with 1.6 and the following requirements shall be observed:

3.2.1 Special rim zones such as welding edges are to be classified in the severity levels SM1, LM1, AM1, SP1, CP1, LP1, AP1, UV1 and RV1 over their entire length and over a width of 3 x wall thickness, but at least of 50 mm.

For welding edges with thickness larger than 50 mm the severity levels SM2, LM2, AM2, SP2, CP2, LP2, AP2, UV2 and RV2 are sufficient. For valve casings DIN 1690 part 10 does apply.

Table 6.15 Overview of the severity levels

Testing of	Test method	Description of severity levels (1)
Outer condition	VT	V1, V2, V3, V4
	MT	SM1, SM2, SM3, SM4, LM1, LM2, LM3, LM4, AM1, AM2, AM3, AM4,
	PT	SP1, SP2, SP3, SP4, CP1, CP2, CP3, LP1, LP2, LP3, LP4, AP1, AP2, AP3, AP4,
Inner condition	UT	UV1, UV2, UV3, UV4,
	RT	RV1, RV2, RV3, RV4,
(1) *According to EN 1370, EN 1369, EN 1371-1, EN 12680-2, EN 12681 and EN 1559-2*		

3.2.2 For fabrication weldings as a basic principle the same requirements as for the base material do apply.

3.2.3 For zones of steel castings for machinery parts, for valve casings as well as for dynamically loaded hull structural parts where no higher requirements are prescribed at least the severity levels SM3, LM3 and AM3 are to be met.

3.2.4 Apart from the specifications in 3.2.1 to 3.2.3, and if in the purchasing documents no higher classifying is required, for not specified zones at least severity level V2 does apply.

3.2.5 For the inner and outer condition of cast steel components equivalent severity levels as well as different severity levels may be determined.

3.3 Before testing is commenced the position and dimension of the zones to be tested and the severity levels to be met are to be specified in test plans, drawings or specifications taking into account 1.5, 3.1 and 3.2. These documents are to be provided to **TL**.

4. Special Agreements for the Surface Roughness

For the surface roughness limit values such as e.g. comparators **(1)** may be agreed upon if requested by the customer or necessary due to technical reasons. Requirements for the surface condition of surfaces of cast steel components depending on the smallest indication to be registered are listed in Tables 6.16 and 6.17 for the magnetic particle testing and for the penetrant testing. Concerning the surface roughness for non-destructive testing then the following applies:

- Cast steel components where requirements for the surface roughness were specified are to be tested visually in accordance with 5.
- Cast steel components which are subjected to radiographic, magnetic particle or ultrasonic testing shall comply at least with the comparators 3 S1 or 4 S2.
- Cast steel components which are subjected to penetrant testing shall comply at least with the comparators 3 S2.

Table 6.16 Recommended surface condition for magnetic particle testing

Dimension of the smallest indication [mm]	Surface comparators (1)	
	BNIF (2)	SCRATA (2)
1.5	1S1 – 2S1 3S2 – 4S2	–
2	2S1 – 3S1 4S2 – 5S2	A2 H2
≥ 3	not specified (rough surface)	A3 – A4 H3
(1) *See EN 1370.* **(2)** *See Annex A of EN 1369.*		

5. Visual testing (VT)

5.1 The manufacturer is to verify for each production stage of the cast steel components the external condition and the compliance of the dimensions. Minor casting defects such as small sand and slag inclusions, small cold shuts and small hot tears are to be cleaned out in case they may affect the testability.

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(1) ***Reference to standards:***

- *"Technische Empfehlung (technical recommendation) 359-1 des Bureau de Normalisation de l' Industrie de la Fonderie"*
- *"SCRATA comparators for the definiton of surface quality of steel castings"; Steel castings Technology International; 7, East Bank road, Sheffield, S2 3PL United Kingdom*

Table 6.17 Recommended surface condition for penetration testing

Dimension of the smallest indication [mm]	Surface comparators (1)	
	BNIF (2)	SCRATA (2)
1.5	1S1 – 2S1 3S2 – 4S2	A1 H1
2	2S1 – 3S1 4S2 – 5S2	A2 H2
≥ 3	not specified (rough surface)	A3 – A4 H3

(1) *See EN 1370.*
(2) *See Annex A of EN 1371-1.*

5.2 Discontinuities which may affect the employability and the processability appropriate for the material more than irrelevant, such as larger non-metallic inclusions, cavities, gas holes or cracks, are not allowed and are to be repaired.

5.3 After special agreement with **TL** or if specified in the order the evaluation of the surface condition may be performed by means of comparators in accordance with Table 6.18 (cf. EN 1370 "Visual examination of surface discontinuities - Steel sand castings").

5.4 The Surveyor certifies the visual inspection on the **TL** acceptance test certificate; e.g. the following text can be typed in the test certificate: "The aforementioned cast steel components were visually tested. The prescribed requirements are fulfilled."

5.5 On demand of the customer the manufacturer is to issue a test report containing the details of the tests, the prescribed severity levels and the test results.

6. Magnetic Particle Testing (MT)

6.1 The surfaces of the cast steel component to be tested are to be free of oil, grease, and remnants of the moulding material and the blackening, as well as scale, dust and other contaminations.

The required surface condition may be achieved by shot-blasting, grinding or machining. A specific surface roughness that is to be complied with may be agreed upon.

6.2 In case black magnetic particles are employed the surface to be tested is to be coated with a permanent white paint, applied as thinly as possible (max. 20 µm). A decrease of the test sensibility is to be observed.

6.3 In order to avoid burn marks on the surface of cast steel components in quenched and tempered condition when magnetization is performed by means of prods with alternating current only fusible supply electrodes made of tin-aluminium alloys are to be employed. Contact points visible on the surface are to be ground if necessary and to be retested by yoke magnetization. On already machined surfaces of the cast steel component testing is only allowed with yoke magnetization.

6.4 The indications of magnetic particle testing are to be evaluated concerning their type, size and number in accordance with Tables 6.19, 6.20 and 6.21. The reference area for this is to be a rectangle with 105 mm x 148 mm (size DIN A6) and is to be placed on the specific most unfavorable area for each case (area with the highest number of indications). In addition for the evaluation the reference figures according to EN 1369 are to be consulted.

6.5 Definition of indications of magnetic particle testing

6.5.1 Non-linear indications (SM)

Indications are to be assessed as non-linear if the length L is smaller than 3 times the width W.

The symbol for non-linear indications is SM (S for surface and M for magnetic particle).

6.5.2 Linear indications (LM)

Indications are to be assessed as linear if L is equal or larger than 3 times W.

The symbol for linear indications is LM (L for linear and M for magnetic particle).

Table 6.18 Allocation of severity levels to the selected comparators (1) for the surface condition

Category	Severity Levels			
	V1	V2	V3	V4
	Designation according to the "Technischen Empfehlung 359-1" (2)			
Inclusions close to the surface	B 1	B 2	B 4	B 5
Gas porosity	C 1	C 2	C 3	C 4
Cold shuts	D 1	D 2	D 5	-
Hot tears	E 3	E 5	-	-
Inserts	F 1	F 3	-	-
Welds	J 1	J 2	J 3	J 5

(1) *The required severity level can be different for each category.*
(2) *See references to standards in 4.*

Table 6.19 Nature of discontinuities and the corresponding indications for magnetic particle testing

Nature of discontinuities	Symbol	Types of magnetic particle inspection indications		
		non-linear SM	linear LM	aligned AM
Gas porosity	A	X	-	X
Sand and slag inclusions	B	X	-	X
Cracks	D	-	X	X
Chill cracks	E	-	X	X
Inserts	F	-	X	X
Cold shuts	H	-	X	X

Table 6.20 Severity levels for magnetic particle testing - non-linear indications isolated (SM)

Characteristic		Severity level			
		SM 1	SM 2	SM 3	SM 4
Inspection means		eye			
Magnification for observation of magnetic particle indication.		1			
Length Lj of the smallest indication to be considered [mm].		1.5	2	3	5
Non-linear indications (SM)	Maximum total surface area allowed [mm^2]	10	35	70	200
	Maximum individual length L_2 allowed [mm]	2 **(1)**	4 **(1)**	6 **(1)**	10 **(1)**

(1) *At maximum 2 indications of the designated maximum dimension are permitted.*
Note: *Only values expressed in this table are valid. The reference figures according to EN 1369 Annex B and C are for information only.*

Table 6.21 Severity levels for magnetic particle testing - linear (LM) and aligned (AM) indications

Characteristic		Severity level							
		LM 1 AM 1		LM 2 AM 2		LM 3 AM 3		LM 4 AM 4	
Inspection means		eye							
Magnification for observation of magnetic particle indication		1							
Length L1 of the smallest indication to be considered [mm]		1.5		2		3		5	
Arrangement of indications **(1)** isolated (I) or cumulative (C)		I	C	I	C	I	C	I	C
Maximum length of linear (LP) and aligned (AP) indications allowed depending on the wall thickness t [mm]	Wall thickness class a t ≤ 16 mm	2	4	4	6	6	6	10	18
	Wall thickness class b 16 mm <t ≤ 50 mm	3	6	6	12	9	18	18	27
	Wall thickness class c t > 50 mm	5	10	10	20	15	30	30	45
Following Annex C		Figure C.3		Figure C.4		Figure C.5		Figure C. 6	

Note : *Only values expressed in this table are valid. The reference figures are according to EN 1369 annex C are for information.*

(1) *The linear and aligned indications shall be taken into consideration for the calculation of the cumulative length.*

6.5.3 Aligned indications (AM)

In the following cases the indications are assessed as aligned:

- Non-linear: the distance between the indications is less than 2 mm and at least 3 indications are registered,

- Linear: the distance between 2 indications is smaller than the length L of the longest discontinuity in a line.

Aligned indications are assessed as one single indication. Its length equals the total length L of this line, see Fig. 6.1.

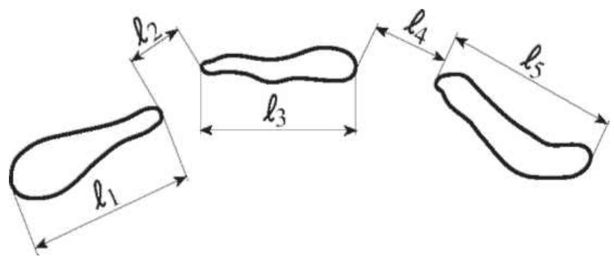


Fig. 6.1 Example for L

The symbol for aligned indications is AM (A for aligned and M for magnetic particle).

Note :

The total length L equals the distance between the start of the first indication and the end of the last indication.

Example: $L = \ell_1 + \ell_2 + \ell_3 + \ell_4 + \ell_5$

6.6 Defects which concerning their size and number exceed the requirements for the prescribed severity levels as well as cracks are not allowed and are to be removed. Repaired zones are to be retested.

7. Penetrant Testing (PT)

7.1 Testing is to be performed with an inspection system consisting of penetrant remover, penetrant and developer.

7.2 The surface of the cast steel component to be tested is to correspond to the requirements for the surface condition specified in 6.1 and 4.

Table 6.22 Nature of discontinuities and type of corresponding indications for penetrant testing

Nature of discontinuities	Symbol	Type of corresponding indications for penetrant testing			
		Non-linear		Linear	Aligned
		isolated SP	clustered CP	LP	AP
Gas porosity	A	X	X	-	X
Sand and slag inclusions	B	X	X	-	X
Cracks	D	-	-	X	X
Chill cracks	E	-	-	X	X
Inserts	F	X	-	X	X
Cold Shuts	H	-	-	X	X

Table 6.23 Severity levels for penetrant testing – non-linear indications (1), isolated (SP) or clustered (CP)

Characteristic	Severity level			
	SP 1 CP 1	SP 2 CP 2	SP 3 CP 3	SP 4
Inspection means	eye			
Magnification for observation of penetrant indication	1			
Diameter of the smallest indication to be considered [mm]	1.5	2	3	5
Maximum number of non-linear indications allowed	8	8	12	20
Maximum size of discontinuity indication A, B and F [mm] - Isolated indications SP - Clustered indications CP	 3 10	 6 16	 9 25	 14 -

Note : *Only values expressed in this table are valid . The reference figures according to EN 1371-1, Annex B and C are for information only.*

(1) *Such that L ≤ 3 W where L is the length and W is the width of the indication.*

Table 6.24 Severity Levels for penetrant testing - linear (LP) and aligned (AP) indications (1)

Characteristic		Severity level							
		LP 1 AP 1		LP 2 AP 2		LP 3 AP 3		LP 4 AP 4	
Inspection means		eye							
Magnification for observation of penetrant indication		1							
Length L1 of the smallest indication to be considered [mm]		1.5		2		3		5	
Arrangement of indications isolated (I) or cumulative (C)		I	C	I	C	I	C	I	C
Maximum length of linear (LP) and aligned (AP) indications allowed depending on the wall thickness t [mm]	Wall thickness class a t ≤ 16 mm	2	4	4	6	6	10	10	18
	Wall thickness class b 16 mm < t ≤ 50 mm	3	6	6	12	9	18	18	27
	Wall thickness class c t > 50 mm	5	10	10	20	15	30	30	45
Following Annex D		Figure D.3		Figure D.4		Figure D.5		Figure D.6	

Note: *The penetrant indications may grow over a period of time and this should be taken into account.*
Only values expressed in this table are valid. The reference figures according to EN 1371-1 annex D are for information only.

(1) *The length L of an aligned indication is the distance between the starting point of the first discontinuity and the opposite end of the last discontinuity (L ≥ 3 W).*

7.3 The indications are to be evaluated concerning their type, size and number in accordance with Tables 6.22, 6.23 and 6.24. The reference area for this is to be a rectangle with 105 mm x 148 mm (size DIN A6) and is to be placed on the specific most unfavorable area for each case (area with the highest number of indications). In addition for the evaluation the reference figures according to EN 1371-1 or another recognized standard, may be consulted.

7.4 Definition of indications of penetrant testing

7.4.1 Linear indication (LP)

Indication where the largest dimension equals at least 3 times the smallest dimension (i.e. L ≥ 3 W).

7.4.2 Non-linear indication: Indication where the largest dimension is smaller than 3 times the smallest dimension (i.e. L < 3 W).

- Isolated (SP),

- Cumulative (CP): area with many indications, the distance between the indications can not be measured (seemingly they form only one single indication).

7.4.3 Aligned indications (AP)

- Linear: the distance between 2 indications is smaller than the length of the largest defect in the line; or

- Non-linear: the distance between 2 indications is less than 2 mm and at least 3 indications are registered.

7.5 Defects which concerning their size and number exceed the requirements for the prescribed severity levels as well as discontinuities in the material (cracks) are not allowed and are to be removed. Repaired zones are to be retested. For this the same inspection system as before is to be employed.

8. Ultrasonic Testing (UT)

8.1 Ultrasonic testing is preferably performed for cast steel components with larger wall thickness and for examination of fabrication weldings as well as in addition to radiographic testing for determining the position in thickness and the dimension of defects.

8.2 All cast steel components are to be presented for testing in heat treated condition. As a rule ultrasonic testing may not be considered for austenitic and austenitic-ferritic cast steel grades.

8.3 In the areas to be tested an appropriate condition of the surface of the cast steel component is to be achieved which enables a faultless coupling of the probe. For this the surface is to be clear of remnants of the moulding material and the blackening, scale, dust and other contaminations which may affect the coupling.

A specific surface roughness that is to be complied with according to 4. may be agreed upon.

8.4 Ferritic cast steel components are to only then be subjected to ultrasonic testing if disc shaped reflectors of 3 mm, 4 mm and 6 mm diameter can be verified definitely for the specific wall thickness regime, cf. Table 6.25. The echo height of these smallest disc shaped reflectors to be verified is to be at least 6 dB higher than the spurious echo at the end of the thickness regime to be evaluated. The fulfillment of the aforementioned conditions is to be proven to the **TL** Surveyor within the testing.

8.5 If possible zones to be tested are to be tested from both sides. In case only one side is accessible near resolving probes, SE probes, are to be used in order to detect inhomogeneities close to the surface. Testing with SE probes is convenient only for thicknesses up to 50 mm.

8.6 If not otherwise agreed on by the purchaser and the manufacturer for all cast steel components in addition the following zones are to be tested with SE-straight beam and/or angle probes up to 50 mm depth:

- Grooves, transitions in wall thickness, zones with outer cooling webs,

- Fabrication weldings, welding edges and special rim zones,

- Fabrication weldings with depths exceeding 50 mm shall be tested in addition with other appropriate angle probes.

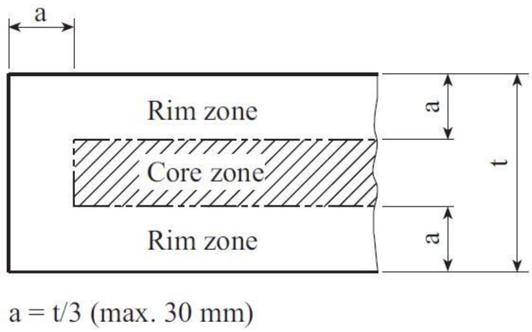
8.7 All echo indications and attenuations of the back wall echo are to be registered which are equal to the registration levels indicated in Table 6.26 or exceed them.

8.8 Indications exceeding the acceptance limits contained in Table 6.27 or Fig. 6.3 are not allowed and will result in rejection of the cast steel component by the Surveyor. Nevertheless acceptance of the cast steel component is possible on condition that after further evaluation of the indications performed by the customer and **TL** proof has been furnished that in case no repair will be performed the employability of the cast steel component will not be effected considerably, or repair will be performed. In the later case the testing shall be repeated.

8.9 For determining the acceptance criteria according to Table 6.27 the cast wall is to be divided in rim and core zones according to Fig. 6.2.

9. Radiographic Testing (RT)

9.1 Selection of radiation source depends on the required testing category and the wall thickness to be penetrated, see Table 6.28 If necessary radiographic testing is to be performed in addition to ultrasonic testing if doubts exist concerning the evaluation of indications of ultrasonic testing.



(The classification of the wall refers to the dimensions of the cast steel component ready for assembling.)

Fig 6.2 Deviation of wall section into zones

9.2 Indications which concerning their type and dimension exceed the maximum permissible values indicated in Table 6.29 for the required test category are not allowed and will result in rejection of the cast steel component by the Surveyor. Nevertheless acceptance of the cast steel component is possible on condition that after further evaluation of the indications performed by the customer and **TL** proof has been furnished that in case no repair is to be performed the employability of the cast steel component is to not be affected considerably, or repair is to be performed. In the later case the testing is to be repeated.

Table 6.25 Ultrasonic testability requirements according to EN 12680-1

Wall thickness [mm]	Smallest flat-bottom hole diameter detectable [mm]
≤ 300	3
> 300 to ≤ 400	4
> 400 to ≤ 600	6

Table 6.26 Registration levels for ultrasonic testing of ferritic steel castings in accordance with EN 12680-1

Wall thickness [mm]	Inspected area	Reflectors without measurable dimension diameter of the equivalent flat-bottomed hole (1) min. [mm]	Reflectors with measurable dimension diameter of the equivalent flat-bottomed hole (1) min. [mm]	Attenuation of back wall echo min. [mm]
≤ 300	-	4	3	12
≤ 300 to ≤ 400	-	6	4	
> 400 to ≤ 600	-	6	6	
-	Severity level 1 areas	3	3	6
-	special rim zone	3	3	-

(1) *Formula for converting the flat-bottomed hole diameter into the side-drilled hole diameter, see EN 12680-1*

Table 6.27 Acceptance limits for ultrasonic testing for volumetric discontinuities following EN 12680-1

<table>
<tr><th rowspan="2">Characteristic</th><th rowspan="2">Unit</th><th rowspan="2">Zone (see figure 2)</th><th colspan="10">Severity level</th></tr>
<tr><th>UV 1</th><th colspan="3">UV 2</th><th colspan="3">UV 3</th><th colspan="3">UV 4</th></tr>
<tr><td>Casting wall thickness at the examined area</td><td>mm</td><td></td><td>-</td><td>≤50</td><td>>50 ≤100</td><td>>100 ≤600</td><td>≤50</td><td>>50 ≤100</td><td>>100 ≤600</td><td>≤50</td><td>>50 ≤100</td><td>>100 ≤600</td></tr>
<tr><td colspan="13">Reflectors without measurable dimension</td></tr>
<tr><td rowspan="2">Largest diameter of equivalent flat-bottomed hole</td><td rowspan="2">mm</td><td>rim</td><td rowspan="2">3</td><td colspan="9" rowspan="2">1</td></tr>
<tr><td>core</td></tr>
<tr><td rowspan="2">Number of discontinuities to be recorded in a frame 100 mm • 100 mm</td><td rowspan="2">-</td><td>rim</td><td rowspan="2">3 **(2)**</td><td>3</td><td colspan="2">5</td><td colspan="2">6</td><td>6</td><td colspan="3" rowspan="2">Not used as criterion</td></tr>
<tr><td>core</td><td colspan="6">Not used as criterion</td></tr>
<tr><td colspan="13">Reflectors with measurable dimension</td></tr>
<tr><td rowspan="2">Largest diameter of equivalent flat-bottomed hole</td><td rowspan="2">mm</td><td>rim</td><td rowspan="2">3</td><td colspan="9" rowspan="2">1</td></tr>
<tr><td>core</td></tr>
<tr><td rowspan="2">Maximum values of dimension in through-wall direction of discontinuities</td><td rowspan="2">-</td><td>rim</td><td rowspan="10">Not permitted</td><td colspan="9">15 % of zone thickness</td></tr>
<tr><td>core</td><td colspan="9">15 % of wall thickness</td></tr>
<tr><td rowspan="2">Maximum length without measurable width</td><td rowspan="2">mm</td><td>rim</td><td>75</td><td>75</td><td>75</td><td>75</td><td>75</td><td>75</td><td>75</td><td>75</td><td>75</td></tr>
<tr><td>core</td><td>75</td><td>75</td><td>100</td><td>75</td><td>75</td><td>120</td><td>100</td><td>100</td><td>150</td></tr>
<tr><td rowspan="2">Largest individual area **(3) (4)**</td><td rowspan="2">mm^2</td><td>rim</td><td>600</td><td>1000</td><td>1000</td><td>600</td><td>2000</td><td>2000</td><td>2000</td><td>2000</td><td>2000</td></tr>
<tr><td>core</td><td>10000</td><td>10000</td><td>15000</td><td>15000</td><td>15000</td><td>20000</td><td>15000</td><td>15000</td><td>20000</td></tr>
<tr><td rowspan="2">Largest total area for a reference area **(3)**</td><td rowspan="2">mm^2</td><td>rim</td><td>10000</td><td>10000</td><td>10000</td><td>10000</td><td>10000</td><td>10000</td><td>10000</td><td>15000</td><td>15000</td></tr>
<tr><td>core</td><td>10000</td><td>15000</td><td>15000</td><td>15000</td><td>20000</td><td>20000</td><td>15000</td><td>20000</td><td>20000</td></tr>
<tr><td>Reference area</td><td>mm^2</td><td>-</td><td colspan="3">150000 ≈ (390 mm x 390 mm)</td><td colspan="6">100000 ≈ (320 mm x 320 mm)</td></tr>
</table>

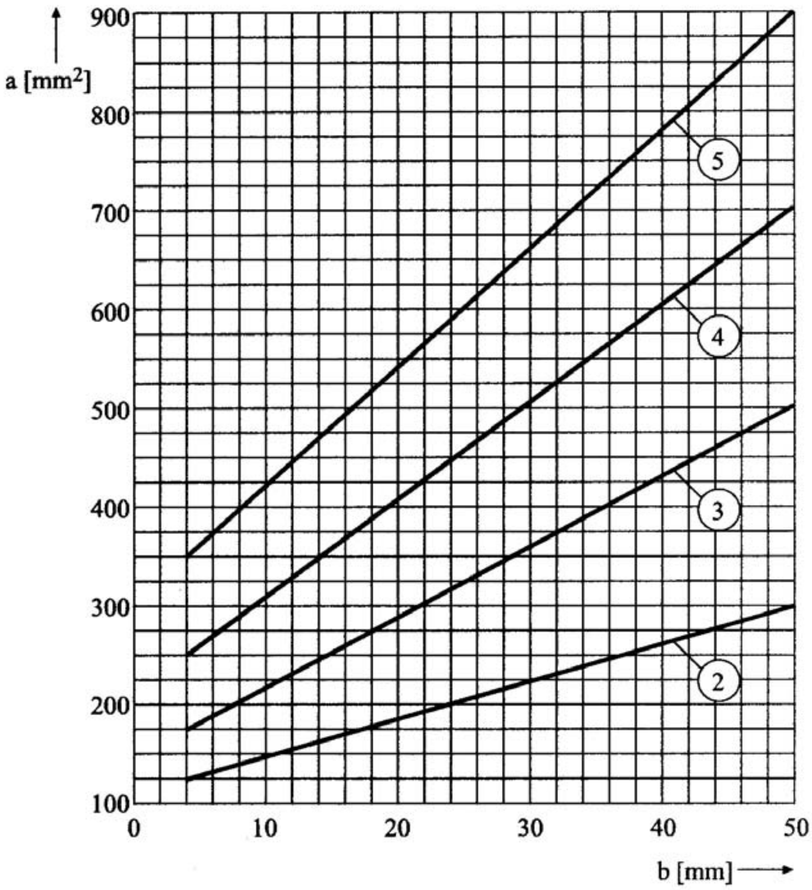
(1) *For wall thickness not greater than 50 mm, flat-bottomed holes exceeding 8 mm are unacceptable.*

For wall thickness greater than 50 mm the acceptability of flat-bottomed holes exceeding 8 mm in the rim zone shall be agreed between the manufacturer and the purchaser.

(2) *Accumulated in core zone and rim zone.*

(3) *Indications less than 25 mm apart shall be considered as one discontinuity.*

(4) *If the indication in the core zone is caused by an individual reflector the thickness of which does not exceed 10 % of the wall thickness, (e.g. centreline shrinkage) then, in case of severity levels 2 to 4, values 50 % higher than those specified in this table, are acceptable and in case of severity level 5, no limit is specified.*



Key

UV 2 Severity level 2

UV 3 Severity level 3

UV 4 Severity level 4

UV 5 Severity level 5

a Largest acceptable individual indication area [mm^2]

b Distance from test surface [mm]

Indications with measureable dimensions are not allowed for severity level 1.

Fig 6.3 Acceptance criteria for ultrasonic testing for individual planar indications mainly orientated in through-wall direction, detected with angle probes following EN 12680-1

Table 6.28 Radiation source in dependence of the test class and the penetrated thickness following ISO 5579 and EN 12681

Radiation source	Penetrated thickness ω [mm]	
	Class A	Class B
TM 170	w ≤ 5	w ≤ 5
Yb 169	1 ≤ w ≤ 15	2 ≤ w ≤ 15
Se 75	10 ≤ w ≤ 40	14 ≤ w ≤ 40
Ir 192	20 ≤ w ≤ 100	20 ≤ w ≤ 90
Co 60	40 ≤ w ≤ 170	60 ≤ w ≤ 150
X-ray equipment with energy from 1 MeV to 4 MeV	30 ≤ w ≤ 200	50 ≤ w ≤ 180
X-ray equipment with energy from 4 MeV to 12 MeV	w ≥ 50	w ≥ 80
X-ray equipment with energy above 12 MeV	w ≥ 80	w ≥ 100

Table 6.29 Maximum permissible defects for radiographic testing

Defect				Maximum permissible defect for severity level			
Type	**Code letter as ASTM (1)**	**Wall thickness [mm]**	**Assessment as in ASTM (1)**	**RV 1**	**RV 2 (2)**	**RV 3 (2)**	**RV 4 (2)**
Blowholes	A	Up to 50 Over 50 up to 115 Over 115 up to 300	E 446 E 186 E 280	A1 A1 **(3)**	A3 A3 A3	A3 A3 A3	A4 A4 A4
Non-metallic inclusions	B	Up to 50 Over 50 up to 115 Over 115 up to 300	E 446 E 186 E 280	B1 B1 **(3)**	B3 B3 B3	B3 B3 B3	B4 B4 B4
Shrinkage	C	Up to 50 Over 50 up to 115 Over 115 up to 300	E 446 E 186 E 280	Ca1, Cb1 Cc1, Cd1 Ca1, Cb1, Cc1 **(3)**	Ca2, Cb2 Cc2, Cd2 Ca2, Cb2, Cc2 Ca2, Cb2, Cc2	Ca3, Cb3 Cc3, Cd3 Ca3, Cb3, Cc3 Ca3, Cb3, Cc3	Ca4, Cb4 Cc4, Cd4 Ca4, Cb4, Cc4 Ca4, Cb4, Cc4
Cracks	D+E			Not permitted	Not permitted **(4)**	Not permitted **(4)**	Not permitted **(4)**
Chaplets and iron chills	F	Up to 50 Over 50 up to 115 Over 115 up to 300	E 446 E 186 E 280	Not permitted Not permitted Not permitted	Not permitted Not permitted Not permitted	Not permitted Not permitted Not permitted	F1 **(5)** F1 **(5)** F1 **(5)**

(1) *Caption: ASTM-E 446 — Reference radiographs for steel castings up to 2 in. (51 mm) in thickness,*
ASTM-E 186 — Reference radiographs for heavy walled (2 to 4 1/2 in. (51 to 114 mm) steel castings sowie
ASTM-E 280 — Reference radiographs for heavy walled (4 1/2 to 12 in. (114 to 305 mm) steel castings.

(2) *If for example it is shown by ultrasonic testing that the defects are in the core zone (see Fig. 6.1), the specifications for the next higher (numerical) severity level is to apply, unless otherwise specified in the material standard or in the order.*

(3) *The values to be adhered are to be agreed.*

(4) *Unless the minor nature of the cracks is proved by fracture-mechanical tests.*

(5) *Chaplets may be present, but they are to be welded free from cracks at the surface.*

H. List of Cast Steel Components for which Non-destructive Tests are Required

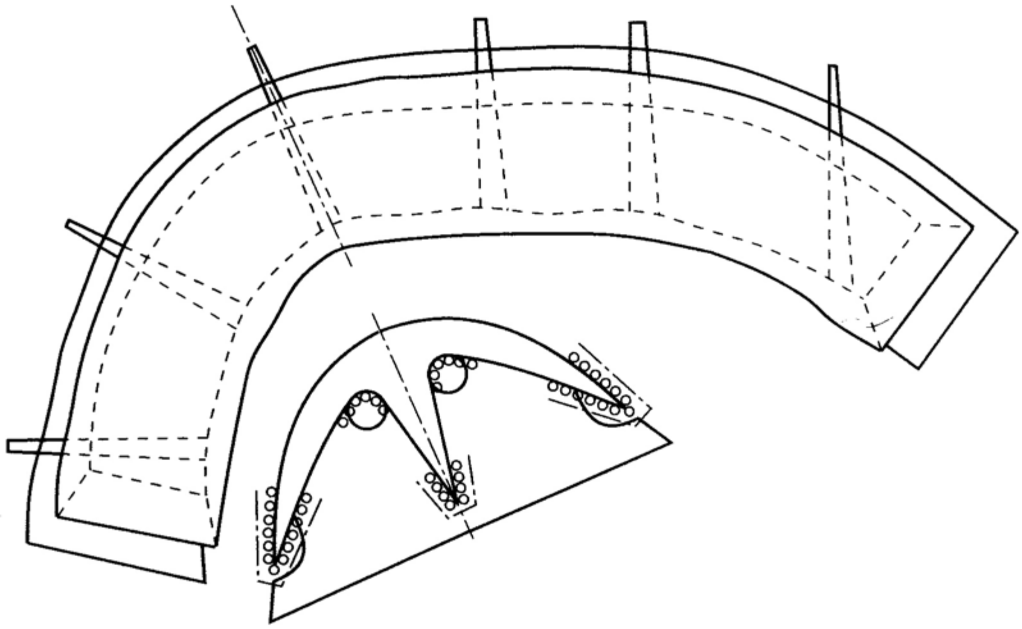
Table 6.30 Test methods to be employed

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 **(4)**	-	X **(4)**	-
Cylinder covers	X	X **(4)**	-	X **(4)**	-
Camshaft drive gear wheels and chain wheels	X	X **(4)**	-	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 with NW > 100	X	X	-	-	X **(3)**

(1) *Testing in the prescribed areas.*
(2) *PT may be employed instead of MT.*
(3) *Random testing according to testing plan.*
(4) *For diesel engines with cylinder diameter > 400 mm*

I. Testing Instructions for Hull Structural Parts

In the figures 6.4 to 6.11 the specifications for the non-destructive testing are prescribed.



Testing scope:

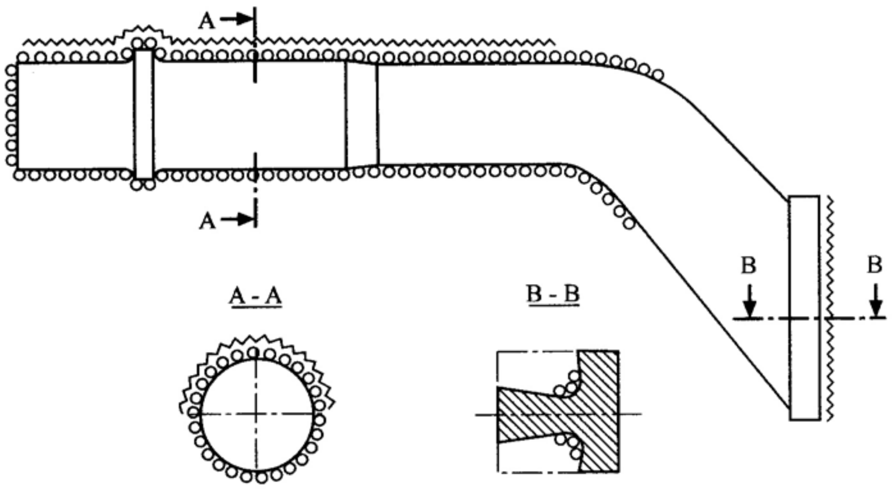
Visual testing	: Entire surface
Magnetic particle testing	: Welding edges (ooooooooo)
Radiographic testing	: Welding edges (–·–·–)
Ultrasonic testing	: Welding edges (–·–·–), if permitted by the geometry

Severity levels

Visual testing	: VI for welding edges; V3 remaining areas
Magnetic particle testing	: SMI; LM1; AMI for welding edges; SM2; LM2; AM2 remaining areas
Radiographic testing	: RV1 up to thickness 50 mm and RV2 for thickness > 50 mm **(1)**
Ultrasonic testing	: UV2 instead of radiographic testing for thickness > 50 mm **(1)**

(1) *Thickness - Thickness of the cast component at the area to be tested.*

Fig. 6.4 Testing instruction for stern



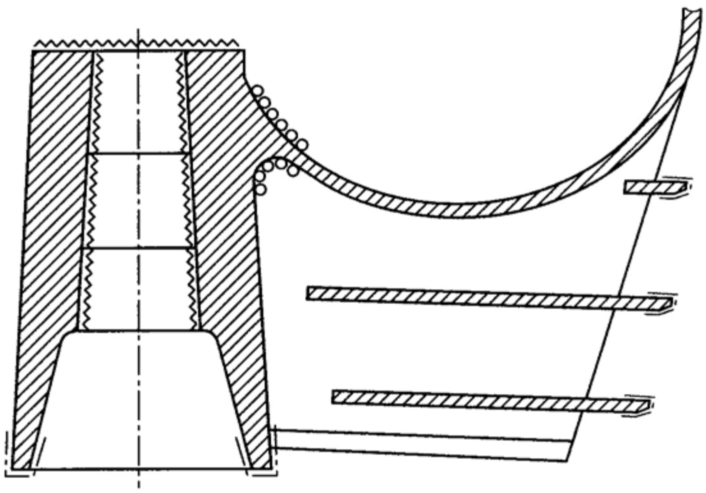
Testing scope:

Visual testing	:	Entire surface
Magnetic particle testing	:	Areas marked with (ooooooooo)
Radiographic testing	:	Areas marked with ( )

Severity levels

Visual testing	:	V2 (ooooooooo)
Magnetic particle testing	:	SM2, LM2, AM2 (ooooooooo)
		SM3, LM3, AM3 remaining areas
Ultrasonic testing	:	UV2

Fig. 6.5 Testing instruction for rudder stock



Testing scope:

Visual testing : Entire surface

Magnetic particle testing : Welding edges (–·–·–·–), (ooooo)

Radiographic testing : Welding edges (–·–·–·–)

Ultrasonic testing : Areas marked with (^^^^^^^^)

Severity levels:

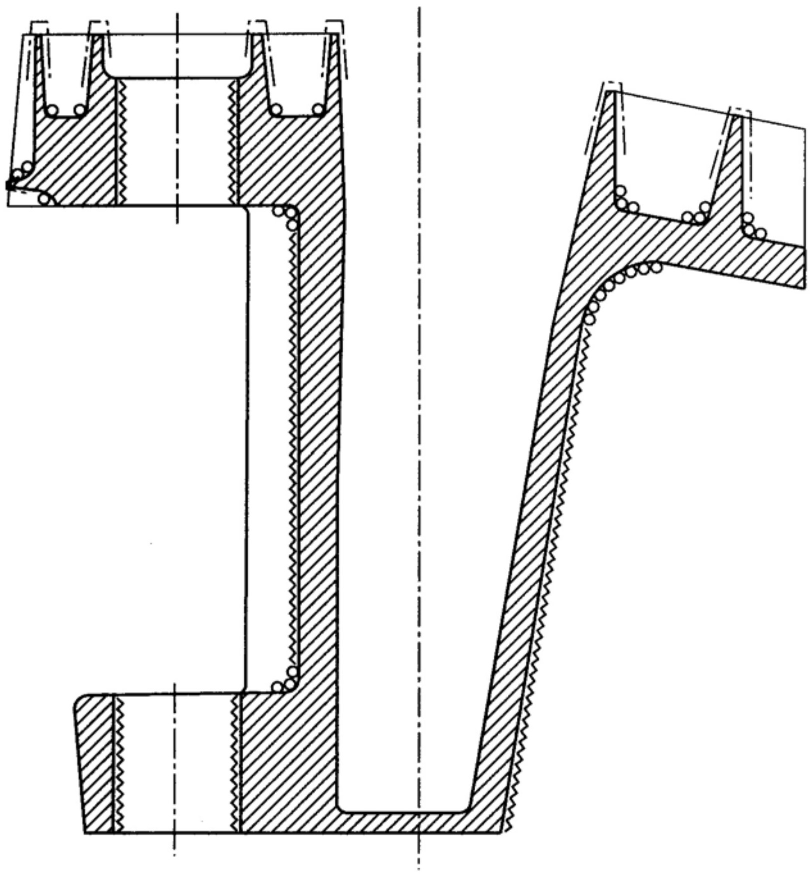
Visual testing : V1 for areas marked with (–·–·–·–);
V2 for areas marked with ( ),
remaining areas V3

Magnetic particle testing : SM1, LM1, AM1 for (–·–·–·–); SM2, LM2, AM2,
for areas marked with (ooooo); SM3, LM3, AM3 for the remaining areas.

Radiographic testing : RV1 up to thickness 50 mm and
RV2 for thickness > 50 mm

Ultrasonic testing : UV2; further instead of radiographic testing for thickness > 50 mm

Fig. 6.6 Testing instruction for stern nut

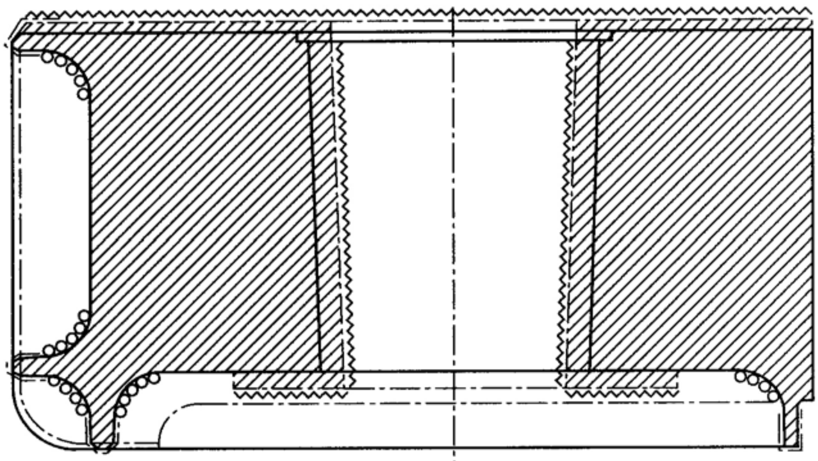


Testing scope:

Visual testing : Entire surface
Magnetic particle testing : Welding edges (–·–·–·–), (ooooo)
Radiographic testing : Welding edges (–·–·–·–)
Ultrasonic testing : Areas marked with (﹏﹏﹏﹏)

Severity levels:
Visual testing : V1 for areas marked with (–·–·–·–) and remaining areas V3
Magnetic particle testing : SM1, LM1, AM1 for (–·–·–·–); SM2, LM2, AM2, for areas marked with (ooooo); SM3, LM3, AM3 for the remaining areas.
Radiographic testing : RV1 up to thickness 50 mm and RV2 for thickness > 50 mm
Ultrasonic testing : UV2; further instead of radiographic testing for thickness > 50 mm

Fig. 6.7 Testing instruction for rudder horn



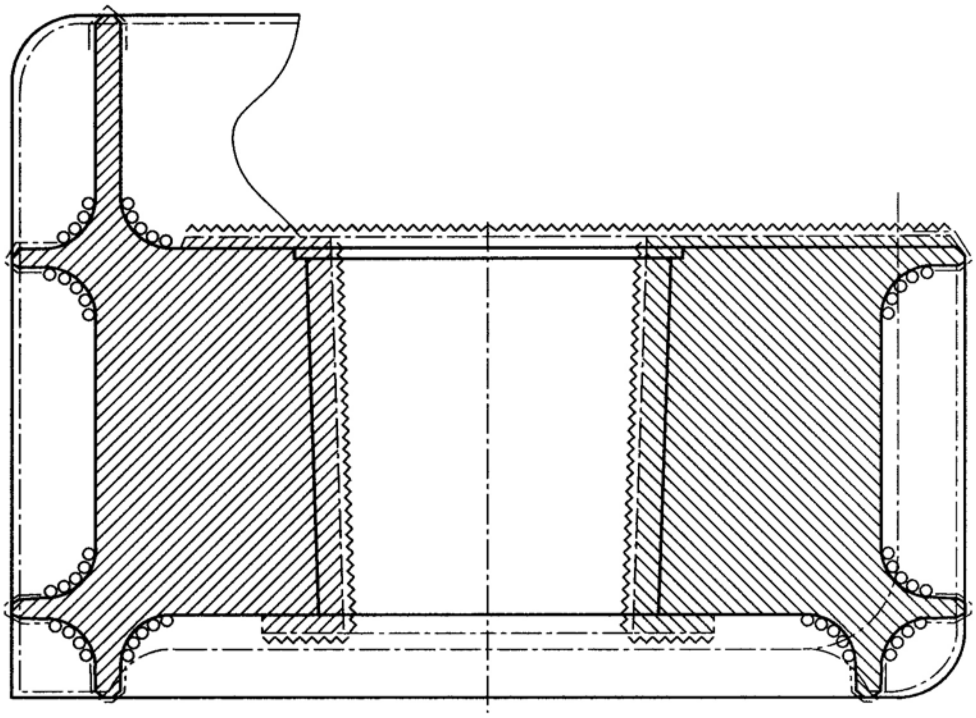
Testing scope:

Visual testing	: Entire surface
Magnetic particle testing	: Welding edges (–·–·–·–), (ooooo)
Radiographic testing	: Welding edges (–·–·–·–)
Ultrasonic testing	: Areas marked with ( )

Severity levels:

Visual testing	: V1 for areas marked with (–·–·–·–) and V2 for remaining areas
Magnetic particle testing	: SM1, LM1, AM1 for (–·–·–·–); SM2, LM2, AM2, for areas marked with (ooooo); SM3, LM3, AM3 for the remaining areas.
Radiographic testing	: RV1 up to thickness 50 mm and RV2 for thickness > 50 mm
Ultrasonic testing	: UV2; further instead of radiographic testing for thickness > 50 mm

Fig. 6.8 Testing instruction for upper rudder coupling



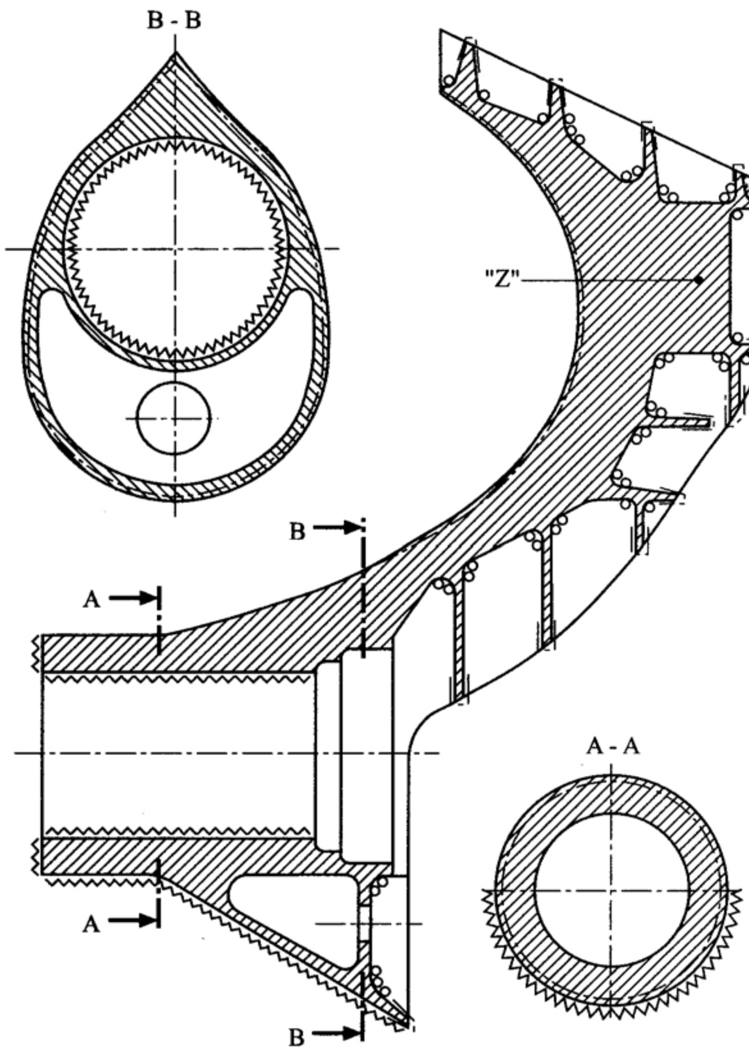
Testing scope:

Visual testing	: Entire surface
Magnetic particle testing	: Welding edges (–·–·–·–), (ooooo)
Radiographic testing	: Welding edges (–·–·–·–)
Ultrasonic testing	: Areas marked with ( )

Severity levels:

Visual testing	: V1 for areas marked with (–·–·–·–); V2 remaining areas
Magnetic particle testing	: SM1, LM1, AM1 for (–·–·–·–); SM2, LM2, AM2 for areas marked with (ooooo); SM3, LM3, AM3 for the remaining areas.
Radiographic testing	: RV1 up to thickness 50 mm and RV2 for thickness > 50 mm
Ultrasonic testing	: UV2; further instead of radiographic testing for thickness > 50 mm

Fig. 6.9 Testing instruction for lower rudder coupling



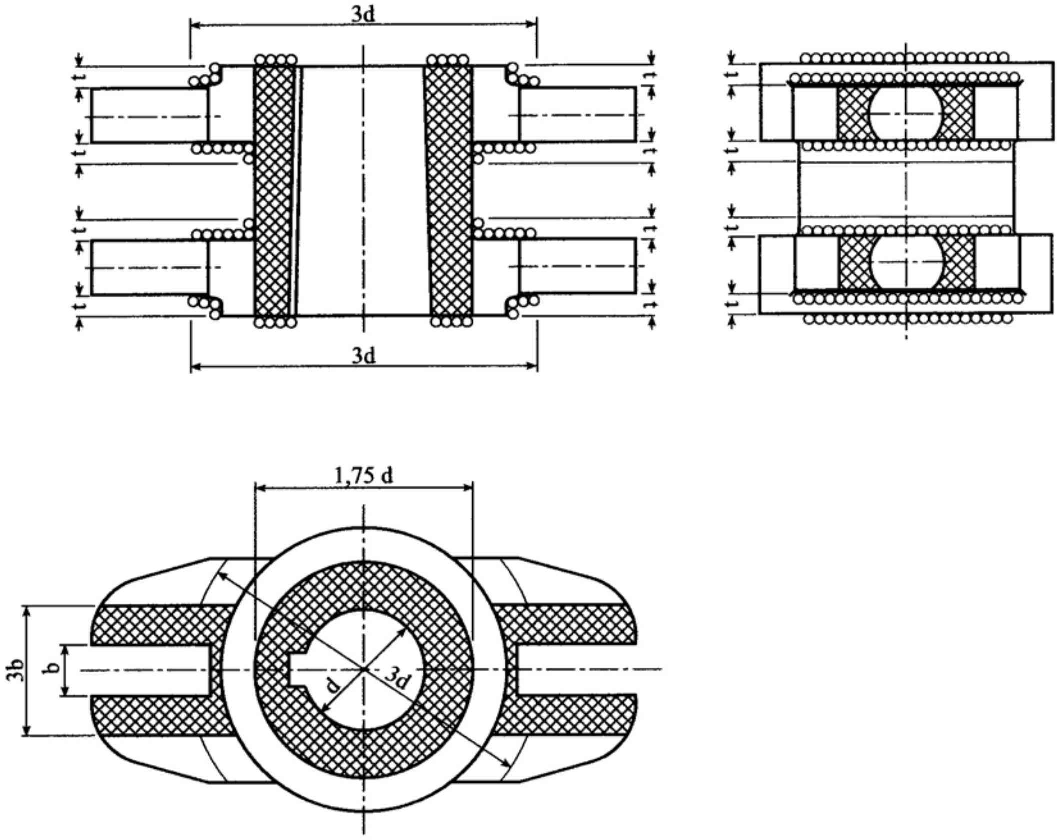
Testing scope:

Visual testing	: Entire surface
Magnetic particle testing	: Welding edges (–·–·–·–), (ooooo)
Radiographic testing	: Welding edges (–·–·–·–)
Ultrasonic testing	: Areas marked with ( )

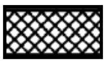
Severity levels:

Visual testing	: V1 for (–·–·–·–); V2 remaining areas
Magnetic particle testing	: SM1, LM1, AM1 for (–·–·–·–); SM2, LM2, AM2 for areas marked with (ooooo); SM3, LM3, AM3 for the remaining areas.
Radiographic testing	: RV1 up to thickness 50 mm and RV2 for thickness > 50 mm
Ultrasonic testing	: UV2; further instead of radiographic testing for thickness > 50 mm

Fig. 6.10 Testing instruction for stern frame



Testing scope:

Visual testing	: Entire surface
Magnetic particle testing	: (ooooo)
Penetrant testing	: (oooooo)
Ultrasonic testing	: Areas marked with 

Severity levels:

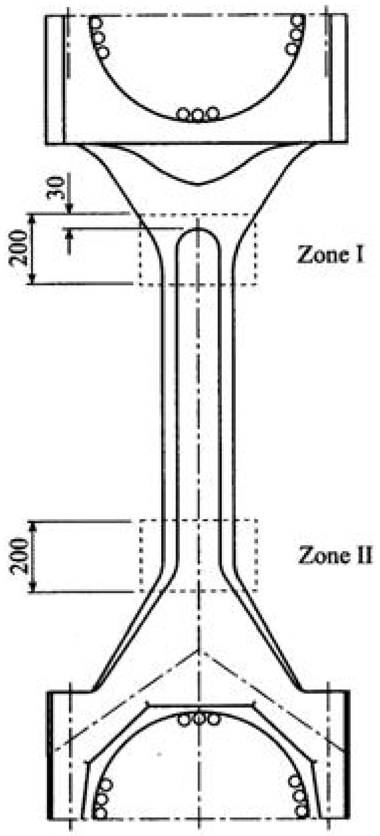
Visual testing	: V1	Key way, bore: conical or cylindrical, remaining areas V2
Magnetic particle testing or	: SM1, LM1, AM1	Tiller arms: Contact areas for slide piece and ground, lower and upper
Penetrant testing	: SP1, CP1, LP1, AP1	plane areas
Magnetic particle testing or	: SP2, LM2, AM2	remaining areas
Penetrant testing	: SP2, CP2, LP2, AP2	remaining areas
Ultrasonic testing	: UV2	The indicated areas / zones of slide are to be tested before machining the slide surface. remaining areas UV3

Cracks are not permitted. The machined areas shall not have open sand marks. Whether indications are left as they are, ground or fabrication welded is decided by **TL**.

Fig. 6.11 Testing instruction for tiller

J. Testing Instruction for Diesel Engine Parts

In the figures 6.12 and 6.13 the specifications for the non-destructive testing are prescribed.



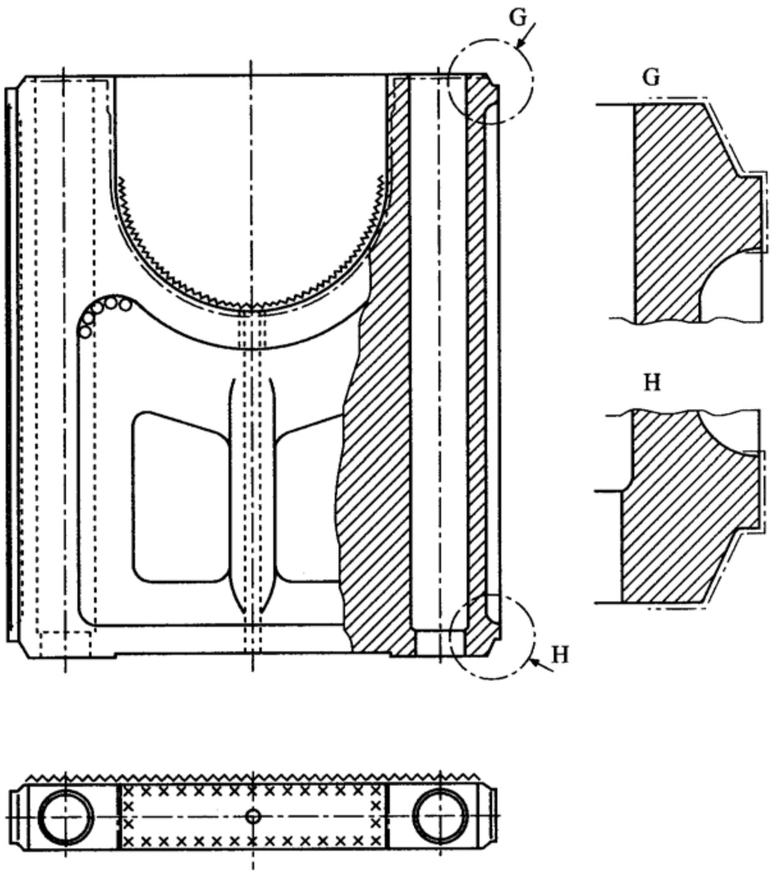
Testing scope:

Visual testing	: Entire surface
Magnetic particle testing	: Entire surface
Ultrasonic testing	: Shaft and bearing areas
Penetrant testing	: Machined bearing surfaces (ooooo)

Severity levels:

Visual testing	: V1 for zone I and II; remaining areas V2
Magnetic particle testing	: SM1, LM1, AM1 for zone I and II; remaining areas SM2, LM2, AM2
Ultrasonic testing	: UV1 for zone I and II; remaining areas UV2
Penetrant testing	: SP2, CP2, LP2, AP2 for areas marked with (ooooo)

Fig. 6.12 Testing instruction for connecting rods



Testing scope:

Visual testing	: Entire surface
Magnetic particle testing	: Welding edges (–·–·–), (ooooo)
Ultrasonic testing	: Marked areas with (∿∿∿∿∿∿∿∿∿∿)
Penetrant testing	: Marked areas with (xxxxxxxxxx)

Severity levels:

Visual testing	: V1 for (–·–·–), remaining areas V2,
Magnetic particle testing	: SM1, LM1, AM1 for the areas marked with (–·–·–); SM2, LM2, AM2 for the areas marked with (oooooo)
Ultrasonic testing	: UV1 for the areas marked with (–·–·–) UV2 for the areas marked with (∿∿∿∿∿∿∿∿∿∿)
Penetrant testing	: SP2, CP2, LP2, AP2 for the areas marked with (xxxxxxxxxx)

Fig. 6.13 Testing instruction for main bearing support

SECTION 7

IRON CASTINGS

Sayfa

A. Spheroidal or Nodular Graphite Iron Castings

1. Scope

1.1 All important spheroidal or nodular graphite iron castings are to be manufactured and tested in accordance with the requirements of the following items.

1.2 These requirements are applicable only to castings where the design and acceptance tests are related to mechanical properties at ambient temperature. For other applications additional requirements may be necessary, especially when castings are intended for service at low or elevated temperatures.

1.3 Alternatively, castings which comply with national or proprietary specifications may be accepted provided such specifications give reasonable equivalence to these requirements or otherwise specially approved or required by **TL.**

1.4 Where small castings are produced in large quantities the manufacturer may adopt alternative procedures for testing and inspection subject to the approval of **TL.**

2. Manufacture

2.1 All important castings are to be made at foundries where the manufacturer has demonstrated to the satisfaction of the **TL** that the necessary manufacturing and testing facilities are available and are supervised by qualified personnel. A programme of approval tests may be required in accordance with the procedures of **TL**.

2.2 Suitable mechanical methods are to be employed for the removal of surplus material from castings. Thermal cutting processes are not acceptable, except as a preliminary operation to mechanical methods.

2.3 Where castings of the same type are regularly produced in quantity, the manufacturer is to make any tests necessary to prove the quality of the prototype castings and is also to make periodical examinations to verify the continued efficiency of the manufacturing technique. The Surveyor is to be given the opportunity to witness these tests.

3. Quality of castings

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

4. Chemical Composition

4.1 Unless otherwise specially required, the chemical composition of the iron used is left to the discretion of the manufacturer, who is to ensure that it is suitable to obtain the mechanical properties specified for the castings. When required **TL** the chemical composition of ladle samples is to be reported.

5. Heat Treatment

5.1 Apart from the exceptions provided for in 5.2, the castings may be supplied in as cast or heat-treated condition. The method of treatment is to be specified at the time of the approval test.

5.2 Cast iron of grades EN-GJS-350-22-LT/-22-U-LT to EN-GJS-400-18-LT/-18U-LT or the special qualities according to Table 7.1 with nominal strengths of 350 and 400 N/mm^2 are to undergo ferritizing heat treatment.

5.3 Where it is proposed to locally harden the surfaces of a casting full details of the proposed procedure and specification are to be submitted for approval by **TL**.

Where castings are subject to special requirements in respect of their dimensional or geometrical stability, any heat treatment needed is to 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.

6. Mechanical Properties

6.1 Table 7.1 gives the minimum requirements for 0,2% proof stress and elongation corresponding to different strength levels. Typical Brinell hardness values are also given in Table 7.1 and are intended for information purposes only.

6.2 Castings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Table 7.1 but subject to any additional requirements of the relevant construction Rules

6.3 Unless otherwise agreed only the tensile strength and elongation need be determined. The results of all tensile tests are to comply with the appropriate requirements of Table 7.1

6.4 Re-test requirements for tensile tests are to be in accordance with Section 2.

6.5 Nodular cast iron conforming to DIN EN 1563

The requirements specified in the standard and given in Table 7.2 for separately cast samples and in Table 7.3 for integrally cast samples are applicable.

In case of requirements regarding impact energy, the minimum values specified in Tables 7.4 and 7.5 are to be proven.

In addition the requirements in 6.6 and 6.7 are applied regarding graphite- or metallic matrix structure respectively.

6.6 Graphite structure

The manufacturing process shall ensure that 90 % of the graphite is precipitated in nodular form according to Form VI of EN ISO 945-1. The remaining graphite shall have a structure at least of form V according to the above mentioned standard.

Table 7.1 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 KV (3) [J] min.	Impact energy Test temp. [°C]	Structure of metallic matrix
Ordinary qualities	370	230	17	120-180	-	-	Ferrite
	400	250	12	140-200	-	-	Ferrite
	450	310	10	160-210	-	-	Ferrite
	500	320	7	170-240	-	-	Ferrite/perlite
	600	370	3	190-270	-	-	Ferrite/perlite
	700	420	2	230-300	-	-	Perlite
	800	480	2	250-350	-	-	Perlite/sorbite or tempered structure
Special qualities	350	220	22 **(4)**	110-170	17 (14)	-20	Ferrite
	400	250	18 **(4)**	140-200	14 (11)	-20	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.*

6.7 Structure of metallic matrix

The metallic matrix shall have the structure indicated in Table 7.1.

The proportion of perlite in the ferritic grades may not exceed 10 %. The graphite- and metallic matrix structures are to be demonstrated by micrographs.

7. Testing

The following tests are to be performed:

7.1 Test of chemical composition

The manufacturer is to determine and make known to the Surveyor the chemical composition of each heat treatment batch. The analysis report is to 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.

7.2 Mechanical tests

7.2.1 Test material, sufficient for the required tests and for possible retest purposes, is to be provided for each casting or batch for castings

Table 7.2 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	Ferrit
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	Ferrite / Perlite
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

Note : *The values for these materials apply to units cast in sand moulds with comparable temperature conductibility.*
(1) *LT = for low temperatures*
(2) *RT = for room temperature.*

Table 7.3 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.	0.2 % Proff 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 7.4 Minimum values for impact energy determined from samples with V-notch from separately cast test specimens

Material designation		Minimum values 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-350-22-RT **(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	-	-	-	-

Note : *The values for these materials apply to units cast in sand moulds with comparable temperature conductibility*

(1) *LT = for low temperatures.*

(2) *RT = for room temperature.*

Table 7.5 Minimum values for impact energy determined from samples with V-notch from integrally cast test specimens

Material designation		Determining wall thickness t [mm]	Minimum values 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-350-22U-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				

Note : *The values for these materials apply to units cast in sand moulds with comparable temperature conductibility.*

(1) *LT = for low temperatures.*

(2) *RT = for room temperature.*

7.2.2 The test samples are generally to be one of the standard types detailed in Figs. 7.1, 7.2 and 7.3 with a thickness of 25 mm. Test samples of other dimensions, as detailed in Figs. 7.1, 7.2 and 7.3 may, however, be specially required for some components.

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

7.2.4 For large castings where more than one ladle of treated metal is used, additional test samples are to be provided so as to be representative of each ladle used.

7.2.5 As an alternative to 8.2.3, a batch testing procedure may be adopted for castings with a fettled mass of 1 ton or less. All castings in a batch are to be of similar type and dimensions, cast from the same ladle of treated metal. One separately cast test sample is to be provided for each multiple of 2 ton of fettled castings in the batch.

7.2.6 Where separately cast test samples are used, they are to be cast in moulds made from the same type of material as used for the castings and are to be taken towards the end of pouring of the castings. The samples are not to be stripped from the moulds until the temperature is below 500 °C.

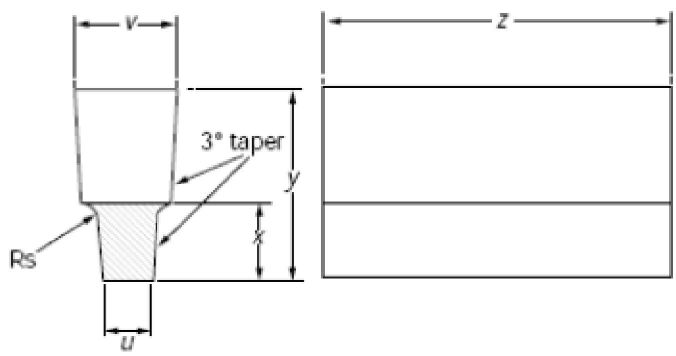
7.2.7 All test samples are to be suitably marked to identfy them with the castings which they represent.

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

7.2.9 One tensile test specimen is to be prepared from each test sample and is to be machined to the dimensions given in Section 2.

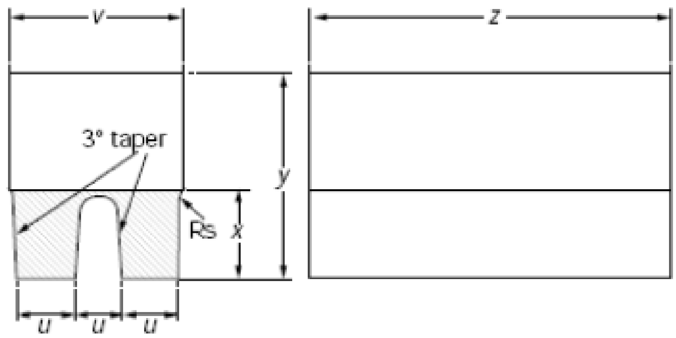
7.2.10 All tensile tests are to be carried out using test procedures in accordance with Section 2. Unless otherwise agreed all tests are to be carried out in the presence of the surveyor.

7.2.11 Impact tests may additionally be required and in such cases a set of three test specimens of agreed typeis to be prepared fron each sample. Where Charpy V-notch test specimens are used, the dimensions and testing procedures are to be in accordance with Section 2.



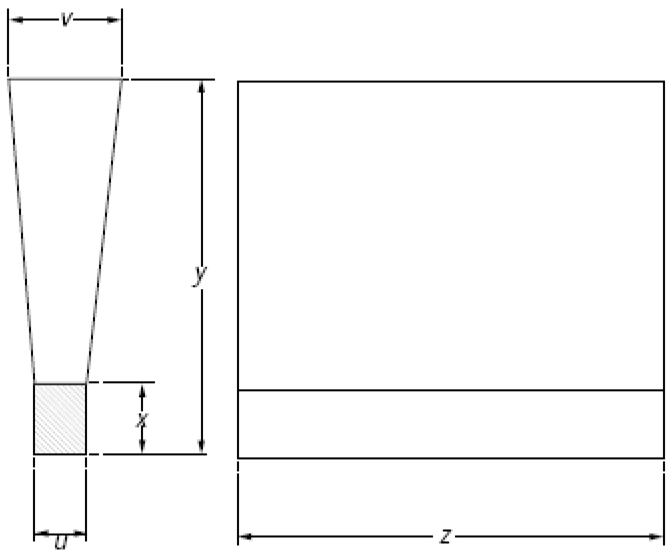
Dimensions	Standard Sample	Alternative samples when specially required		
u(mm)	*25*	*12*	*50*	*75*
v (mm)	*55*	*40*	*90*	*125*
x (mm)	*40*	*30*	*60*	*65*
y (mm)	*100*	*80*	*150*	*165*
z	*To suit testing machine*			
R_S	*Approximately 5 mm*			

Figure 7.1 Type A test samples (U-type)



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

Figure 7.2 Type B test samples (double U-type)



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

Figure 7.3 Type C test samples (Y-type)

8. Inspection

8.1 All castings are to be cleaned and adequately prepared for examination. The surfaces are not to be hammered, peened or treated in any way which may obscure defects.

8.2 Before acceptance, all castings are to be visually examined including, where applicable, the examination of internal surfaces. Unless otherwise agreed the verification of dimensions is the responsibility of the manufacturer.

8.3 Supplementary examination of castings by suitable nondestructive testing procedures is generally not required except in circumstances where there is reason to suspect the soundness of the casting.

8.4 When required by the relevant construction Rules, castings are to be pressure tested before final acceptance.

8.5 In the event of any casting proving defective during subsequent machining or testing is to be rejected notwithstanding any previous certification.

8.6 Cast crankshaft are to be subjected to a magnetic particle inspection. Crack like indications are not allowed.

9. Metallographic Examination

9.1 For crankshafts the metallographic examination will be mandatory.

9.2 When required, a representative sample from each ladle of treated metal is to be prepared for metallographic examination. These samples may conveniently be taken from the tensile test specimens but alternative arrangements for the provision of the samples may be adopted provided that they are taken from the ladle towards the end of the casting period.

9.3 Examination of the samples is to show that at least 90% of the graphite is in a dispersed spheroidal or nodular form. Details of typical matrix structures are given in Table 7.1 and are intended for information purposes only.

10. Rectification of defective castings

10.1 At the discretion of the Surveyor, small surface blemishes mat be removed by local grinding.

10.2 Subject to the prior approval of the Surveyor, castings containing local porosity may be rectified by impregnation with a suitable plastic filler, provided that the extent of the porosity is such that it does not adversely affect the strength of the casting.

10.3 Repairs by welding are generally not permitted.

11. Identification of castings

11.1 The manufacturer is to adopt a system of identification which will enable all finished castings to be traced to the original ladle of treated metal and the Surveyor is to be given full facilities for so tracing the castings when required.

11.2 Before acceptance, all castings which have been tested and inspected with satisfactory results are to be clearly marked by the manufacturer. At the discretion of TL any of the following particulars may be required.

- Quality of cast iron.
- Identification number or other marking which will enable the full history of the casting to be traced.
- Manufacturer's name or trade mark.
- TL's name, initials or symbol.
- Abbreviated name of TL's local office.
- Personal stamp of Surveyor responsible for inspection.
- Where applicable, test pressure.
- Date of final inspection.

11.3 Where small castings are manufactured in large numbers, modified arrangements for identification may be specially agreed with **TL**.

12. Certification

12.1 The manufacturer is to provide the Surveyor with a test certificate or shipping statement giving the following particulars for each casting or batch of castings which has been accepted:

- Purchaser's name and order number.

- Description of castings and quality of cast iron.

- Identification number.

- Results of mechanical tests.

- Where applicable, general details of heat treatment.

- Where specifically required, the chemical analysis of ladle samples.

- Where applicable, test pressure.

B. Grey Iron Castings

1. Scope

1.1 All major grey iron castings, as defined in the relevant construction Rules, are as be manufactured and tested in accordance with the requirements of the following items.

1.2 Alternatively, castings which comply with national or proprietary specifications may be accepted provided such specifications give reasonable equivalence to these requirements or otherwise are specially approved or required by **TL**.

1.3 Where small castings are produced in large quantities, the manufacturer may adopt alternative procedures for testing and inspection subject to the approval of **TL**.

2. Manufacture

2.1 All major castings are to be made at foundries where the manufacturer has demonstrated to the satisfaction of **TL** that the necessary manufacturing and testing facilities are available and are supervised by qualified personnel. A programme of approval tests may be required in accordance with the procedures of individual **TL**.

2.2 Suitable mechanical methods are to be employed for the removal of surplus material from castings. Thermal cutting processes are not acceptable, except as a preliminary operation to mechanical methods.

2.3 Where castings of the same type are regularly produced in quantity, the manufacturer is to make any tests necessary to prove the quality of the prototype castings and is also to make periodical examinations to verify the continued efficiency of the manufacturing technique. The Surveyor is to be given the opportunity to witness these tests.

3. Quality of castings

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

4. Chemical composition

4.1 The chemical composition of the iron used is left to the discretion of the manufacturer, who is to ensure that it is suitable to obtain the mechanical properties specified for the castings. When required by individual, **TL** the chemical composition of ladle samples is to be reported.

5. Heat Treatment

5.1 Except as required by 5.2 castings may be supplied in either the as cast or heat treated condition.

5.2 For some applications, such as high temperature service or where dimensional stability is important, castings may require to be given a suitable tempering or stress relieving heat treatment.

6. Mechanical Properties

6.1 Only the tensile strength is to be determined and the results obtained from tests are to comply with the minimum value specified for the castings being supplied. The value selected for the specified minimum tensile strength is to be not less than 200 N/mm^2 but subject to any additional requirements of the relevant construction Rules. The fractured surfaces of all tensile test specimens are to be granular and grey in appearance.

6.2 Re-test requirements for tensile tests are to be in accordance with Section 2.

7. Testing

The following tests are to be performed:

7.1 Test of chemical composition

The manufacturer is constant to monitor the chemical composition and the saturation level of each treatment unit (ladle) and is to pass this information on to the Surveyor on request. Determination of at least the following elements is required: C, Mn, Si, P and S.

7.2 Mechanical tests

7.2.1 Test material sufficient for the required tests and for possible retests is to be provided for each casting or batch of castings.

7.2.2 Separately cast test samples are to be used unless otherwise agreed between the manufacturer and purchaser and generally are to be in the form of bars 30 mm in diameter and of a suitable length. They are to be cast from the same ladle as the castings in moulds of the same type of material as the moulds for the castings and are not to be stripped from the moulds until the metal temperature is below 500 ºC. When two or more test samples are cast simultaneously in a single mould, the bars are to be at least 50 mm apart as given in Fig. 7.4.

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

7.2.4 With the exception 7.2.7, at least one test sample is to be cast with each batch.

7.2.5 With the exception 7.2.6, a batch consists of the castings poured from a single ladle of metal, provided that they are all of similar type and dimensions. A batch should not normally exceed 2 tons of fettled castings and a single casting will constitute a batch is its mass is 2 tons or more.

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

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

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

7.2.9 Where castings are supplied in the heat treated condition, the test samples are to be heat treated together with the castings which they represent. For cast-on-test samples the sample shall not be cut off from the casting until after the heat treatment.

7.2.10 One tensile test specimen is to be prepared from each test sample and for 30 mm diameter samples is to be machined to the dimensions given in Section 2. Where test samples of other dimensions are specially required the tensile test specimens are to be machined to agreed dimensions.

7.2.11 All tensile tests are to be carried out using test procedures in accordance with Section 2. Unless otherwise agreed all tests are to be carried out in the presence of the surveyor.

8. Inspection

8.1 All castings are to be cleaned and adequately prepared for examination. The surfaces are not to be hammered, peened or treated in any way which may obscure defects.

Table 7.6 Tensile strength of grey iron casting

Material designation		Determining wall thickness [mm]		Tensile strength R_m values to comply with	
Material code	**Number**	**over**	**up to**	**in separately cast test specimens [N/mm²]**	**in separately cast test specimens [N/mm²] 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*

Dimensions in millimeters

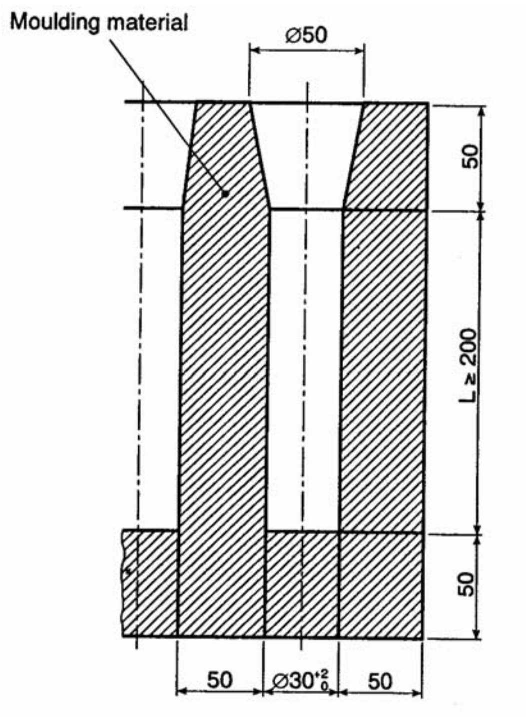


Figure 7.4 Test sample for grey cast iron

8.2 Before acceptance, all castings are to be visually examined including, where applicable, the examination of internal surfaces. Unless otherwise agreed, the verification of dimensions is the responsibility of the manufacturer.

8.3 Supplementary examination of castings by suitable non destructive testing procedures is generally not required except in circumstances where there is reason to suspect the soundness of the casting.

8.4 When required by the relevant construction Rules, castings are to be pressure tested before final acceptance.

8.5 In the event of any casting proving defective during subsequent machining or testing it is to be rejected notwithstanding any previous certification.

9. Rectification of Defective Castings

9.1 At the discretion of the Surveyor, small surface blemishes may be removed by local grinding.

9.2 Subject to the prior approval of the Surveyor, castings containing local porosity may be rectified by impregnation with a suitable plastic filler, provided that the extent of the porosity is such that it does not adversely affect the strength of the casting.

9.3 Repairs by welding are generally not permitted.

10. Identification of Castings

10.1 The manufacturer is to adopt a system of identification, which will enable all finished castings to be traced to the original ladle of metal. The Surveyor is to be given full facilities for so tracing the castings when required.

10.2 Before acceptance, all castings which have been tested and inspected with satisfactory results are to be clearly marked by the manufacturer. At the discretion of individual **TL** any of the following particulars may be required:

- Quality of cast iron.
- Identification number or other marking which will enable the full history of the casting to be traced.
- Manufacturer's name or trade mark.
- **TL**'s name, initials or symbol.
- Abbreviated name of **TL**'s local office.
- Personal stamp of Surveyor responsible for inspection.
- Where applicable, test pressure.
- Date of final inspection

10.3 Where small castings are manufactured in large numbers, modified arrangements for identification may be specially agreed with **TL**.

11. Certification

The manufacturer is to provide the Surveyor with a test certificate or shipping statement giving the following particulars for each casting or batch of castings which has been accepted:

- Purchaser's name and order number.
- Description of castings and quality of cast iron.
- Identification number.
- Results of mechanical tests.
- Where applicable, general details of heat treatment.
- When specially required, the chemical analysis of ladle samples.
- Where applicable, test pressure.

SECTION 8

ALUMINIUM ALLOYS

A. Wrought Aluminium Alloys

1. Scope

1.1 These rules apply to wrought aluminium alloys used in the construction of hulls, superstructure and other marine structures.

They are not applicable to the use of aluminium alloys at low temperature for cryogenic applications.

1.2 These rules are applicable to wrought aluminium alloy products within a thickness range of 3 mm and 50 mm inclusive.

The application of aluminium alloy products apart from this thickness range requires prior agreement of **TL.**

1.3 The numerical designation (grade) of aluminium alloys and the temper designation are based on those of the Aluminium Association.

1.4 Temper conditions (delivery heat treatment) are defined in EN 515 or ANSI H35.1/H35.1M.

1.5 Consideration may be given to aluminium alloys not specified in these rules, and to alternative temper conditions, subject to prior agreement with **TL** further to a detailed study of their properties, including corrosion resistance, and of their conditions of use (in particular welding procedures).

2. Approval

All materials, including semi finished products, are to be manufactured at works which are approved by **TL** for the grades of alloy supplied.

3. Aluminium Alloys and Their Temper Conditions

3.1 Rolled products (sheets, strips and plates)

The following aluminium alloys are covered by these rules: 5083, 5086, 5383, 5059, 5754 and 5456

With the hereunder temper conditions: O,H 111, H 112, H 116, H 321

3.2 Extruded products (sections, shapes, bars and closed profiles)

The following aluminium alloys are covered by these rules:

5083, 5383, 5059 and 5086

with the hereunder temper conditions:

O, H111, H112

and:

6005A, 6061, 6082

with the hereunder temper conditions:

T5 or T6

Note:

The alloy grades 6005A, 6061, of the 6000 series should not be used in direct contact with sea water unless protected by anodes and/or paint system.

4. Chemical Composition

4.1 The manufacturer is to determine the chemical composition of each cast.

4.2 The chemical composition of aluminium alloys is to comply with the requirements given in Table 8.1.

4.3 The manufacturer's declared analysis will be accepted subject to occasional checks if required by the surveyor, in particular, product analysis may be required where the final product chemistry is not well represented by the analysis from the cast.

4.4 When the aluminium alloys are not cast in the same works in which they are manufactured into semi finished products, **TL** surveyor is to be given a certificate issued by the works in question which indicates the reference numbers and chemical composition of the heats.

Table 8.1 Chemical composition (1)

Grade	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Other elements (2)	
									Each	Total
5083	0.40	0.40	0.10	0.4-1.0	4.0-4.9	0.05-0.25	0.25	0.15	0.05	0.15
5383	0.25	0.25	0.20	07-1.0	4.0-5.2	0.25	0.40	0.15	0.05 **(5)**	0.15 **(5)**
5059	0.45	0.50	0.25	0.6-1.2	5.0-6.0	0.25	0.4-0.9	0.20	0.05 **(6)**	0.15 **(6)**
5086	0.40	0.50	0.10	0.2-0.7	3.5-4.5	0.05-0.25	0.25	0.15	0.05	0.15
5754	0.40	0.40	0.10	0.50 **(3)**	2.6-3.6	0.30 **(3)**	0.20	0.15	0.05	0.15
5456	0.25	0.40	0.10	0.5-1.0	4.7-5.5	0.05-0.20	0.25	0.20	0.05	0.15
6005A	0.5-0.9	0.35	0.30	0.5 **(4)**	0.4-0.7	0.30 **(4)**	0.20	0.10	0.05	0.15
6061	0.4-0.8	0.70	0.15-0.40	0.5	0.8-1.2	0.04-0.35	0.25	0.15	0.05	0.15
6082	0.7-1.3	0.50	0.10	0.4-1.0	0.6-1.2	0.25	0.20	0.10	0.05	0.15

(1) *Composition in percentage mass by mass maximum unless shown as a range or as a minimum.*
(2) *Includes Ni, Ga, V and listed elements for which no specific limit is shown. Regular analysis need not be made.*
(3) *Mn + Cr : 0.10-0.60*
(4) *Mn + Cr : 0.12-0.50*
(5) *Zr : maximum 0.20. The total for other elements does not include Zr.*
(6) *Zr : 0.05-0.25. The total for other elements does not include Zr.*

5. Mechanical Properties

The mechanical properties are to comply with the requirements given in Tables 8.2 and 8.3

Note:
It should be recognized that the mechanical properties of the welded joint are lower for strain hardened or heat treated alloys, when compared with those of the base material, in general. For reference, see the UR for Aluminium consumables(Türk Loydu Rules Chapter 3 Section 5 .J)

6. Freedom of Defects

6.1 The finished material is to have a workmanlike finish and is to be free from internal and surface defects prejudicial to the use of concerned material for the intended application.

6.2 Slight surface imperfections may be removed by smooth grinding or machining as long as the thickness of the material remains within the tolerances given in 7.

7. Tolerances

7.1 The under thickness tolerances for rolled products given in Table 8.4 are minimum requirements. Table 8.4

7.2 The under thickness tolerances for extruded products are to be in accordance with the requirements of recognized international or national standards.

7.3 Dimensional tolerances other than under thickness tolerances are to comply with a recognized national or international standard.

8. Testing and Inspection

8.1 Tensile test

The test specimens and procedures are to be in accordance with Section 2.

8.2 Non-destructive examination

In general, the non-destructive examination of material is not required for acceptance purposes.

Note:
Manufacturers are expected, however, to employ suitable methods of non-destructive examination for the general maintenance of quality standards.

8.3 Dimensions

It is the manufacturer's responsibility to check the materials for compliance with the tolerances given in 7.

8.4 Verification of proper fusion of press welds for closed profiles

8.4.1 The manufacturer has to demonstrate by macro section tests or drift expansion tests of closed profiles performed on each batch of closed profiles that there is no lack of fusion at the press welds.

Table 8.2 Mechanical properties for rolled products, 3 mm ≤ t ≤ 50 mm

Grade	Temper condition (3)	Thickness, t	Yield strength $R_{p0.2}$ min.or range N/mm^2	Tensile strength R_m min. or range N/mm^2	Elongation, % min. (1)	
					A 50 mm	A 5d
5083	O	3 ≤ t ≤ 50 mm	125	275-350	16	14
	H111	3 ≤ t ≤ 50 mm	125	275-350	16	14
	H112	3 ≤ t ≤ 50 mm	125	275	12	10
	H116	3 ≤ t ≤ 50 mm	215	305	10	10
	H321	3 ≤ t ≤ 50 mm	215-295	305-385	12	10
5383	O	3 ≤ t ≤ 50 mm	145	290	-	17
	H111	3 ≤ t ≤ 50 mm	145	290	-	17
	H116	3 ≤ t ≤ 50 mm	220	305	10	10
	H321	3 ≤ t ≤ 50 mm	220	305	10	10
5059	O	3 ≤ t ≤ 50 mm	160	330	24	24
	H111	3 ≤ t ≤ 50 mm	160	330	24	24
	H116	3 ≤ t ≤ 20 mm	270	370	10	10
		20 < t ≤ 50 mm	260	360	-	10
	H321	3 ≤ t ≤ 20 mm	270	370	10	10
		20 < t ≤ 50 mm	260	360	-	10
5086	O	3 ≤ t ≤ 50 mm	95	240-305	16	14
	H111	3 ≤ t ≤ 50 mm	95	240-305	16	14
	H112	3 ≤ t ≤ 12.5 mm	125	250	8	-
		12.5 < t ≤ 50 mm	105	240	-	9
	H116	3 ≤ t ≤ 50 mm	195	275	10 **(2)**	9
5754	O	3 ≤ t ≤ 50 mm	80	190-240	18	17
	H111	3 ≤ t ≤ 50 mm	80	190-240	18	17
5456	O	3 ≤ t ≤ 6.3 mm	130-205	290-365	16	-
		6.3 < t ≤ 50 mm	125-205	285-360	16	14
	H116	3 ≤ t ≤ 30 mm	230	315	10	10
		30 < t ≤ 40 mm	215	305	-	10
		40 < t ≤ 50 mm	200	285	-	10
	H321	3 ≤ t ≤ 12.5 mm	230-315	315-405	12	-
		12.5 < t ≤ 40 mm	215-305	305-385	-	10
		40 < t ≤ 50 mm	200-295	285-370	-	10

(1) *Elongation in 50 mm applies for thicknesses up to and including 12.5 mm and in 5d for thicknesses over 12.5 mm.*
(2) *8 % for thicknesses up to and including 6.3 mm.*
(3) *The mechanical properties for the O and H111 tempers are the same. However, they are separated to discourage dual certification as these tempers represent different processing.*

8.4.2 Drift expansion tests

8.4.2.1 Every fifth profile is to be sampled after final heat treatment. Batches of five profiles or less is to be sampled one profile. Profiles with lengths exceeding 6 m shall be sampled every profile in the start of the production. The number of tests may be reduced to every fifth profile if the results from the first 5 profiles are found acceptable.

8.4.2.2 Each profile sampled will have two samples cut from the front and back end of the production profile.

8.4.2.3 The test specimens are to be cut with the ends perpendicular to the axis of the profile. The edges of the end may be rounded by filling.

8.4.2.4 The length of the specimen is to be in accordance with Section 2.

8.4.2.5 Testing is to be carried out at ambient temperature and is to consist of expanding the end of the profile by means of a hardened conical steel mandrel having an included angle of at least 60˚.

Table 8.3 Mechanical properties for extruded products, 3 mm ≤ t ≤ 50 mm

Grade	Temper	Thickness, t	Yield strength $R_{p0.2}$ min. N/mm^2	Tensile strength R_m min. or range N/mm^2	Elongation, % min. (1) (2)	
					$A_{50\ mm}$	A_{5d}
5083	O	3 ≤ t ≤ 50 mm	110	275-350	14	12
	H111	3 ≤ t ≤ 50 mm	165	275	12	10
	H112	3 ≤ t ≤ 50 mm	110	270	12	10
5383	O	3 ≤ t ≤ 50 mm	145	290	17	17
	H111	3 ≤ t ≤ 50 mm	145	290	17	17
	H112	3 ≤ t ≤ 50 mm	190	310	-	13
5059	H112	3 ≤ t ≤ 50 mm	200	330	-	10
5086	O	3 ≤ t ≤ 50 mm	95	240-315	14	12
	H111	3 ≤ t ≤ 50 mm	145	250	12	10
	H112	3 ≤ t ≤ 50 mm	95	240	12	10
6005A	T5	3 ≤ t ≤ 50 mm	215	260	9	8
	T6	3 ≤ t ≤ 10 mm	215	260	8	6
		10 ≤ t ≤ 50 mm	200	250	8	6
6061	T6	3 ≤ t ≤ 50 mm	240	260	10	8
6082	T5	3 ≤ t ≤ 50 mm	230	270	8	6
	T6	3 ≤ t ≤ 5 mm	250	290	6	-
		5 ≤ t ≤ 50 mm	260	310	10	8

(1) *The values are applicable for longitudinal and transverse tensile test specimens as well*

(2) *Elongation in 50 mm apply for thicknesses up to and including 12.5 mm and in 5d for thicknesses over 12.5 mm.*

Table 8.4 Under thickness tolerances for rolled products

Nominal thickness (t), mm	Thickness tolerances for nominal width (w), mm		
	w ≤ 1500	1500 < w ≤ 2000	2000 < w ≤ 3500
3.0 ≤ t < 4.0	0.10	0.15	0.15
4.0 ≤ t < 8.0	0.20	0.20	0.25
8.0 ≤ t < 12.0	0.25	0.25	0.25
12.0 ≤ t < 20.0	0.35	0.40	0.50
20.0 ≤ t < 50.0	0.45	0.50	0.65

8.4.2.6 The sample is considered to be unacceptable if the sample fails with a clean split along the weld line which confirms lack of fusion.

8.5 Corrosion testing

8.5.1 Rolled 5xxx-alloys of type 5083, 5383, 5059, 5086 and 5456 in the H116 and H321 tempers intended for use in marine hull construction or in marine applications where frequent direct contact with seawater is expected are to be corrosion tested with respect to exfoliation and intergranular corrosion resistance.

8.5.2 The manufacturers are to establish the relationship between microstructure and resistance to corrosion when the above alloys are approved. A reference photomicrograph taken at 500x,under the conditions specified in ASTM B928, Section 9.4.1, is to be established for each of the alloy-tempers and thickness ranges relevant. The reference photographs are to 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 G 66 (ASSET). The samples are 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 G 67 (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 **TL.** Production practices are not to be changed after approval of the reference micrographs.

Other test methods may also be accepted at the discretion of **TL.**

8.5.3 For batch acceptance of 5xxx-alloys, in the H 116 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 is to be prepared for metallographic examination, under the conditions specified in ASTM B928, Section 9.6.1. If this 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 G 66 and G 67 or equivalent standards. Acceptance criteria are that the sample shall exhibit no evidence of exfoliation corrosion and a pitting rating of PB or better when test subjected to ASTM G66 ASSET test, and the sample shall exhibit resistance to intergranular corrosion at a mass loss no greater than 15mg/cm^2 when subjected to ASTM G67 NAMLT test. If the results from testing satisfy the acceptance criteria stated in item 8.5.2 the batch is accepted, else it is to be rejected.

As an alternative to metallographic examination, each batch may be tested for exfoliation-corrosion resistance and intergranular corrosion resistance, in accordance with ASTM G 66 and G 67 under the conditions specified in ASTM B928, or equivalent standards. If this alternative is used, then the results of the test must satisfy the acceptance criteria stated in 8.5.3.

9. Test Material

9.1 Definition of batches

Each batch is made up of products:

- Of the same alloy grade and from the same cast
- Of the same product form and similar dimensions (for plates, the same thickness)
- Manufactured by the same process
- Having been submitted simultaneously to the same temper condition.

9.2 The test samples are to be taken

- At one third of the width from a longitudinal edge of the 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.

9.3 Test samples are to be taken so that the orientation of test specimens is as follows:

9.3.1 Rolled products

Normally, tests in the transverse direction are required. If the width is insufficient to obtain transverse test specimen, or in the case of strain hardening alloys, tests in the longitudinal direction will be permitted.

9.3.2 Extruded products

The extruded products are tested in longitudinal direction.

9.4 After removal of test samples, each test specimen is to be marked in order that its original identity, location and orientation is maintained.

10. Mechanical Test Specimens

The type and location of tensile test specimen are to be in accordance with Section 2.

11. Number of Test Specimens

11.1 Tensile Test

11.1.1 Rolled products

One tensile test specimen is to be taken from each batch of the product. If the weight of one batch exceeds 2000 kg, one extra tensile test specimen is to be taken from every 2000 kg of the product or fraction thereof, in each batch.

For single plates or for coils weighting more than 2000 kg each, only one tensile test specimen per plate or coil is to be taken.

11.1.2 Extruded products

For the products with a nominal weight of less than 1 kg/m, one tensile test specimen is to be taken from each 1000 kg, or fraction thereof, in each batch. For nominal weights between 1 and 5 kg/m, one tensile test specimen is to be taken from each 2000 kg or fraction thereof, in each batch. If the nominal weight exceeds 5 kg/m, one tensile test specimen is to be taken for each 3000 kg of the product or fraction thereof, in each batch.

11.2 Verification of proper fusion of press welds

For closed profiles, verification of proper fusion of press welds is to be performed on each batch as indicated in 8.4.

11.3 Corrosion tests

For rolled plates of grade 5083, 5383, 5059, 5086 and 5456 delivered in the tempers H116 or H321, one sample is to be tested per batch.

12. Retest Procedures

12.1 When the tensile test from the first piece selected in accordance with item 11 fails to meet the requirements, two further tensile tests may be made from the same piece. If both of these additional tests are satisfactory. This piece and the remaining pieces from the same batch may be accepted.

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

12.3 In the event of any material bearing the **TL**'s mark failing to comply with the test requirements, the mark is to be unmistakably defaced by the manufacturer.

13. Branding

13.1 The manufacturer is to mark each product at least one place with the following details:

- Manufacturer's mark,
- Abbreviated designation of aluminium alloy according to item 3,
- Abbreviated designation of temper condition according to item 3,
- Tempers that are corrosion tested in accordance with item 8.5 are to be marked "M" after the temper condition, e.g. 5083 H321 M,
- Number of the manufacturing batch enabling the manufacturing process to be traced back.

13.2 The product is also to bear **TL**'s mark.

13.3 When extruded products are bundled together or packed in crates for delivery, the marking specified in item 13.1 should be affixed by a securely fastened tag or label.

14. Documentation

For each tested batch, the manufacturer must supply to **TL**'s surveyor a test certificate, or a shipping statement containing the following details:

- Purchaser and order number,
- Construction project number, when known,
- Number dimensions and weight of the product,
- Designation of the aluminium alloy (grade) and of its temper condition (delivery heat treatment),
- Chemical composition
- Manufacturing batch number or identifying mark
- Mechanical Test Results.
- Corrosion Test results (if any).

B. Aluminium Alloy Castings

1. Scope

These rules are applicable to aluminium casting alloys which are intended for hull construction, as well as machine construction parts and also other shipbuilding components.

2. Requirements to be Met by Aluminium Foundries

2.1 Foundries wishing to supply castings conforming to these Rules are to be approved by **TL** for the grades of castings concerned. **TL** 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 **TL.**

3. Permitted Grades of Casting

3.1 Suitable grades of castings to international or national standards, e.g. to EN 1706 are generally to be used. Where castings conforming to manufacturer's specifications are to be used, these are to be submitted to **TL** 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, use may be made of the casting alloys conforming to EN 1706 listed in Table 8.5.

Use may be made of other alloys provided these are suitable for the intended application and their use have been approved by **TL.**

4. Requirements

4.1 The chemical composition of the castings is to correspond to the standards or to recognized manufacturer's specifications and is to 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 are to meet the requirements for separately cast sample bars.

Table 8.5 Aluminium alloy castings

Designation of alloy	Cast procedure	Material condition	Sea water suitability
EN AC-41000 (AlSi2MgTi)	S, K	F, TG	Good
EN AC-42100 (AlSi7Mg0.3)	S, K, L	TG, TG4	Good
EN AC-42200 (AlSi7Mg0.6)	S, K, L	TG, TG4	Good
EN AC-43100 (AlSi10Mg(b))	S, K, L	F, TG, TG4	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*
TG = *Solution annealed and completely artificially aged*
TG4 = *Solution annealed and not completely artificially aged-under aged (only for permanent mould casting)*

4.3 All castings are to 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 is to be produced by the manufacturer for this purpose and the approval of the Surveyor sought.

5. Tests

5.1 Castings which 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 is to 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 castings.

5.3 Specimens for tensile testing are normally to 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 are to be subject to special agreement with **TL** 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 is to 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. Branding

As a minimum requirement, the manufacturer is to 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. Documentation

For each delivery, the manufacturer is to 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.

C. Rivets

1. Scope

The requirements of these rules apply to aluminium alloy rivets intended for use in the construction of marine structures.

2. Chemical Composition

2.1 For rivets or rivet bars which are made up of magnesium alloys, the magnesium content is not to exceed a maximum of 3.9%.

In particular, the chemical composition of bars used for the manufacture of rivets is to comply with the requirements of Table 8.6.

Table 8.6 Chemical composition of rivets (%)

Element	5154A	6082
Copper	0.10 max	0.10 max
Magnesium	3.10-3.90	0.60-1.20
Silicon	0.50 max	0.70-1.30
Iron	0.50 max	0.50 max
Manganese	0.10-0.50	0.40-1.00
Zinc	0.20 max	0.20 max
Chromium	0.25 max	0.25 max
Titanium	0.20 max	0.10 max
Other elements: each total	0.05 max 0.15 max	0.05 max 0.15 max
Aluminium	remainder	remainder

3. Heat Treatment

Rivets are to be supplied in the following conditions:
5154A-annealed

6082-solution treated.

4. Test Material

Bars intended for the manufacture of rivets are to be presented for testing in batches of no more than 250 kg.

The material in each batch is to be of the same alloy, manufacturing process and final heat treatment and have the same or a comparable diameter. One test sample is to be taken from each batch and, prior to testing, heat treated in full cross-section and in a manner simulating the heat treatment applied to the finished rivets.

5. Mechanical Tests

5.1 At least one tensile specimen and one flattening test specimen are to be prepared from each test sample.

5.2 The tensile test specimen is to be a short length of bar having the original diameter of the product.

5.3 The flattening test consists of compressing the specimen between two rigid and parallel plates in a direction perpendicular to its longitudinal axis; the plates are to cover the whole specimen after flattening.

The flattening test specimen is to consist of a full section of bar having the original diameter of the product and a length of 1.5 times the diameter cut from the bar.

The test is to be continued until the distance between the two plates, measured under load, reaches a value corresponding to one half of the original length of the specimen.

The test is to be performed at ambient temperature.

The result of the test is satisfactory if, after compression, the specimen is free from cracks.

5.4 The results of tensile tests are to comply with the appropriate requirements of Table 8.7.

5.5 At least three samples are to be selected from each consignment of manufactured rivets. Flattening tests as detailed in 5.3 are to be carried out on each sample.

Table 8.7 Mechanical properties of rivets

Mechanical properties	5154A	6082
0.2% proof stress (N/mm^2) min	90	120
Tensile strength (N/mm^2) min	220	190
Elongation (%) on $5.65\sqrt{So}$ min	18	16

6. Branding

Each package of manufactured rivets is to be identified with attached labels giving the following details:

- Manufacturer's name or trade mark,

- Alloy grade,

- Rivet size.

7. Documentation

The test certificate for each consignment of manufactured rivets is to include the following particulars:

- Purchaser's name and order number,
- Description and dimensions,
- Specification of the alloy.

D. Transition Joints

1. Scope

The requirements of this Article apply to explosion bonded composite aluminium/steel transition joints used for the connection of aluminium structures to steel plating.

2. Manufacturing

Transition joints are to be manufactured at works which are approved by **TL.** The specification of the manufacturer is to be submitted for approval. The maximum temperature allowable at the interface during welding is to be indicated; approval tests are required.

2.2 The aluminium material is to comply with the requirements of A and the steel is to be of an appropriate grade complying with the requirements of Section 3

3. Tests and Inspections

3.1 Each composite plate is to be subjected to 100% visual and ultrasonic examination in accordance with a relevant national standard to determine the extent of any unbounded areas. The latter are unacceptable and any such area plus 25 mm of surrounding sound material is to be discarded.

3.2 The series of tests includes, from each end of one plate in a batch of three plates:

- One through thickness tensile test,
- One shear test,
- One bend test.

3.3 Tests are made on specimens equivalent to those specified at the approval.

The results of these tests are to comply with the requirements of the manufacturing specification.

4. Branding

Each package of manufactured rivets is to be identified with attached labels giving the following details:

Manufacturer's name or trade mark, grade and size of the product.

5. Documentation

The test certificate for each consignment of manufactured transition joints is to include the following particulars:

- Purchaser's name and order number,
- Description and dimensions,
- Specification of the alloy.

SECTION 9

COPPER ALLOYS

Page

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 are to be submitted to **TL** for approval.

2. Requirements to be Met by Pipe Manufacturers

Manufacturers wishing to supply products in accordance with these Rules are to be approved by **TL**.

3. Method of Manufacture

3.1 The pipes are generally to 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 is to be made known to **TL. TL** reserves the right to demand a procedure approval test in these cases.

3.3 Cold-formed pipes and fittings are to 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 are to 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 9.1.

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 9.1.

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 has been confirmed by **TL**.

5. Surface Finish

5.1 Pipes are to have a smooth surface compatible with the method of manufacture. The surface is to 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 are to be those prescribed in EN 12449, see on this also Tables 9.4 to 9.9. Pipe ends are to be cut off at right angles to the pipe axis and are to be free from burrs.

7. Resistance to Leakage

Pipes are not to 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 9.1.

Table 9.1 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**	**Others total**
Cu-DHP	CW024A	min.	99.9**(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**(4)**	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**(4)**	-	0.03	0.5**(4)**	0.2
CuNi30Mn1Fe**(4)**	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
CiUm20A12As	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 applications exposed to seawater : 1.5 ≤ Fe ≤ 1.8.*

(4) *When the product is for subsequent welding applications and so specified by the purchaser, the following maximum limits apply:*
Zinc 0.50%, Lead 0.02%, Phosphorus 0.02%, Sulphur 0.02% and Carbon 0.05%.

8.2 Mechanical properties

The mechanical properties are to conform to the relevant standards. Table 9.2 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 are to 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 are to 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 9.2 in the conditions mentioned in the Table is to 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 are to be grouped into test batches in accordance with Table 9.3.

A test batch is to 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 two or more test specimens are required, they are to be taken from different pipes in the test batch.

Table 9.2 Condition and mechanical properties of pipes made of copper and wrought copper alloys to EN 12449

Material designation	Material condition		Wall thickness t [mm]	Yield strength $R_{p0.2}$ [N/mm^2]	Tensile strength R_m [N/mm^2]	Elongation A_5 [%] min.
Cu-DHP	Soft	R200	≤20	≤110	≥200	40
	Half -hard	R250	≤10	≥150	≥250	20
	Hard **(1)**	R290	≤5	≥250	≥290	5
CuZn20Al2	Annealed	R340	≤10	≥120	≥340	45
CuNi10Fe1Mn	Annealed	R290	≤20	≥90	≥290	30
CuNi30Mn1Fe	Annealed	R370	≤10	≥120	≥370	35
CuNi2Si	Solution annealed	R260	≤10	≥60	≥260	30
	Solution annealed **(1)** and precipitation hardened	R460		≥300	≥460	12
	Solution annealed cold formed	R380		≥260	≥380	6
	Solution annealed cold formed and precipitation hardened	R600		≥480	≥600	8

(1) *Without former annealing, cold forming is not possible.*

If pipes are supplied in rings, a test specimen is to be taken from every fifth ring; if there are less than five rings, however, at least one specimen is to be taken.

Table 9.3 Test batches

Test batch [kg] Over	Up to	No. of specimens for testing according to 9.3 to 9.8
	500	1 each
500	1000	2 each
1000	2000	3 each
2000	3000	4 each
Each subsequent 1000		1 more each

9.2 Test of chemical composition

The manufacturer is to determine the chemical composition of each manufacturing batch and pass this information on to the Surveyor.

9.3 Determination of grain size

In the case of condenser and heat exchanger tubes, the manufacturer is to determine the average grain diameter on at least one specimen from each test batch according to ISO 2624.

9.4 Tensile test

Pipes are to be subjected to tensile test to determine the tensile strength, the 0.2 % proof stress and the elongation.

9.5 Ring flattening test

Pipes are to be submitted to the ring flattening test. The test specimens are to 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 are to 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.

Table 9.4 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 9.8)*
- *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 9.5 Limiting sizes for the wall thickness

Outside diameter (nominal) [mm]		**Limiting sizes for the wall thickness t (nominal)**				
Over	**Up to**	**> 0.3 ≤ 1**	**> 1 ≤ 3**	**> 3 ≤ 6**	**> 6 ≤ 10**	**> 10**
3 **(1)**	40	±15	±13	±11	±10	-
40	120	±15	±13	±12	±11	±10
120	250	-	±13	±13	±12	±11
250	450	-	-	±15	±15	±15
(1) *Including 3.*						

9.7 Testing for absence of internal stresses (CuZn pipes)

The manufacturer is to prove that CuZn alloy pipes are free from internal stresses by carrying out the ammonia test according to DIN 50916-1 or ISO 6957 and 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 is to be rejected. The manufacturer is to 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 are to 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 is to inspect the finish of the inner and outer surfaces of every pipe and also check the diameters and wall thicknesses. The pipes are then to be submitted to the Surveyor for final inspection.

9.10 Tightness test

The manufacturer is to subject all pipes to a tightness test. Preferably, this is to 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 is to be performed. Each pipe is to be subjected for at least 5 s to an inner water pressure, which shall be calculated according to the following formula:

$$p = \frac{2 \cdot S \cdot t}{D}$$

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. may be applied.

Table 9.6 Limiting sizes for fixed lengths of linear pipes

Outside diameter (nominal) [mm]		Limiting sizes for fixed lengths			
Over	**Up to**	**≤ 250**	**> 250 ≤ 1000**	**> 1000 ≤ 4000**	**> 4000**
3 **(1)**	25	+1	+3	+5	Upon agreement
		0	0	0	
25	100	+2	+5	+7	
		0	0	0	
100	450	+3	+5	+10	
		0	0	0	
(1) *Including 3.*					

Table 9.7 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 9.8 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	±0.30	400
6	10	±0.50	600
10	20	±0.70	800
20	30	±0.90	1000
(1) *Including 3.*			

Table 9.9 Straightness tolerance

Ratio of outside diameter / wall thickness [mm]		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 Figure 9.1.*			

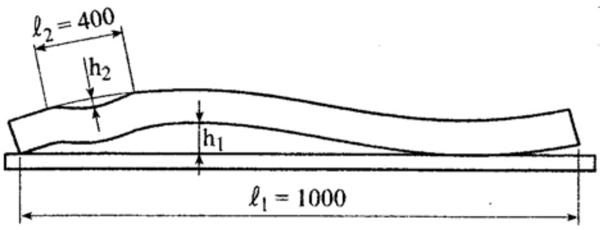


Figure 9.1 Measuring of straightness

10. Marking

10.1 The following marks are to 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

In the case of pipes with an outside diameter < 25 mm, the marking is to be in a form which enables the pipe to be matched up with the test certificate.

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 ≥ 25 mm are to be marked individually.

11. Certificates issued by the manufacturers

For each consignment the manufacturer is to 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 are to be used.

12.2 Approval

Fitting manufacturers are to 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 **TL**.

12.3 Properties

The chemical composition and mechanical properties of the fittings are to correspond to those of the grades of pipe used for their manufacture.

12.4 Testing

If testing is required under the **TL** Rules for Construction, the procedure is to be as follows:

12.4.1 The manufacturer is to 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 are to be grouped into test batches. A test batch is to 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 are to 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 is to 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. Copper Alloy Castings

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 are to be approved by **TL.**

3. Manufacture

The method of manufacture is to 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 are to be suitable for the intended application. Subject to these conditions, the following grades may be used.

4.1 Grades conforming to EN 1982, see Table 9.11 for applications exposed to sea water.

4.2 Grades conforming to other standards or specifications, provided that their suitability has been confirmed by **TL**.

5. Characteristics of Castings

5.1 All castings are to be supplied in a clean fettled condition. They are to 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 are to be submitted to the Surveyor for approval before the repair work begins and the Surveyor is to 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 are to be those specified in the relevant standards. The standards are to be stated in the order and made known to the Surveyor.

7. Resistance to Leakage

Castings subjected to internal pressure by the operating medium are to be tight at the prescribed test pressure.

8. Requirements Applicable to the Material

The chemical composition and mechanical properties are to conform to Table 9.10 and 9.11, the relevant standards or the approved specifications.

9. Testing

The following tests are to be performed:

9.1 Test of chemical composition

The manufacturer is to 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 is to be determined by analyzing the casting.

9.2 Tensile test

For this purpose a specimen is to 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 are to be taken as follows:

9.2.1 In the case of sand and chill casting, the specimens are to be taken from integrally cast sample bars or from separately cast sample pieces. Separately cast sample pieces are to have the dimensions shown in Fig. 9.2, originate from the same heat and are to be cast using the same mould material.

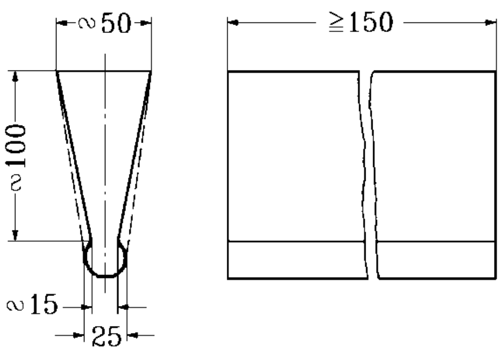


Figure 9.2 Sample piece

9.2.2 In the case of centrifugal and continuous casting, the specimen is to be taken from the cast part.

9.2.3 Where castings are supplied in the heat-treated condition, the test specimen is to be subjected to the same heat treatment.

9.3 Test of surface finish and dimensions

The manufacturer is to inspect each casting with regard to its surface finish and compliance with the dimensional and geometrical tolerances, after which the casting is to be presented to the Surveyor for final inspection.

9.4 Tightness test

Where this is called for in the Rules for Construction, the castings are to be subjected to a hydraulic pressure test in the presence of the Surveyor. Shaft liners are to 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 is to employ a monitoring system which enables all castings to be traced back to their heat. On request, the Surveyor is to be given proof of this.

10.2 Prior to final inspection by the Surveyor, each casting is to 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 is also to be stamped on. In the case of small castings produced in series, e.g. valve housings, the marking are to be in a form which enables the casing to be matched up with the test certificate.

11. Test Certificates

For each consignment the manufacturer is to 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.

Table 9.10 Suitable cast copper alloys

Material designation			Composition [%]																				
TL – 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**
TL-CuAl10Ni	CC333G/	min.	8.5		-			-	76.0	4.0	-	-		4.0		-				-	-		-
(1)	CuAl10Fe5Ni5-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
TL -CuAl11Ni	CC334G/	min.	10.0						72.0	4.0	-	-		4.0		-				-	-		-
(2)	CuAl11Fe6Ni6-C	max.	12.0						82.5	7.0	0.05	2.5		7.5		0.05				0.10	0.2		0.5
TL -CuNi10	CC380H/	min.	-			-			84.5	1.0		1.0	-	9.0		-				-			-
	CuNi10Fe1Mn1-C	max.	0.01			0.10			-	1.8		1.5	1.0	11.0		0.03				0.10			0.5
TL -CuNi30	CC383H/	min.	-	-	-	-	-		Remainder	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
TL -CuSn10	CC480K/	min.	-						88.0	-		-		-	-	-	-	-		-	9.0		-
(3)	CuSn10-C	max.	0.01						90.0	0.2		0.1		2.0	0.20	1.0	0.05	0.2		0.02	11.0		0.5
TL -CuSn12	CC483K/	min.	-						85.0	-		-		-	-	-	-	-		-	11.0		-
(4)	CuSn12-C	max.	0.01						88.5	0.2		0.2		2.0	0.60	0.7	0.05	0.15		0.01	13.0		0.5
TL -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
TL - CuSn5ZnPb	CC491K/	min.	-						83.0	-				-	-	4.0	-	-		-	4.0		4.0
(3)	CuSn5Zn5Pb5-C	max.	0.01						87.0	0.3				2.0	0.10	6.0	0.10	0.25		0.01	6.0		6.0
TL - CuSn7ZnPb	CC493K/	min.	-						81.0	-				-	-	5.0	-	-		-	6.0		2.0
(3), (5)	CuSn7Zn4Pb-7-C	max.	0.01						85.0	0.2				2.0	0.10	8.0	0.10	0.3		0.01	8.0		5.0

(1) *For permanent mould castings minimum iron content shall be 3.0% and minimum nickel content shall be 3.7%.*

(2) *For permanent mould castings minimum iron content shall be 3.0%, and minimum aluminium content shall be 9.0%. In this case maximum copper content shall be 84.5%.*

(3) *Nickel included (For copper).*

(4) *For continuous and centrifuge castings, minimum tin content shall be 10.5% and maximum copper content shall be 89%.*

(5) *For continuous and centrifuge castings minimum tin content shall be 5.2%, maximum copper content shall be 86%.*

Table 9.11 Mechanical properties of cast copper alloys acc. to 4.1

TL material code	Condition of supply	Proof stress $R_{p0.2}$ [N/mm^2] min.	Tensile strength R_m [N/mm^2] min.	Elongation A_5 [%] min.	Hardness HB 10 min.
TL-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
TL-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
TL-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
TL-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
TL-CuSn12Ni	Sand cast	160	280	14	90
	Centrifugally cast	180	300	8	100
	Continuously cast	180	300	10	95
TL-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
TL-CuAl11Ni	Sand cast	320	680	5	170
	Permanent mould cast	400	750	5	200
	Centrifugally cast	400	750	5	185
TL-CuCuNi10	Sand cast	150	310	20	100
	Centrifugally cast	100	280	25	70
	Continuously cast	100	280	25	70
TL-CuNi30	Sand cast	230	440	18	115

SECTION 10

MATERIALS FOR EQUIPMENT

A. Anchors

1. General Requirements

1.1 Scope

These rules apply to the materials, manufacture, testing and certification of anchors, shanks and anchor shackles produced from cast or forged steel, or fabricated by welded rolled steel plate and bars.

1.2 Types of Anchor

The types of anchor covered include:

- Ordinary anchors (Refer to UR A1.4.1.1)
  - Stockless anchors
  - Stocked anchors
- HHP (high holding power) anchors(Refer to UR A1.4.1.2)
- SHHP (Super high holding power) anchors, not exceeding 1500 kg in mass. (Refer to UR A1.4.1.3)

Any changes to the design made during manufacture are to have prior written agreement from **TL.**

2. Design

2.1 The design of the anchors is to be approved by **TL**.

To this end, the anchor manufacturer is to submit to **TL** 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).

2.2 Connecting components, such as shackles and swivel shackles are to be designed to withstand at least the test loads of the appropriate anchors.

2.3 Anchors with HHP anchors may only be used in conjunction with TL-K2 or TL-K3 chains and those with SHHP anchors only in conjunction with TL-K3 chains.

2.4 HHP anchors and SHHP anchors and also swivel shackles which are regarded as part of the anchor are to be subjected to a type test in the presence of the Surveyor. In the case of swivel shackles, the proof and breaking loads are to also be demonstrated in accordance with Table 10.8.

3. Materials

3.1 Materials for anchors

All anchors are to be manufactured from materials meeting the requirements indicated below.

3.1.1 Cast steel anchor flukes, shanks, swivels and shackles are to be manufacture and tested in accordance with the requirements of Section 6 and comply with the requirements for castings for welded construction. The steel is to be fine grain treated with aluminium. If test program B is selected in item 6.3, then Charpy V notch impact testing of cast material is required. Special consideration is to be given to the use of other grades of steels for the manufacture of swivels.

3.1.2 Forged steel anchor pins, shanks, swivels and shackles are to be manufactured and tested in accordance with the requirements of Section 5. Shanks, swivels and shackles are to comply with the requirements for carbon and carbon-manganese steels for welded construction. Special consideration is to be given to the use of other grades of steels for the manufacture of swivels.

3.1.3 Rolled billets, plate and bar for fabricated steel anchors are to be manufactured and tested in accordance with the requirements of Section 3, B.

3.1.4 Rolled bar intended for pins, swivels and shackles are to be manufactured and tested in accordance with the requirements of Section 3, B or Section 5.

3.2 Materials for SHHP anchors

The base steel grades in welded SHHP anchors are to be selected with respect to the material grade requirements for Class II in Chapter 1, Hull, Section 3, Table 3.2. The welding consumables are to meet the toughness for the base steel grades in accordance with Chapter 3, Welding, Section 5 and Section 12 E.

In addition to the requirements of 3.1, SHHP anchors are to be produced in accordance with the material toughness requirements mentioned below(Refer to UR A1.4.4):

The toughness of the anchor shackles for SHHP anchors is to meet that for grade TL-K3 anchor chain. The toughness of steel castings for SHHP anchors is to be not less than a Charpy V-notch energy average of 27 J at 0ºC.

4. Testing of Materials

4.1 For all anchor components, the anchor manufacturer is to 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.

4.2 All cast steel parts are to be subjected, in the presence of the Surveyor, to a material test as set out in Section 6.

4.3 Contrary to Section 6, A.9.2.3 the dimensions of integrally cast specimens are to be adjusted to the determining wall thickness as described in the following

4.4 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

4.5 If anchors are made from forged parts, these are to be subjected to a material test in the presence of the Surveyor.

5. Manufacture of Anchors

5.1 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 tons weight, 4 mm for anchors up to 5 tons weight, 6 mm for anchors up to 7 tons 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 pind 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 Figure 10.1.

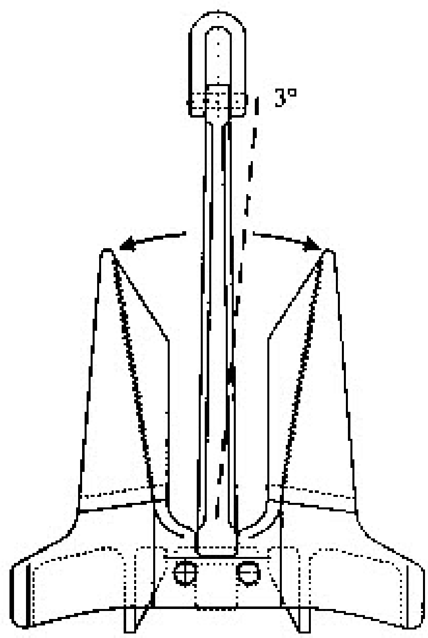


Figure 10.1 Allowable lateral movement of shank

5.2 Welding of anchors

Welded construction of fabricated anchors is to be done in accordance with procedures approved by **TL.** Welding is to be carried out by qualified welders, following the approved welding procedures(Refer to IACS UR W28 ,Türk Loydu Welding Rules Section 12 F and Section 4) using consumables manufactured in accordance with the requirements of Product tests(see 6.3). NDT is to be carried out in accordance with the requirements of 6.3 product tests.

5.3 Heat treatment

Components for cast or forged anchors are tp properly heat treated, fully annealed, normalised or normalised and tempered in accordance with Sections 5 (IACS UR W7) and 6 (IACS UR W8).

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.

5.4 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.

5.5 Repairs

Any necessary repairs to forged and cast anchors are to be agreed by the surveyor and carried out in accordance with the repair criteria indicated in Sections 5 and 6. Repairs to fabricated anchors are to be agreed by the surveyor and carried out in accordance with weld procedures, by qualified welders, following the parameters of the welding procedures used in construction.

5.6 Anchor assembly

Assembly and fitting are to be done in accordance with the design details.

Securing of the anchor pin, shackle pin or swivel nut by welding is to be done in accordance with an approved procedure.

6. Testing and Certification of Anchors

Proof load tests are to be carried out by an approved testing facility.

Proof load testing for Ordinary, HHP and SHHP anchors is to be carried out in accordance with the pertinent requirements of UR A1.4.3.

6.1 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.

6.2 Load test

6.2.1 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 10.1 using a calibrated testing machine approved by **TL**.

6.2.2 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 **TL**.

6.2.3 The test load is to 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.

Table 10.1 Test loads for anchors (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	49.0	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, SHHPanchors and mooring anchors, the weight stated in the table is to be multiplied by the factors given in.6.2.4.*

6.2.4 The following anchor weights are to be applied in establishing the test loads in accordance with Table 10.1:

- 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 SHHP (VHHP): a weight equal to 2.0 times the actual weight of the anchor;
- Mooring anchors: weight equal to 1.33 times the actual weight, unless specified otherwise.

6.2.5 After the load test, anchors are to be submitted to the Surveyor for verification of their delivery condition. Verification comprises visual inspection according to 6.3 as well as surface crack testing. In case of anchors of composite construction the freedom of movement of the arms is to be demonstrated.

6.3 Product tests

6.3.1 Product test programs

TL can request that either program A or program B be applied (see Table 10.2 and 10.3).

Table 10.2 Applicable programs for each product form

Product test	Product form		
	Cast components	Forged components	Fabricated/ welded components
Prog. A	Applicable	Not applicable	Not applicable
Prog. B	Applicable **(1)**	Applicable	Applicable

(1) *Charpy V-notch impact tests are to be carried out to demonstrate at least 27 J average at 0ºC.*

6.3.2 Drop test

Each anchor fluke and shank is individually raised to a height of 4 m and dropped on to a steel slab without fracturing. The steel slab is to be suitable to resist the impact of the dropped component.

Table 10.3 Product test requirements for program A and B

Program A	Program B
Drop test	-
Hammering test	-
Visual inspection	Visual inspection
General NDT	General NDT
-	Extended NDT

6.3.3 Hammering test

After a drop test, hammering tests are carried out on each anchor fluke and shank, which is slung clear of the ground, using a non-metallic sling, and hammered to check the soundness of the component. A hammer of at least 3 kg mass is to be used.

6.3.4 Visual inspection

After proof loading visual inspection of all accessible surfaces is to be carried out.

6.3.5 General non-destructive test

After proof loading general NDT is to be carried out as indicated in the Tables 10.4 and 10.5.

Table 10.4 General NDT for ordinary and HHP anchors

Location	Method of NDT
Feeders of castings	PT or MT
Risers of castings	PT or MT
Weld repairs	PT or MT
Forged components	Not required
Fabrication welds	PT or MT

Table 10.5 General NDT for SHHP 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
Weld repairs	PT or MT
Forged components	Not required
Fabrication welds	PT or MT

Note:
IACS recommendation No:69 "Guidelines for NDT of marine steel casting" is regarded as example of an acceptable standard for surface and volumetric examination

6.3.6 Extended non-destructive test

After proof loading general NDT is to be carried out as indicated in Table 10.6.

Table 10.6 Extended NDT for ordinary, HHP and SHHP 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

Note:

IACS recommendation No:69 "Guidelines for NDT of marine steel casting" is regarded as example of an acceptable standard for surface and volumetric examination.

6.3.7 Repair criteria

If defects are detected by NDT, repairs are to be carried out in accordance with 5.5. For fracture and unsoundness detected in a drop test or hammering test, repairs are not permitted and the component is to be rejected.

6.4 Mass and dimensional inspection

Unless otherwise agreed, the verification of mass and dimensions is the responsibility of the manufacturer. The surveyor is only required to monitor this inspection. The mass of the anchor is to exclude the mass of the swivel, unless this is an integral component.

6.5 Retests

Mechanical retests are permitted in accordance with the requirements of Section 2.

7. Marking

Anchors which meet the requirements are to be stamped on the shank and the fluke. The markings on the shank are to be approximately level with the fluke tips. On the fluke, these markings are to be approximately at a distance of two thirds from the tip of the bill to the centre line of the crown on the right hand fluke looking from the crown towards the shank. The markings are to included:

- Mass of anchor
- Identification, e.g. test no or certification no.
- **TL**'s stamp
- Manufacturer's mark

Additionally the unique cast identification is to be cast on the shank and the fluke.

8. Certification

Anchors which meet the requirements are to be certified by **TL** at least with the following items:

- Manufacturer's name
- Type
- Mass
- Fluke and shank identification numbers
- Grade of materials
- Proof test loads
- Heat treatment
- Marking applied to anchor.

9. Painting

All types of anchor are not to be painted until all tests and inspections have been completed.

B. Anchor Chain Cables and Accessories

1. General Requirements

1. 1 Scope

These Rules apply to the materials, design, manufacture and testing of stud link chain cables and accessories used for ships. Where, in exceptional cases, studless short-linked chain cables are used with **TL**'s approval, they must comply with recognized national or international standard. For connecting components fixed to the anchor, A. is applicable.

The requirements for chafing chain for Emergency Towing Arrangements (ETA) are given in the B.6

1.2 Chain cable grades

Depending on the nominal tensile strength of the steel used to manufacture the chain cable, stud link chain cables are classified into the grades TL-K1, TL-K2 and TL-K3.

1.3 Approval of chain cable manufacturers

1.3.1 Anchor chain cables and accessories may only be manufactured by works approved by **TL**. For this purpose approval tests are to be carried out, the scope of which is to be agreed with **TL.**

1.3.2 Applications for approval are to be made to **TL**, stating the method of manufacture used, the grades of materials, the nominal dimensions and, where applicable, the material specification. A procedure test carried out on a high-strength chain cable may cover approval of lesser grades, provided that the material type, method of manufacture and the nature of the heat treatment are the same.

2. Materials

2.1 Scope

These Rules apply to rolled steels, forgings and cast steels for the manufacture of anchor chain cables and accessories.

2.2 Requirements for material manufacturers

2.2.1 All materials used for the manufacture of anchor chain cables and accessories may only be supplied by manufacturers approved by **TL**.

TL approval is not required for grade TL-K1 steel bars.

Material suppliers or chain cable manufacturers are to submit specifications for Grade 3 steel bars. These specifications should contain all necessary details, such as manufacturing procedure, deoxydation practice, specified chemical composition, heat treatment and mechanical properties.

2.3 Rolled steel bars

2.3.1 Condition of supply

Unless otherwise specified, the steel bars are to be supplied in as rolled condition.

2.3.2 Chemical composition

The chemical composition of the steel bars is to conform to the data in Table 10.7.

Rolled steel bars are to be supplied with a certificate of the manufacturer about the chemical composition of each heat.

2.3.3 Mechanical tests

2.3.3.1 Mechanical tests representing the steel bars are normally to be carried out by the steel mill, and the results are to meet the requirements in Table 10.8. The test coupons are to be in a heat treatment condition equivalent to that of the finished chain cable and accessories.

2.3.3.2 For performance of the mechanical tests the steel bars are to be sorted according to heats and diameters into test units not exceeding 50 tons each.

From each test unit a test sample is to be taken for the tests mentioned in 2.3.3.4 and 2.3.3.5. Prior to sampling, the test samples must be subjected to the heat treatment provided for the finished chain cable.

Details of the heat treatment must be indicated by the chain cable manufacturer.

2.3.3.3 Tensile and Charpy V-notch impact test specimens are to be taken from the test sample in the longitudinal direction at a distance of 1/6 diameter from the surface or as close as possible to this position, as shown in Figure 10.2.

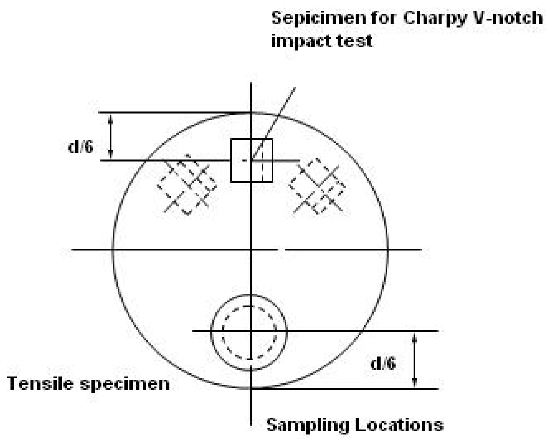


Figure 10.2 Sampling locations

2.3.3.4 For the tensile test, one specimen is to be taken from each test unit and tested, all in accordance with Section 2.

2.3.3.5 One set of longitudinal Charpy V-notch test specimens is to be taken from each test unit and tested at the temperature prescribed in Table 10.7, all in accordance with Section 2. The specimen transverse axis is to be radial to the steel bar. The average value obtained from one set of three impact specimens is to comply with the requirements given in Table 10.7. One individual value only may be below the specified average value provided it is not less than 70 % of that value.

2.3.3.6 Re-test requirements for tensile tests are to be in accordance with Section 2 with the specimens taken drom the same sample. Failure to meet the specified requirements of either both additional tests will result in rejection of the test unit represented unless it can be clearly attributable to improper simulated heat treatment (See 2.3.3.8).

2.3.3.7 Re-test requirements for charpy impact tests are to be in accordance with Section 2. Specimens are to be selected from the same sample. Failure to meet the requirements will result in rejection of the test unit represented unless it can be clearly attributable to improper simulated heat treatment (See 2.3.3.8).

2.3.3.8 If failure to pass the tensile test or the Charpy V-notch impact test is definitely attributable to improper heat treatment of the test sample, a new test sample may be taken from the same piece and reheat treated. The complete test (both tensile and impact test) is to be repeated, and the original results obtained may be disregarded.

2.3.4 Dimensional tolerances

The diameter and oval shape of rolled steels shall lie within the permitted dimensional tolerances shown in Table 10.9, unless otherwise agreed.

2.3.5 Freedom from defects

The materials are to 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

2.3.6 Identification of material

The manufacturers are to have an identification system which enables the material to be traced back to its manufacture.

Table 10.7 Chemical composition of rolled steel bars

Grade	Chemical composition in maximum percent, unless specified					
	C	Si	Mn	P	S	Al_{tot} (1) min.
TL-K1	0.20	0.15-0.35	min. 0.40	0.040	0.040	--
TL-K2 **(2)**	0.24	0.15-0.55	max. 1.60	0.035	0.035	0.020
TL-K3 **(3)**	According to the approved specification					

(1) *Aluminium may be partly replaced by other grain refining elements.*
(2) *With TL approval, additional alloying constituents may be added*
(3) *To be killed and fine grain.*

Table 10.8 Mechanical properties of chain cable materials

Grade	R_{eH} [N/mm^2] min.	R_m [N/mm^2]	A_5 [%] min.	Z [%] min.	Charpy V-notch impact test	
					Test temperature [°C]	KV (1) [J] Min.
TL-K1	--	370-490	25	-	--	-
TL-K2	295	490-690	22	-	0	27 **(1)**
TL-K3	410	min. 690	17	40	0 **(2)** (-20)	60 (35)

(1) *The impact test of Grade TL-K2 materials may be waived, if the chain cable is to be supplied in a heat treated condition as per Table 10.12.*

(2) *Testing is normally to be carried out at 0ºC.*

Table 10.9 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	3.00

Table 10.10 Condition of supply of chain cables and accessories

Grade	Chain cables	Accessories
TL-K1	As welded or normalized	Not applicable
TL-K2	As welded or normalized **(1)**	Normalized
TL-K3	Normalized, normalized and tempered or quenched and tempered	Normalized, normalized and tempered or quenched and tempered

(1) *Grade TL-K2 chain cables made by forgings or castings are to be supplied in the normalized condition.*

2.3.7 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.

2.3.8 Material certification

Bar material for Grade TL-K2 or TL-K3 is to be certified by **TL.** For each consignment manufacturers are to forward to the surveyor a certificate containing at least the following data:

- Manufacturer's name and/or purchaser's order number,

- Number and dimensions of bars and weight of consignment,

- Steel specification and chain grade,

- Heat number,

- Manufacturing procedure,

- Chemical composition,

- Details of heat treatment of the test sample (where applicable),

- Results of mechanical tests (where applicable),

- Number of test specimens (where applicable).

2.4 Forged steels for chain cables and accessories

2.4.1 General requirements

Forgings intended for the manufacture of chain cables and accessories are to satisfy the requirements specified in Section 5, unless otherwise prescribed below.

2.4.2 Chemical composition

The chemical composition is to comply with the specification approved by **TL**. The steel manufacturer must determine and certify the chemical composition of every heat.

2.4.3 Heat treatment

The stock material may be supplied in the as-rolled condition. Finished forgings are to be properly heat treated, i.e. normalized, normalized and tempered or quenched and tempered, whichever is specified for the relevant steel grade in Table 10.10.

2.5 Cast steels for chain cables and accessories

2.5.1 General requirements

Steel castings intended for the manufacture of chain cables and accessories are to satisfy the requirements specified in Section 6, unless otherwise prescribed below.

2.5.2 Chemical composition

The chemical composition is to comply with the specification approved by **TL**. The foundry must determine and certify the chemical composition of every heat.

2.5.3 Heat treatment

All steel castings are to be properly heat treated, i.e. normalized, normalized and tempered or quenched and tempered, whichever is specified for the relevant steel grade in Table 10.10.

2.6 Material for studs

The studs of chain links are to be made of a type of steel which correspond to the chain cable or of unalloyed rolled, forged or cast mild steels. The use of other materials such as grey or nodular cast iron is not permitted.

3. Design and Manufacture of Chain Cables and Accessories

3.1 Design

Chain cables must be designed according to a standard recognized by **TL,** such as ISO 1704. A length of chain cable must comprise an odd number of links. Where designs do not comply with this and where accessories are of welded construction, drawings giving full details of the design, the manufacturing process and heat treatment are to be submitted to **TL** for approval.

3.2 Dimensions and dimensional tolerances

3.2.1 The shape and proportion of links and accessories must conform to a recognized standard, such as ISO 1704 or the designs specially approved.

3.2.2 The following tolerances are applicable to links:

3.2.2.1 Diameter measured at the crown (two measurements are to be taken at the same location; one in the plane of the link –see dp in Figure 10.3- and one perpendicular to the plane of the link):

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 cross sectional area of the crown must have no negative tolerance.

3.2.2.2 Diameter measured at locations other than the crown:
The diameter is to have no negative tolerance. The plus tolerance may be up to 5% of the nominal diameter. The approved manufacturer's specification is applicable to the plus tolerance of the diameter at the flush-butt weld.

3.2.2.3 The maximum allowable tolerance on assembly measured over a length of 5 links may equal + 2.5%, but may not be negative (measured with the chain under tension after proof load test).

3.2.2.4 All other dimensions are subject to a manufacturing tolerance of ± 2.5%, provided always that all of the final link parts of the chain cable fit together properly.

3.2.2.5 Studs must be located in the links centrally and at right angles to the sides of the link, although the studs at each end of any length may also be located off-centre to facilitate the insertion of the joining shackle. The following tolerances are regarded as being inherent in the method of manufacture and will not be objected to provided that the stud fits snugly and its end lie practically flush against the inside of the link.

Maximum off-centre distance "X"	:10% of the nominal diameter d
Maximum deviation "α" from the 90° - position	: 4°

The tolerances are to be measured in accordance with Figure 10.3

3.2.3 The following tolerances are applicable to accessories:

Nominal diameter	: + 5 %, - 0 %
Other dimansions	: ± 2.5 %.

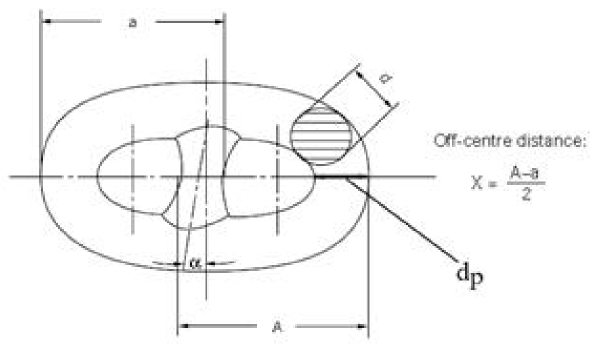


Figure 10.3 Manufacturing tolerances

3.3 Manufacturing process

3.3.1 Stud link chain cables should preferably be manufactured by flush butt welding using Grade TL-K1, TL-K2 or TL-K3 bar material. Manufacture of the links by drop forging or castings is permitted. On request, pressure butt welding may also be approved for studless, Grade TL-K1 and TL-K2 chain cables, provided that the nominal diameter of the chain cable does not exceed 26 mm.

3.3.2 Accessories such as shackles, swivels and swivel shackles are to be forged or cast in steel of at least Grade TL-K2. The welded construction of these parts may also be approved.

3.4 Welding of studs

The welding of studs is to be in accordance with an approved procedure subject to the following conditions:

3.4.1 The studs must be of weldable steel (See B. 2.6).

3.4.2 The studs are to be welded at one end only, i.e. opposite to the weldment of the link. The stud ends must fit the inside of the link without appreciable gap.

3.4.3 The welds, preferably in the horizontal position, are to be executed by qualified welders using suitable welding consumables.

3.4.4 All welds must be carried out before the final heat treatment of the chain cable,

3.4.5 The welds must be free from defects liable to impair the proper use of the chain. Under-cuts, end craters and similar defects are, where necessary to be ground off.

TL reserves the right to call for a procedure test for the welding of chain studs.

3.5 Heat treatment

According to the grade of steel, chain cables and accessories are to be supplied in one of the conditions specified in Table 10.10. The heat treatment is, in every case, to be performed before the proof load test, the breaking load test, and all mechanical testing. The mechanical properties of finished chain cables and accessories are to be in accordance with Table 10.13.

3.6 Freedom from defects

3.6.1 All individual parts must have a clean surface consistent with the method of manufacture and be free from cracks, norches, inclusions and other defects impairing the performance of the product. The flashes produced by upsetting or drop forging must properly be removed.

3.6.2 Minor surface defects may be ground off so as to leave a gentle transition to the surrounding surface. Remote from the crown local grinding up to 5% of the nominal link diameter may be permitted.

4. Testing and Certification of Finished Chain Cables

4.1 Proof and breaking load tests

4.1.1 Finished chain cables are to be subjected to the proof load test and the breaking load test in the presence of the surveyor, and shall not fracture or exhibit cracking. Special attention is to be given to the visual inspection of the flash-butt weld if present. For this purpose, the chain cables must be free from paint and anti-corrosion media.

4.1.2 Each chain cable length (27.5 m) is to be subjected to a loading test at the proof load appropriate to the particular chain cable as given by Table 10.11 and using an approved testing machine.

4.1.3 For the breaking load test, one sample comprising at least of three linksis to be taken from every four lengths or fraction of chain cables and tested at the breaking loads given by Table 10.11. The breaking load is to be maintained for a minimum of 30 seconds. The links concerned shall be made in a single manufacturing cycle together with the chain cable and must be welded and heat treated together with it. Only after this issue, they may be separated from the chain cable in the presence of the surveyor.

Table 10.11 Proof and breaking loads for stud link chain cables

Chain diameter [mm]	Grade TL-K1		Grade TL-K2		Grade TL-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	3.40
14	58	82	82	116	116	165	4.30
16	76	107	107	150	150	216	5.60
17.5	89	127	127	179	179	256	6.70
19	105	150	150	211	211	301	7.90
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
44	538	769	769	1080	1080	1540	42.4
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

(1) *For footnotes, see end of table.*

Table 10.11 Proof and breaking loads for stud link chain cables (continued)

Chain diameter [mm]	Grade TL-K1		Grade TL-K2		Grade TL-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
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	219.0
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	326.0
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	411.0
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	506.0
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).*

4.1.4 If the tensile loading capacity of the testing machine is insufficient to apply the breaking load for chain cables of larger diameter, another equivalent testing method is to be agreed with **TL.**

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 is to be considered successful if the requirements are then satisfied.

If the retest fails, the length of chain cable concerned is to be rejected. If the manufacturer so wishes, the remaining three lengths belonging to the unit test quality may then be individually subjected to test at the breaking load. If one such test fails to meet the requirements, the entire unit test quantity is rejected.

4.2.2 Should a proof load test fail, the defective link(s) is (are) to be replaced. A local heat treatment to be carried out on the new link(s) and the proof load test is to be repeated. In addition, an investigation is to be made to identify the cause of the failure.

4.3 Mechanical tests on grade TL-K2 and TL-K3 chain cable

4.3.1 For Grade TL-K2 and TL-K3 chain cables, mechanical test specimens required in Table 10.12 are to be taken from every four lengths in accordance with 4.3.2. For forged or cast chain cables where the batch size is less than four lengths, the sampling frequency will be by heat and heat treatment charge. Mechanical tests are to be carried out in the presence of the surveyor. For the location of the test specimens see 2.3.3.3 and Figure 10.2. Testing is to follow 2.3.3.4 and 2.3.3.5. Retesting is to follow 2.3.3.6 and 2.3.3.7.

4.3.2 An additional link (or where the links are small, several links) for mechanical test specimen removal is (are) to be provided in a length of chain cable not containing the specimen for the breaking test. The specimen link must be manufactured and heat treated together with the length of chain cable.

4.3.3 The mechanical properties must be in accordance with the values indicated in Table 10.13.

4.4 Marking

Chain cables which have met the requirements are to be stamped on both end links of each length of chain cable with the following identifying marks, see Fig. 10.4:

- Grade of chain cable,
- Certificate number,
- Surveyor's stamp,
- Month and year of test

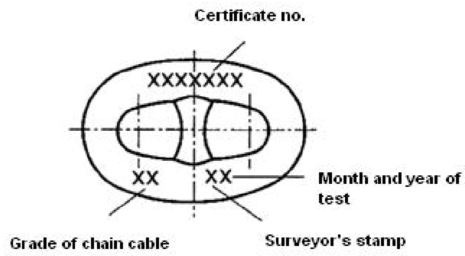


Figure 10.4 Marking of chain cables

4.5 Certification

Chain cables which meet the requirements are to be certified by **TL** at least with the following items:

- Manufacturer’s name,
- Grade,
- Chemical composition (including total aluminium content),
- Nominal diameter/weight,
- Proof/break loads,
- Heat treatment,
- Marks applied to chain,
- Length,
- Mechanical properties, where applicable.

Table 10.12 Number of mechanical test specimens for finished chain cables and accessories

Grade	Manufacturing method	Condition of supply (1)	Number of test specimens		
			Tensile test for base metal	Charpy V-notch impact test	
				Base metal	Weldment
TL-K1	Flush-butt welded	AW N	NR	NR	NR
TL-K2	Flush-butt welded	AW	1	3	3
		N	NR	NR	NR
	Forged or cast	N	1	3 **(2)**	NA
TL-K3	Flush-butt welded	N NT QT	1	3	3
	Forged or cast	N NT QT	1	3	NA

(1) *AW= As welded, N=Normalized, NT=Normalized and tempered, QT=Quenched and tempered*

(2) *For chain cables, Charpy V-notch impact test is not required.*

NR= Not required

NA= Not applicable

Table 10.13 Mechanical properties of finished chain cables and accessories

Grade	R_{eH} N/mm^2 min.	R_m N/mm^2	A_5 % min.	Z % min.	Charpy V-notch impact test		
					Test temp. ° C	Absorbed energy, J, min.	
						Base metal	Weldment
1	NR	NR	NR	NR	NR	NR	NR
2	295	490-690	22	NR	0	27	27
3	410	690 min.	17	40	0 **(1)** -20	60 35	50 27

(1) *Testing is normally to be carried out at 0 ° C.*

NR= Not required.

5. Testing and Certification of Accessories

5.1 Proof load test

All accessories are to be subjected to the proof load test at the proof load specified for the corresponding chain given by Table 10.11 and in accordance with the provisions of 4.1, as appropriate.

5.2 Breaking load test

5.2.1 From each manufacturing batch (same accessory type, grade, size and heat treatment charge, but not necessarily representative of each heat of steel or individual purchase order) of 25 units or less of detachable links, shackles, swivels, swivel shackles, enlarged links, and end links, and from each manufacturing batch of 50 units or less of kenter shackles, one unit is to be subjected to the breaking load test at the break load specified for the corresponding chain given by Table 10.11 and in accordance with the provisions 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.

5.2.2 **TL** may waive the breaking load test, if:

5.2.2.1 The breaking load has been demonstrated on the occasion of the approval testing of parts of the same design, and

5.2.2.2 The mechanical properties of each manufacturing batch are proved, and

5.2.2.3 The parts are subjected to suitable non-destructive testing.

5.2.3 Notwithstanding the above, the accessories, which have been successfully tested at the prescribed breaking load appropriate to the chain, may be used in service at the discretion of **TL** where the accessories are manufactured with the following:

5.2.3.1 The material having higher strength characteristics than those specified for the part in question (e.g. Grade TL-K3 material for accessories for Grade TL-K2 chain).

5.2.3.2 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.

5.3 Mechanical properties and tests

Unless otherwise specified, the forging or casting must at least comply with the mechanical properties given in Table 10.13, when properly heat treated. For test sampling, forgings or castings of similar dimensions originating from the same heat treatment charge and the same heat of steel are to be combined into one test unit. Mechanical tests are to be carried out in the presence of the surveyoe depending on the type and grade of material used. From each test unit, one tensile test specimen and three Charpy V-notch impact test specimens are to be taken in accordance with Table 10.12 and tested in accordance with Section 2. For the location of the test specimens see 2.3.3.3 and Figure 10.2. Testing is to follow 2.3.3.4 and 2.3.3.5. Retesting is to follow 2.3.3.6 and 2.3.3.7. Enlarged links and end links need not be tested provided that they are manufactured and heat treated together with the chain cable.

5.4 Marking

Accessories which meet the requirements are to be stamped as follows:

- Chain cable grade,
- Certificate number,
- Surveyor's stamp,
- Month and year of test.

5.5 Certification

Chain accessories which meet the requirements are to be certified by **TL** at least with the following items:

- Manufacturer’s name,
- Grade,
- Heat number,
- Chemical composition (including total aluminium content),
- Nominal diameter/weight,
- Proof/break loads,
- Heat treatment,
- Marks applied to accessories,
- Mechanical properties, where applicable.

6. Chafing Chains for Emergency Towing Arrangements

6.1 Scope

These requirements apply to the chafing chains for chafing gear of two types of emergency towing arrangements (ETA) 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 **TL**.

6.2 Approval of manufacturing

The chafing chain is to be manufactured by works approved by **TL (See B.18.1.3).**

6.3 Materials

The materials used for the manufacture of the chafing chain are to satisfy the requirements mentioned herein.

6.4 Design, manufacture, testing and certification of chafing chain

6.4.1 The chafing chain is to be designed, manufactured, tested and certified in accordance with the requirements B.3 to B.5.

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. 10.5.

6.4.3 The common link is to be of stud link type grade TL-K2 or TL-K3.

6.4.4 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 10.14.

Table 10.14 Nominal diameter of common link

Type of ETA	Nominal diameter of common link, d min.	
	Grade TL-K 2	Grade TL-K3
ETA 1000	62 mm	52 mm
ETA 2000	90 mm	76 mm

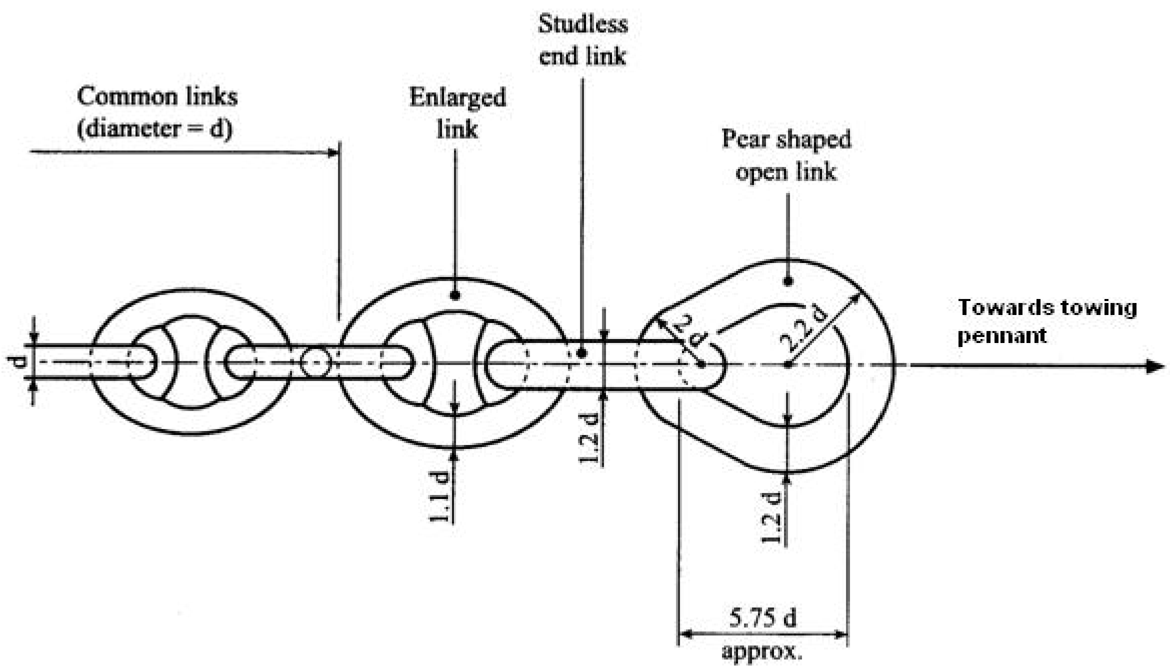


Figure 10.5 Typical outboard chafing chain end

C. Offshore Mooring Chains and Accessories

1. General Requirements

1.1 Scope

1.1.1 These rules apply to the materials, design, manufacturing and testing of offshore mooring chains 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, 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 C.6

1.2 Chain grades

1.2.1 Depending on the nominal tensile strength of the steels used for manufacture, chains are to subdivided into five grades, i.e.: TL-R3, TL-R3S, TL-R4, TL-R4S and TL-R5.

1.2.2 Manufacturers propriety specifications for R4S and R5 may vary subject to design conditions and the acceptance of **TL.**

1.2.3 Each grade is to be individually approved. Approval for a higher grade does not constitute approval of a lower grade.

1.3 Approval of chain manufacturers

1.3.1 Offshore mooring chain are to be manufactured only by works approved by **TL**. 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 process:

1.3.2.1 Bar heating and bending including method, temperatures, temperature control and recording.

1.3.2.2 Flash welding including current, force, time and dimensional variables as well as control and recording of parameters.

1.3.2.3 Flash removal including method and inspection.

1.3.2.4 Stud insertion method, for stud link chain.

1.3.2.5 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.

1.3.2.6 Proof and break loading including method/machine, means of horizontal support (if applicable), method of measurement and recording.

1.3.2.7 Non-destructive examination procedures.

1.3.2.8 The manufacturer's surface quality requirement of mooring components is to be submitted.

1.3.3 For initial approval CTOD (Crack Tip Opening Displacement) 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 EN ISO 12737 and 15653. The CTOD test piece is to be a standard 2 x 1 single edge notched bend piece, test location as shown in Figure 10.6. The minimum test piece size shall be 50 x 25mm 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 20ºC and meet the minimum values indicated below, Table 10.15.

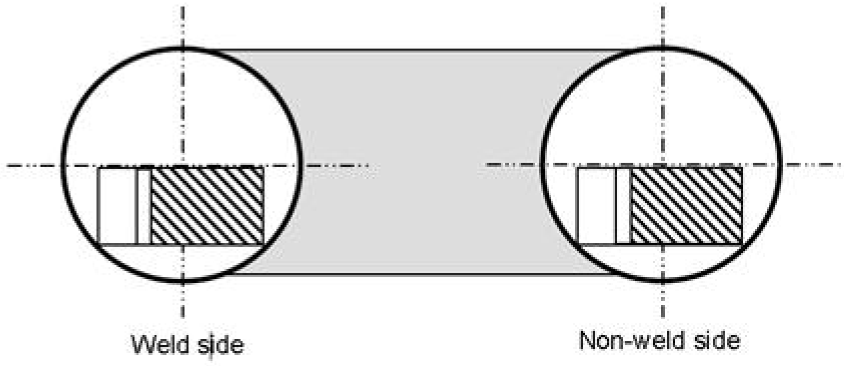


Figure 10.6 Location of CTOD test specimens

Table 10.15 Effect on uncertainty in measurements

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. Thermocouples are to be placed both on the surface and in a drilled hole located to the mid thickness position of the calibration block.

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 **TL**. 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 2 to 5.

1.5 Approval of steel mills for rolled bars

1.5.1 Bar materials intended for chain and accessories are to be manufactured only by works approved by **TL.** 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. 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. 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 **TL** and by the chain manufacturer. For grades TL-R4, TL-R4S and TL-R5 chain the steel should contain a minimum of 0.20 percent molybdenum.

1.5.4 A heat treatment sensitivity study simulating chain production conditions is to 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 **TL.**

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 TL-R3S, TL-R4, TL-R4S and TL-R5, hydrogen embrittlement. All test details and results are to be submitted to **TL.**

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 **TL.** A description of manufacturing processes and process controls is to be submitted to **TL.** The scope of approval is to be agreed with **TL**. 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. 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. Qualification of accessory pins to maximum diameters is also required. Individual accessories of complex geometries will be subject to **TL** requirements.

1.6.3 For forgings, 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.

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 **TL**. For grades TL-R4, TL-R4S and TL-R5 chain, the steel should contain a minimum of 0.20 percent 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 TL-R4S and TL-R5 grades, hydrogen embrittlement.

A heat treatment sensitivity study simulating accessory production conditions is to 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 **TL.**

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 EN ISO 12737 and 15653. The CTOD test piece is to be a standard 2 x 1 single edge notched bend specimen taken from the quarter thickness location. The minimum test piece size shall be 50 x 25mm for chain diameters less than 120 mm, and 80 x 40 mm for diameters 120mm and above. The tests are to be taken at minus 20º C and the results submitted for review.

1.6.7 Calibration of furnaces is to 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.

1.6.8 For TL-R4S and TL-R5 refer to additional requirements in 1.3.5.

1.7 Approval of quality system at accessory manufacturers

1.7.1 Refer to 1.4.

2. Materials

2.1 Scope

These rules 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

2.2.1.1 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 is to be 6 or finer in accordance with ASTM E112.

2.2.1.2 Steels for bars intended for TL-R4S and TL-R5 chain is to be vacuum degassed.

2.2.1.3 For TL-R4S and TL-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:

- Each heat is to be examined for non-metallic inclusions. The level of micro inclusions is to be quantified and assessed; to be sure inclusion levels are acceptable for the final product.

- A sample from each heat is to be macro etched according to ASTM E381 or equivalent, to be sure there is no injurious segregation or porosity.

- Jominy hardenability data, according to ASTM A255, or equivalent, is to be supplied with each heat.

2.2.2 Chemical composition

For acceptance tests, the chemical composition of ladle samples of each heat is to be determined by the steelmaker and is to comply with the approved specification.

2.2.3 Mechanical tests

2.2.3.1 Bars of the same nominal diameter are to be presented for test in batches of 50 tons or fraction thereof from the sane heat. Test specimens are to be taken from material heat treated in the same manner as intended for the finished chain.

2.2.3.2 Each heat of grade TL-R3S, TL-R4, TL-R4S and TL-R5 steel bars is to be tested for hydrogen embrittlement. In case of continuous casting, test samples representing both the beginning and the end of the charge are to be taken. In case of ingot casting, test samples representing two different ingots are to be taken.

2.2.3.2.1 Two tensile test specimens are to 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).

2.2.3.2.2 One of the specimens is to be tested with 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 ºC after machining and kept at that temperature for a maximum period of 5 days.

2.2.3.2.3 The second specimen is to be tested after baking at 250 ºC for 4 hours, alternatively 2 hours for 14 mm diameter specimen.

2.2.3.2.4 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.

2.2.3.2.5 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 **TL**. New tests are to be performed after degassing.

2.2.3.3 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 approx. One-third radius below the surface, as shown in Figure 10.7 and prepared in accordance with Section 2. The results of all tests are to be in accordance with the appropriate requirements of Table 10.16.

2.2.3.4 Re-test requirements for tensile and Charpy impact tests are detailed in Section 2.

2.2.3.5 Failure to meet the requirements will result in rejection of the batch represented unless it can be clearly attributable to improper simulated heat treatment.

2.2.4 Dimensional tolerances

The diameter and roundness is to be within the tolerances specified in Table 10.17, unless otherwise agreed.

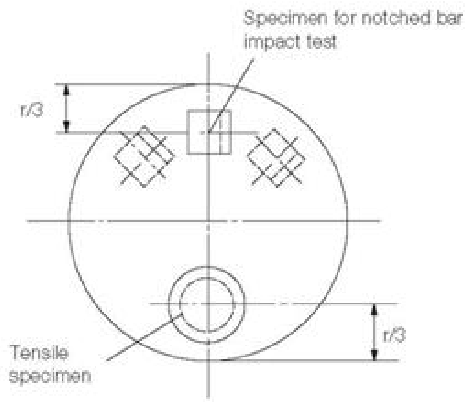


Figure 10.7 Sampling of steel bars, forgings and castings

2.2.5 Non-destructive examination and repair

2.2.5.1 Non-destructive examination is to be performed in accordance with recognized standards. Non- destructive examination procedures, together with rejection/acceptance criteria are to be submitted to **TL.**

2.2.5.2 Non-destructive examination operators are to be appropriately qualified (to a minimum level II in accordance with a recognized Standard such as ISO 9712, SNT-TC-1A or ASNT Central Certification Program) in the method of non-destructive examination.

2.2.5.3 100 percent of bar material intended for either chain or fittings is to be subjected to ultrasonic examination at an appropriate stage of the manufacture. The bars are to be free of pipe, cracks and flakes.

2.2.5.4 100 percent of bar material is to be examined by magnetic particle or eddy current methods. The bars are to be free of injurious surface imperfections such as seams, laps and rolled-in mill scales. Provided that their depth is not greater than 1 % of the bar diameter, longitudinal discontinuities may be removed by grinding and blending to a smoothy contour.

2.2.5.5 The frequency of NDT may be reduced at the discretion of **TL** provided it is verified by statistical means that the required quality is consistently achieved.

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

2.3.1.1 Forged steels used for the manufacture of accessories must be in compliance with approved specifications and the submitted test reports approved by **TL.** 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 is to be 6 or finer in accordance with ASTM E112.

2.3.1.2 Steel for forgings intended for TL-R4S and TL-R5 chain is to be vacuum degassed.

2.3.1.3 For steel intended for TL-R4S and TL-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:

- Each heat is to be examined for non-metallic inclusions. The level of micro inclusions is to be quantified and assessed, to be sure inclusion levels are acceptable for the final product.

- A sample from each heat is to be macroetched according to ASTM E381 or equivalent, to be sure there is no injurious segregation or porosity.

- Jominy hardenability data, according to ASTM A255, or equivalent, is to be supplied with each heat.

Table 10.16 Mechanical properties of offshore mooring chain and accessories

Grade	Yield stress N/mm^2 min. (1)	Tensile strength N/mm^2 min. (1)	Elongation % min.	Reduction of area (3) % min.	Charpy V-notch impact tests		
					Test temperature, º C (2)	Average energy J min.	Avg. energy flash weld J min.
TL-R3	410	690	17	50	0 -20	60 40	50 30
TL-R3S	490	770	15	50	0 -20	65 45	53 33
TL-R4	580	860	12	50	-20	50	36
TL-R4S **(4)**	700	960	12	50	-20	56	40
TL-R5 **(4)**	760	1000	12	50	-20	58	42

(1) *Aim value of yield to tensile ratio: 0.92 max.*

(2) *At the option of* ***TL*** *the impact test of grade TL-R3 and TL-R3S may be carried out at either 0ºC or -20 ºC.*

(3) *Reduction of area of cast steel is to be for grades TL-R3 and TL-R3S : min. 40 %, for TL-R4, TL-R4S and TL-R5: min. 35 %.*

(4) *Aim maximum hardness for TL-R4S is HB 330 and TL-R5 is HB 340.*

Table 10.17 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	0.60
25-35	-0 + 1.2	0.80
36-50	-0 + 1.6	1.10
51-80	-0 + 2.0	1.50
81-100	-0 + 2.6	1.95
101-120	-0 + 3.0	2.25
121-160	-0 + 4.0	3.00
161-210	-0 + 5.0	4.00

2.3.2 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 10.16, 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 Figure 10.7.

2.3.6 Ultrasonic examination

2.3.6.1 Non-destructive examination is to be performed in accordance with recognized standards and the non-destructive examination procedures, together with rejection/acceptance criteria are to be submitted to **TL.**

2.3.6.2 Non-destructive examination Operators are to be appropriately qualified (to a minimum level II in accordance with a recognized Standard such as ISO 9712, SNT-TC-1A or ASNT Central Certification Program) in the method of non-destructive examination.

2.3.6.3 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.

2.3.7 Marking

Marking is to be similar to that specified in 2.2.6.

2.4 Cast steel

2.4.1 Manufacture

2.4.1.1 Cast steels used for the manufacture of accessories must be in compliance with approved specifications and the submitted test reports approved by **TL**. 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 is to be 6 or finer in accordance with ASTM E112.

2.4.1.2 Steel for casting intended for TL-R4S and TL-R5 accessories are to be vacuum degassed.

2.4.1.3 For steel intended for TL-R4S and TL-R5 accessories the following information is to be obtained and the results included in the accessory documentation:

- Each heat is to be examined for non-metallic inclusions. The level of micro inclusions is to be quantified and assessed; to be sure inclusion levels are acceptable for the final product.

- A sample from each heat is to be macro etched according to ASTM E381 or equivalent, to be sure there is no injurious segregation or porosity.

- Jominy hardenability data, according to ASTM A255, or equivalent, is to be supplied with each heat.

2.4.2 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

The castings must comply with the mechanical properties given in Table 10.16. The acceptance requirement for reduction of area is, however, reduced to 40% for grades TL-R3 and TL-R3S and 35% for grades TL-R4, TL-R4S and TL-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 Figure 10.7.

2.4.6 Ultrasonic examination

2.4.6.1 Non-destructive examination is to be performed in accordance with recognized standards and the non-destructive examination procedures, together with rejection/acceptance criteria are to be submitted to **TL.**

2.4.6.2 Non-destructive examination operators are to be appropriately qualified (to a minimum level II in accordance with a recognized standard such as ISO 9712, SNT-TC-1A or ASNT Central Certification Program) in the method of non-destructive examination.

2.4.6.3 The castings are to be subjected to one hundred percent ultrasonic examination in compliance with the standard submitted and approved.

2.4.7 Marking

See 2.3.7.

2.5 Materials for studs

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 Chain 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. For Studless chain the shape and proportions are to comply with the requirements of C. 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 are to be submitted for information. The stud is to 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 is not to cause any harmful notch effect or stress concentration in the chain link.

3.1.3 Machining of Kenter shackles is to result in fillet radius min. 3 percent of nominal diameter.

3.2 Chain cable manufacturing process

3.2.1 General

3.2.1.1 Offshore mooring chains are to 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.

3.2.1.2 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 are to be made available for inspection by the surveyor.

3.2.3 Bar heating

3.2.3.1 For electric resistance heating, the heating phase is to be controlled by an optical heat sensor. The controller is to be checked at least once every 8 hours and records made.

3.2.3.2 For furnace heating, the heat is to be controlled and the temperature continuously recorded using thermocouples in close proximity to the bars. The controls are to be checked at least once every 8 hours and records made.

3.2.4 Flash welding of chain cable

3.2.4.1 The following welding parameters are to be controlled during welding of each link:

- Platen motion,
- Current as a function of time,
- Hydraulic pressure.

3.2.4.2 The controls are to be checked at least every 4 hours and records made.

3.2.5 Heat treatment of chain cable

3.2.5.1 Chain is to be austenitized, above the upper transformation temperature, at a combination of temperature and time within the limits established.

3.2.5.2 When applicable, chain is to be tempered at a combination of temperature and time within the limits established. Cooling after tempering is to be appropriate to avoid temper embrittlement.

3.2.5.3 Temperature and time or temperature and chain speed is to be controlled and continuously recorded.

3.2.6 Mechanical properties

The mechanical properties of finished chain and accessories are to be in accordance with Table 10.16. For the location of test specimens see Figures 10.7 and 10.8.

3.2.7 Proof and breaking test loads

Chains and accessories are to withstand the proof and break test loads given in Table 10.18.

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 item 4.5 using approved procedures.

3.2.9 Dimensions and dimensional tolerances

3.2.9.1 The shape and proportion of links and accessories must conform to ISO 1704 or the designs specially approved.

3.2.9.2 The following tolerances are applicable to links:

3.2.9.1.1 Diameter measured at the crown:

up to 40 mm nominal diameter	:	- 1 mm
over 40 up to 84 mm nominal dia.	:	- 2 mm
over 84 up to 122 mm nominal dia.	:	- 3 mm
over 122 up to 152 mm nominal dia.	:	- 4 mm
over 152 up to 184 mm nominal dia.	:	- 6 mm
over 184 up to 210 mm nominal dia.	:	- 7.5 mm

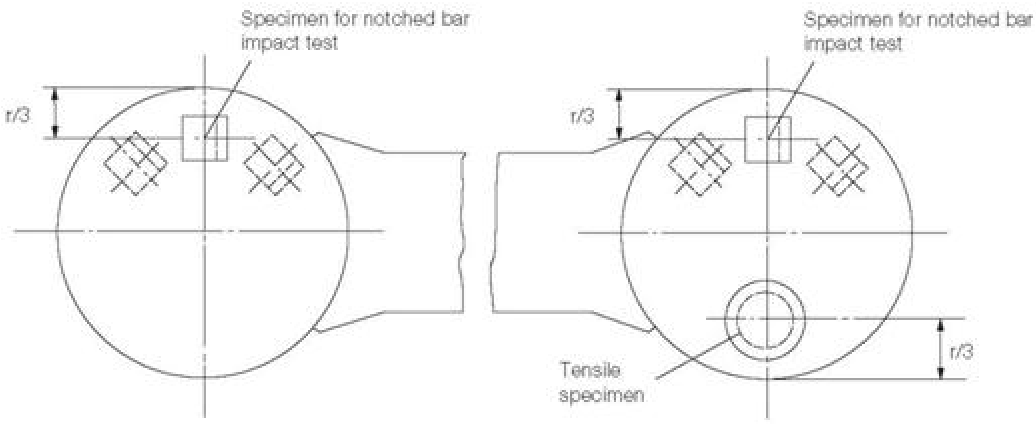


Figure 10.8 Sampling of chain links

Table 10.18 Formulas for proof and break test loads, weight and length over 5 links

Test load, in kN	**Grade TL-R3 stud link**	**Grade TL-R3S stud link**	**Grade TL-R4 stud link**	**Grade TL-R4S stud link**	**Grade TL-R5 stud link**
Proof	$0.0148\ d^2$ (44-0.08 d)	$0.0180\ d^2$ (44-0.08 d)	$0.0216\ d^2$ (44-0.08 d)	$0.0240\ d^2$ (44-0.08 d)	$0.0251\ d^2$ (44-0.08 d)
Break	$0.0223\ d^2$ (44-0.08 d)	$0.0249\ d^2$ (44-0.08 d)	$0.0274\ d^2$ (44-0.08 d)	$0.0304\ d^2$ (44-0.08 d)	$0.0320\ d^2$ (44-0.08 d)
Test load, in kN	**Grade TL-R3 studless**	**Grade TL-R3S studless**	**Grade TL-R4 studless**	**Grade TL-R4S studless**	**Grade TL-R5 studless**
Proof	$0.0148\ d^2$ (44-0.08 d)	$0.0174\ d^2$ (44-0.08 d)	$0.0192\ d^2$ (44-0.08 d)	$0.0213\ d^2$ (44-0.08 d)	$0.0223\ d^2$ (44-0.08 d)
Break	$0.0223\ d^2$ (44-0.08 d)	$0.0249\ d^2$ (44-0.08 d)	$0.0274\ d^2$ (44-0.08 d)	$0.0304\ d^2$ (44-0.08 d)	$0.0320\ d^2$ (44-0.08 d)
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	22 d				
Maximum	22.55 d				

Note:

The plus tolerance may be up to 5 percent of the nominal diameter. The cross sectional area at the crown must have no negative tolerance.

3.2.9.1.2 Diameter measured at locations other than the crown:

The diameter is to have no negative tolerance. The plus tolerance may be up to 5 percent of the nominal diameter. The approved manufacturer's specification is applicable to the plus tolerance of the diameter at the flash butt weld.

3.2.9.1.3 The allowable manufacturing tolerance on a length of five links is + 2.5 percent, but may not be negative.

3.2.9.1.4 All other dimensions are subject to a manufacturing tolerance of ± 2.5 percednt, provided always that all parts fit together properly.

3.2.9.1.5 The tolerances for stud link and studless common links are to be measured in accordance with Figure 10.9.

3.2.9.1.6 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 Figure 10.9 are acceptable provided that the stud fits snugly and its ends lie flush against the inside of the link.

3.2.10 Stud link chain – welding of studs

3.2.10.1 A welded stud may be accepted for grade TL-R3 and TL-R3S. Welding of studs in grades TL-R4, TL-R4S and TL-R5 chain is not permitted unless specially approved.

3.2.10.2 Where studs are welded into the links this is to be completed before the chain is heat treated.

3.2.10.3 The stud ends must be 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.

3.2.10.4 Welding of studs both ends is not permitted unless specially approved.

3.2.10.5 The welds are to be made by qualified welders using an approved procedure and low-hydrogen approved consumables.

3.2.10.6 The size of the fillet weld is as a minimum to be as per API Specification 2F.

3.2.10.7 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.

3.2.10.8 All stud welds are to be visually examined. At least 10 percent of all stud welds within each length of chain is to be examined by dye penetrant or magnetic particles after proof testing. If cracks or lack of fusion are found, all stud welds in that length are to be examined.

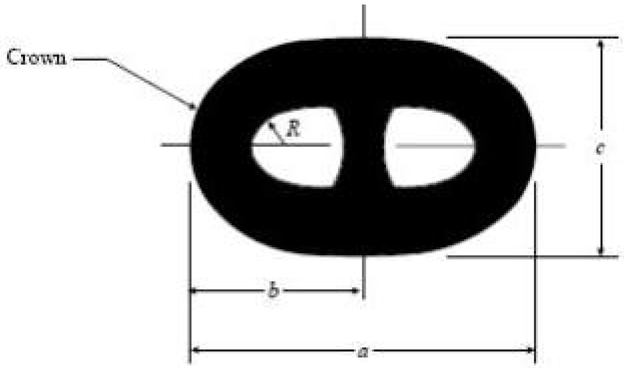
3.2.11 Connecting common links (splice links)

3.2.11.1 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 and the tests are to be made on the maximum size of chain for which approval is sought.

3.2.11.2 Manufacture and heat treatment of connecting common link is not to affect the properties of the adjoining links. The temperature reached by these links is nowhere to exceed 250 ºC.

3.2.11.3 Each link is to be subjected to the appropriate proof load and non-destructive examination as detailed in Table 10.18 and item 4.5. A second link is to be made identical to the connecting common link, the link is to be tested and inspected per item 4.4 and 4.5.

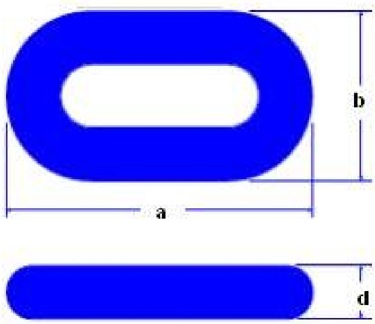
Stud link – The internal link radii (R) and external radii should be uniform



Designation (1)	Description	Nominal dimension of the link	Minus tolerance	Plus tolerance
a	Link length	6 d	0.15 d	0.15 d
b	Link half length	a*/2	0.1 d	0.1 d
c	Link width	3.6 d	0.09 d	0.09 d
e	Stud angular misalignment	0 degrees	4 degrees	4 degrees
R	Inner radius	0.65 d	0	-

(1). *Dimension designation is shown in above figure*
d= nominal diameter of chain, a = actual link length*

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	6 d	0.15 d	0.15 d
b	Link width	3.35 d	0.09 d	0.09 d
R	Inner radius	0.60 d	0	-

(1). *Dimension designation is shown in above figure*
d= nominal diameter of chain
Other dimension ratios are subject to special approval.

Figure 10.9 Stud link and studless common link, proportions dimensions and tolerances

3.2.11.4 Each connecting common link is to be marked either; on the stud for stud link chain or, on the outer straigth length on the side opposite the flash butt weld for studless chain. This marking is to be in accordance with item 4.7 plus a unique number for the link. The adjoining links are also to be marked on the studs or straigth length as above.

4. Testing and Inspection of Finished Chain

4.1 General

4.1.1 This item applies to but not is limited to finished chain cables 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, sample break load tests and sample mechanical tests after final heat treatment in the presence of a syrveyor. Where the manufacturer has a procedure to record proof loads and the surveyor is satisfied with the adequacy of the recording system, the Surveyor needs not to 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 testing and inspection the chain is to be free from scale, paint or other coating. The chain is to be sand-or shot blasted to meet this requirement.

4.2 Proof and break load tests

4.2.1 The entire length of chain is to withstand the proof load specified in Table 10.18 without fracture and is not to crack in the flash weld. The load applied is not to exceed the proof load by more than 10% when stretching the chain. 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 10.19 provided that every cast is represented. Each specimen is to be capable of withstanding the break load specified without fracture and is not to crack in the flash weld. It is to 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-tests will be considered whereby a one link specimen is used. Alternatives are to be approved by **TL**, every heat is to be represented, the test frequency is to be in accordance with Table 10.19, 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, another equivalent method is to be agreed with **TL.**

Table 10.19 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
187-199	370
200-210	395

4.3 Dimensions and dimensional tolerances

4.3.1 After proof load testing measurements are to be taken on at least 5 percent of the links in accordance with item 3.2.9.

4.3.2 The entire chain is to be checked for the length, five links ar a time. By the five link check the first five links are to be measured. From the next set of five links, at least two links from the previous five links set are to be included. This procedure is to be followed for the entire chain length. The measurement are to be taken preferably while the chain is loaded to 5-10% of the minimum proof load. The links held in the end blocks may be excluded from this measurement.

4.4 Mechanical tests

4.4.1 Links of samples detached from finished, heat treated chain are to be sectioned for determination of mechanical properties. A test unit is to consist of one tensile and nine impact specimens. The tensile specimen is to be taken in the side opposite the flash weld. Three impact specimens are to be taken across the flash weld with the notch centred in the middle. Three impact specimens are to be taken across the unwelded side and three impact specimens are to be taken from the bend region.

4.4.2 The test frequency is to be based on tests at sampling intervals according to Table 10.19 provided that every cast is represented. Mechanical properties are to be as specified in Table 10.16.

4.4.3 The frequency of impact testing in the bend may be reduced at the discretion of **TL** provided it is verified by statistical means that the required toughness is consistently achieved.

4.5 Non-destructive examination

4.5.1 After proof testing, all surfaces of every link are to be visually examined. Burrs, irregularities and rough edgesw are to be contour ground. Links are to be free from mill defects, surface cracks, dents and cuts, especially in the vicinity where gripped by clamping dies during flash welding. Studs are to be securely fastened.

Chain is to be positioned in order to have good Access to all surfaces.

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 **TL** for review. Operators are to be appropriately qualified, in the method of inspection, to at least level II in accordance with a recognized Standard such as ISO 9712, SNT-TC-1A or ASNT Central Certification Program.

4.5.3 Magnetic particles are to be employed to examine the flash welded area including the area gripped by the clamping dies. Procedures and equipment in accordance with those approved are to be used. Frequency of examination is to be every link. Additionally, 10% of links are to be tested on all accessible surfaces. Link surfaces and the surface at the flash weld are to be free from cracks, lack of fusion and gross porosity.

4.5.4 Ultrasonics are to be employed to examine the flash weld fusion. Procedures and equipment in accordance with those approved are to be used. On-site calibration standards for chain configurations are to be approved. Frequency of examination is to be every link. The flash weld is to be free from defects causing ultrasonic back reflections equal to or greater than the calibration standard.

4.6 Retest, rejection and repair criteria

4.6.1 If the length over 5 links is short, the chain 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 rabdom lengths of the chain need stretching. If the length exceeds the specified tolerance, the over length chain links are to be cut out and item 4.6.2 shall apply.

4.6.2 If single links are found to be defective or not to 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 subject to **TL**'s approval. Other methods for repair are subject to the written approval of **TL** and the end purchaser.

4.6.3 If a crack, cut or defect in the flash weld is found by visual or magnetic particle examination, it is to be ground down no more than 5% of the link diameter in depth and streamlined to provide no sharp contours. The final dimensions must still conform to the agreed standard.

4.6.4 If indications of interior of flash weld defects, in reference to the accepted calibration standards are detected during ultrasonis 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 are to be compared to the dimensions of 40 more links, 20 on each side of the affected link. If a single particular dimensions fails to meet the required dimensional tolerance in more than 2 of the sample links all links are to be examined. Item 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 break test specimens representing the same sampling length of chain are to be subjected to the break 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 can be accepted. Failure of either or both additional tests will result in rejection of the sampling length of chain represented and item 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 test. In the event that two or more links in the proof loaded length fail, that 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 break test specimen is to be taken from each side of the one failed link, and subjected to the breaking test. Based upon satisfactory results of both break 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 breaking tests will result in rejection of the same proof loaded length. Replacement of defective links is to be in accordance with item 4.6.2.

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 additional tests will result in rejection of the sampling length of chain represented and item 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 item 4.6.2 shall apply.

4.7 Marking

4.7.1 The chain is to 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 are to be stated on the certificate, and the marking is to 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 is to be traceable and adequately marked.
The marking is to be permanent and legible throughout the expected lifetime of the chain.

4.7.3 The chain is to be marked on the studs as follows:

- Chain grade

- Certificate no.

- **TL**'s stamp.

4.7.4 The certificate number may be exchanged against an abbreviation or equivalent. If so, this is to be stated in the certificate.

4.7.5 The chain certificate is to 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 is to be stated in the certificate.

4.8 Documentation

4.8.1 A complete chain inspection and testing report in booklet form are to be provided by the chain manufacturer for each continuous chain length. This booklet is to include all dimensional checks, test and inspection reports, NDT reports, process records, photographs as well as any nonconformity, corrective action and repair work.

4.8.2 Individual certificates are to be issued for each continuous single length of chain.

4.8.3 All accompanying documents, appendices and reports are to 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 produced for a period of at least 10 years.

5. Testing and inspection of accessories

5.1 General

5.1.1 This item 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.

5.1.2 All accessories are to be subjected to proof load tests, sample break load tests and sample 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 testing and inspection the chain accessories are to be free from scale, paint or other coating.

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 accessories are to be tested ar the break load prescribed for the grade and size pf chain for which they are intended. At least one accessory out of every batch or every 25 accessories, whichever is less, is to be tested. For individual produced accessories or accessories produced in small batches (less than 5), alternative testing will be subject to special consideration. Alternative testing is to be approved by **TL**.

5.2.3 A batch is defined as accessories that originate from the same heat treatment charge and the same heat of steel.Reference section 2.3 and 2.4

5.2.4 The accessories which have been subjected to the break load test are to be destroyed and not used as part of an outfit, with the exceptions given in 5.2.5.

5.2.5 Where the accessories are of increased dimension or alternatively a material with higher strength characteristics is used, they may be included in the outfit at the discretion of **TL**, provided that :

5.2.5.1 The accessories are successfully tested at the prescribed breaking load appropriate to the chain for which they are intended, and

5.2.5.2 It is verified by precedure 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.

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:

- Nominal diameter : + 5 %, -0 %

- Other dimensions : ± 2 ½ %

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 item 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. The use of separate representative coupons is not permitted except as indicated in 5.4.4 below.

5.4.2 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 test on smaller diameter shackles can be taken from the straight part of 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 10.16 in the locations specified in Figure 10.7, 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 high stress regions. All non-machined surfaces are to Table 10.16 in the locations specified in Figure 10.7.

5.4.4 The locations of mechanical tests of other accessories with complex geometries are to be agreed with **TL**.

5.4.5 For individually produced accessories or accessories produced in small batches (less than 5), alternative testing can be proposed to **TL**. Each proposal for alternative testing is to be detailed by the manufacturer in a written procedure and submitted to **TL**.

5.4.6 A batch is defined as accessories that originate from the same heat treatment charge and the same heat of steel. Reference sections 2.3 and 2.4.

5.4.7 Mechanical tests of pins are to be taken as per Figure 10.7 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 Figure 10.10.

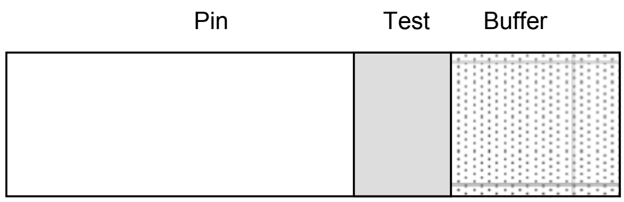


Figure 10.10 Buffer and test piece location

5.5 Non-destructive examination

5.5.1 After proof load testing all chain accessories are to be subjected to a close visual examination. Special attention is to be paid to machined surfaces and be sand or shot blasted to permit a thorough examination. All accessories are to be checked by magnetic particles or dye penetrant.

5.5.2 Testing is to be performed in accordance with a recognized Standard and the procedures, together with acceptance/rejection criteria are to be submitted to **TL** for review. Operators are to be appropriately qualified, in the method of inspection, to at least level II in accordance with a recognized Standard such as ISO 9712, SNT-TC-1A or ASNT Central Certification Program.

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.

5.6 Test failures

In the event of a failure of any test the entire barch 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

5.7.2 The certificate number may be exchanged against an abbreviation or equivalent. If so, this is to be stated in the certificate.

5.8 Documentation

5.8.1 A complete inspection and testing report in booklet form is to be provided by the manufacturer for each order. This booklet is to include all dimensional checks, test and inspection reports, NDT reports, process records as well as any nonconformity, corrective action and repair work.

5.8.2 Each type of accessory is to be covered by separate certificates.

5.8.3 All accompanying documents, appendices and reports are to 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 produced for a period of at least 10 years.

6. Chafing Chain for Single Point Mooring Arrangements

6.1 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 and similar uses.

6.2 The chafing chain is to be manu to factured by works approved by **TL** according to C. 1.3

6.3 Materials

The materials used for the manufacture of the chafing chain are to satisfy the requirements of C.2

6.4 Design, Manufacturing, Testing and Certification

6.4.1 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.

6.4.2 The arrangement of the end connections is to be of an approved type.

6.4.3 The common link is to be of stud link type – Grade TL-R3 or TL-R4.

6.4.4 The chafing chain is to be capable of withstanding the breaking test loads of 4884 kN (Grade TL-R3) and 6001 kN (Grade TL-R4)(Documented evidence of satisfactory testing of similar diameter mooring chain in the prior 6 month period may be used in lieu of break testing subjecy to agreement **TL**).

6.4.5 The chain lengths are to be proof load tested in accordance with item 4.2. The test load for Grade TL-R3 is 3242 kN and for Grade TL-R4 is 4731 kN.

D. Wire Ropes

1. 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.

2. Requirements to be Met by the Manufacturers of Wire Ropes

2.1 With regard to their production and quality control, wire rope manufacturers are to meet the requirements stated in Section 1, B. and are to be approved by **TL**.

2.2 Applications for approval are to be submitted to **TL** 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 is to demonstrate the availability of the equipment required for the proper manufacture and testing of wire ropes. **TL** reserves the right to call for a preliminary test of suitability to be carried out on samples of the rope.

2.3 If the wire rope manufacturer wishes to be approved by **TL** for the independent testing of wire ropes, this is also to be applied for. **TL** will allocate to the manufacturer a special identification number if the conditions for approval stated in 2.1 and 2.2 are satisfied.

3. Manufacture

3.1 The ropes are to conform to recognized national or international standards and should, wherever possible, comply with Table 10.20. 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.

3.2 With the exception of wire ropes made of austenitic stainless steel wires, wire ropes are normally to be manufactured from individually galvanized wires.

The use of ungalvanized wires requires the special consent of **TL.**

4. Requirements Applied to Wire Ropes

4.1 Nominal breaking strength

Wire ropes are to have the nominal breaking strengths of 1570 and 1770 N/mm^2 specified in Table 10.20. These values are not to be exceeded by more than the values shown in Table 10.21.

4.2 Ductility

Individual wires are to 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 **TL** are achieved.

4.3 Tolerance on diameter

The tolerance on the diameter of rope wires is to lie within the limits specified in recognized standards, e.g. in EN 10264.

4.4 Galvanizing method

Hawsers and standing rigging are to be manufactured from fully galvanized wires. Normally galvanized wires may be used for all other ropes. The zinc coating is to conform to the data shown in Table 10.22.

5. Testing of Wire Ropes

The following tests are to be performed.

Table 10.20 Usual types of wires approved by TL

Use	Structure of rope: Number of strands	Structure of rope: Number of wires per strand	Structure of rope: Type of rope core	Construction of strands	Nominal breaking strength [N/mm^2]	Galvanizing method
Standing rigging	6 6	7 19 **(1)**	1 fibre or steel core	Standard	1570 and 1770	Fully galvanized
Hawsers (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 rigging	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 10.21 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

5.1 Testing the zinc coating

5.1.1 The specified weight of the zinc coating is to be determined and certified by the manufacturer by stripping the coating chemically 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 are to be removed from the rope for this purpose.

TL reserves the right to repeat this test in case of doubt.

Table 10.22 Zinc coatings

Nominal wire diameter d [mm]	Minimum mass per unit area of zinc coating g/m^2 for type: 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

5.1.2 The adhesion of the zinc coating is to be verified by the winding test, e.g. to ISO 7802. For this purpose, the wires are to be wound as follows on to a test mandrel of the diameter specified in Table 10.23 so as to form at least 10 adjacent turns.

The zinc coating is to continue to adhere firmly to the substrate after winding. At least 5 wires of each size are to be tested.

Table 10.23 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

5.2 Ductility test

At the option of the manufacturer, the ductility of the rope wires is to 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 are to 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

5.3 Tensile test

5.3.1 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 is to be equal to 30 times the diameter of the rope, subject to a minimum of 600 mm. The minimum breaking load is to 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.

5.3.2 Where the tensile loading capacity of the testing machine is insufficient to test the rope in its entirety, the breaking load of the rope is to 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 are to be individually subjected to the tensile test, e.g. to EN 12385. The wire test specimens are to 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 is to be deemed successful if at least 95 % of the rope wires meet the requirements stated in item 4. 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 10.24.

Table 10.24 Realization factors

Rope construction	Ropes with fibre core	Ropes with steel core
6x7	0.9000	0.8379
6x19	0.8600	0.8007
6x24	0.8700	-
6x36	0.8400	0.7821
6x37	0.8250	0.7681

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 results may not be more than 4 %.

The average value of the four measurements is to be considered to be the actual rope diameter and is to lie within the permitted tolerances. The number and diameter of the individual wires are also to be verified.

6. Verification of Characteristics

6.1 Companies which have been approved by **TL** for the independent performance of tests may test wire ropes at their own responsibility. The result of the test is to be certified on a form prescribed by **TL**

6.2 Notwithstanding the provisions contained in 6.1, the test is to be performed in the presence of the Surveyor in the case of wire ropes of special construction in accordance with 3.1 or if the company concerned has not been approved for independent testing, or if the purchaser has expressed a wish to this effect.

7. Marking

7.1 Wire ropes are to be provided with worked-in colored 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/mm^2: yellow

For special rope constructions in accordance with 3.1 the color of the distinguishing thread is to be specially designated.

7.2 A tape is also to be worked into the ropes bearing the manufacturer's name and, in the case of companies approved by **TL** for independent testing, the identification number allocated by **TL**.

The colored distinguishing thread may be dispensed with if the tape designating the company is of the color specified in 7.1.

Ropes which have been tested in the presence of the Surveyor are also (to) be marked with a seal bearing the **TL** stamp.

E. Fibre Ropes

1. 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.

2. Requirements to be Met by the Manufacturers of Fibre Ropes

2.1 With regard to their production and quality control, fibre rope manufacturers are to meet the requirements stated in Section 1, B. and are to be approved by **TL**.

2.2 Applications for approval are to be submitted to **TL** 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 is to demonstrate the availability of the equipment necessary for the proper manufacture and testing of fibre ropes. **TL** reserves the right to call for a preliminary test of suitability to be carried out on samples of the rope.

2.3 If the manufacturer wishes to be approved by **TL** for the independent testing of fibre ropes (see 5.), this is also to be applied for.

3. Manufacture

3.1 The type, material and structure of the ropes are to conform to a national or international standard recognized by **TL** and should, wherever possible, comply with Table 10.24. Ropes of a different type may be approved on application provided that they are suitable for the proposed application

3.2 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 **TL**.

3.3 Ropes may normally comprise only one material. Exception from this rule, and approved by **TL**, 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) polypropylene are applicable to ropes with these outside layers.

4. Required Properties

The properties of fibre ropes are to fulfill the requirements specified in the standards recognized by **TL**. These include for example:

EN ISO 9554 and the complementary DIN and ISO standards mentioned therein, see Table 10.25

5. Testing the Breaking Load of Ropes

5.1 Test method

The breaking load of ropes is to 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 10.26.

5.2 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 are to 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

Table 10.25 Construction of customary rope types approved by TL

Rope standards	Material	Rope construction (DIN 83307)	
		Form	Construction
EN ISO 1181	Manila	A, B	Hawser laid
EN ISO 1181	Sisal	A, B	Hawser laid
DIN-EN 1261	Hemp	A, B, C	Hawser laid Cable laid
EN ISO 1140	Polyamide	A	Hawser laid
EN ISO 1141	Polyester	A	Hawser laid
EN ISO 1346 **(1)**	Polypropylene	A,B	Hawser laid

(1) *Data only for "3-strand hawser laid" with the same values.*

Table 10.26 Reduction factors

<table>
<tr><th rowspan="4">Nominal diameter of rope

[mm]</th><th colspan="6">Reduction factors r for ropes</th></tr>
<tr><th colspan="3">Of natural fibres</th><th colspan="3">Of synthetic fibres</th></tr>
<tr><th colspan="3">Manila, sisal or hemp rope acc. to EN ISO 1181 or DIN-EN 1261 Form</th><th>Polyamide rope acc. to EN ISO 1140 Form</th><th>Polyester rope acc.to EN ISO 1141 Form</th><th>Polypropylene rope acc. to EN ISO 1346 Form</th></tr>
<tr><th>A</th><th>B</th><th>C</th><th>A</th><th>A</th><th>A</th></tr>
<tr><td>44</td><td>-</td><td>-</td><td>-</td><td>0.68</td><td>-</td><td>-</td></tr>
<tr><td>48</td><td>-</td><td>-</td><td>-</td><td>0.68</td><td>0.51</td><td>0.82</td></tr>
<tr><td>52</td><td>-</td><td>-</td><td>-</td><td>0.68</td><td>0.51</td><td>0.82</td></tr>
<tr><td>56</td><td>-</td><td>-</td><td>-</td><td>0.68</td><td>0.50</td><td>0.82</td></tr>
<tr><td>60</td><td>-</td><td>-</td><td>-</td><td>0.68</td><td>0.49</td><td>0.82</td></tr>
<tr><td>64</td><td>-</td><td>-</td><td>-</td><td>0.67</td><td>0.48</td><td>0.81</td></tr>
<tr><td>72</td><td colspan="2">0.58</td><td>-</td><td>0.67</td><td>0.48</td><td>0.81</td></tr>
<tr><td>80</td><td colspan="2">0.58</td><td>-</td><td>0.66</td><td>0.48</td><td>0.80</td></tr>
<tr><td>88</td><td colspan="2">0.57</td><td>-</td><td>0.66</td><td>0.48</td><td>0.80</td></tr>
<tr><td>96</td><td colspan="3">0.57</td><td>0.65</td><td>0.47</td><td>0.80</td></tr>
</table>

5.3 Tensile testing of test section

5.3.1 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

5.3.2 The breaking load established by the tensile test is to correspond to the data given in the relevant standard. If a test section of rope breaks at the clamp or at the splice, the test requirements are considered to have been met if the result equals at least 90 % of the specified breaking load.

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

5.4 Calculation of the breaking load of rope

5.4.1 In order to determine the breaking load by calculation, a number of yarns are to be taken from the test sections specified in 5.2. which are to be equal to half the numerical value of the rope diameter in mm, and these are to be subjected to a tensile test. In taking the test specimens, attention is to be paid to the following:

The yarns are to 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.

5.4.2 The yarns are to be tested individually by the tensile test in accordance with ISO 2062.

5.4.3 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 10.26.

The breaking load of the rope determined in this way is at least to satisfy the data contained in the relevant standard.

5.5 The certification shall state which method was used to test the breaking load of the rope and whether the specimen broke at the clamp.

5.6 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 results.

6. Verification of the Characteristics

6.1 The manufacturers of yarn and rope are to constantly monitor the characteristics of their products and are to ensure that the products meet the requirements specified in the standards. The manufacturers are to keep records of their quality control and are to present these to **TL** on request.

6.2 If a manufacturer intends to determine the strength of rope by calculation based on the strength of the yarn, then the manufacturer is to demonstrate at least once a year in the presence of a Surveyor of **TL** that the Surveyor is capable of manufacturing rope with the specified reduction factors. This is to be demonstrated by the tensile test on a test section described in 5.3.

6.3 Rope manufacturers who have been approved by **TL** for the independent performance of tests may themselves test the breaking load using the methods described in 5.

7. Marking

7.1 A tape indicating the rope standard designation and the manufacturer's, mark is to be worked into the ropes, each ~ 1m apart. Where companies have been approved for the independent performance of tests, this tape is additionally to bear the identification number allocated to the company by **TL**. In addition, a coloured distinguishing thread denoting the yarn material in accordance with Table 10.27 is also to be worked into the rope.

7.2 The colored distinguishing thread may be omitted where the tape has the color code stipulated in 7.1.

Table 10.27 Distinguishing threads for fibre ropes

Material	Colour code
Manila	Black
Sisal	Red
Hemp	Green
Polyamide	Green
Polyester	Blue
Polypropylen	Brown

SECTION 11

MATERIALS FOR PROPELLER

A. Cast Copper Alloy Propellers

1. Scope

These Rules are applicable to the moulding, casting, testing and to the method for repairing of new propellers, propeller blades and propeller bosses made of cast copper alloys. By agreement with **TL**, these Rules may also be applied to the repair and testing of propellers which have been damaged in service.

2. Foundry Approval

2.1 Approval

All propellers and propeller components are to be cast by foundries approved by **TL** in. To this end, foundries shall furnish proof that they have available the requisite production facilities and qualified personnel in order to be able to manufacture propellers in the appropriate manner and in accordance with these Rules.

2.2 Application for approval

The approval is to be applied for at **TL**. The applications are to be accompanied by specifications of the propeller materials, manufacturing procedures, repair, NDT inspection procedures and a description of the foundry facilities, including the maximum capacity of the ladles.

2.3 Scope of the approval test

The scope of the approval test is to be agreed with **TL**. This should include the presentation of cast test coupons of the propeller materials in question for approval testing in order to verify that the chemical composition and the mechanical properties of these materials comply with these rules.

2.4 Inspection facilities

The foundry is to have a suitably equipped laboratory, staffed by qualified personnel to perform tests on moulding materials, chemical analyses, mechanical tests and microstructural examinations. In addition, provisions is to be made for carrying out non-destructive tests.

Where the requisite facilities are not available at the foundry, specifications are to be furnished giving all the necessary particulars of the laboratory which carries out the tests for the foundry.

3. Moulding and Casting

3.1 Pouring

Pouring must be carried out in dry moulds using degassed liquid metal. The pouring process is to be controlled as to avoid turbulences of flow. Special devices and/or procedures must prevent slag flowing into the mould.

3.2 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 **TL** for approval. Annealing temperatures and holding times are given in Tables 11.4 and 11.5.

4. General Characteristics of Castings

4.1 Freedom from defects

All castings must have a workmanlike finish and must be free from defects liable to impair their intended use. 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(Cf Par 14).

4.2 Removal 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 14. within the limits applicable for the endangered zone in question. A comprehensive report on the repairs carried out is to be made available to the Surveyor.

5. Dimensions, Dimensional and Geometrical Tolerances

5.1 The dimensions and the dimensional and geometrical tolerances are governed by the data contained in the approval drawings or order documents. These documents shall be submitted to the Surveyor at the time of testing.

The accuracy and verification of the dimensions are the responsibility of the manufacturer, unless otherwise agreed.

5.2 All propellers are to be statically balanced as specified in the approved drawings. Dynamic balancing is required for propellers with an operating speed of more than 500 rpm.

6. Chemical Composition and Microstructure Characteristics

6.1 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 11.1. Cast copper alloys whose chemical composition differ from the standard alloys shown in Table 11.1 must specially be approved by **TL**.

6.2 Metallurgical characteristics

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 toughness and resistance to corrosion fatigue, are very heavily affected by the proportion of beta phase. (A high proportion of beta phase has a detrimental effect on these characteristics). To ensure adequate cold deformability and resistance to corrosion fatigue, the proportion of beta phase is to be kept low. The concept of the zinc equivalent should be used as control since it summarizes the effect of the tendency of various chemical elements to produce beta phase in the structure."*The structure of CU1 and CU2 type alloys must contain an alpha phase component of atleast 25 % as measured on a test bar by the manufacturer. To ensure adequate ductility and corrosion fatigue resistance, the proportion of beta phase is to be kept low. For this purpose, the zinc equivalent defined by the following formula shall not exceed a value of 45 %:

$$\text{Zinc equivalent [\%]} = 100 - \frac{100 \text{ x } \% \text{Cu}}{100 + \text{A}}$$

In which A is the algebraic sum of the following values:

1	: % Sn
5	: % Al
-0.5	: % Mn
-0.1	: % Fe
-2.3	: % Ni

Note :
The minus sign preceding the elements Mn, Fe and Ni signifies that these elements tend to reduce the proportion of beta phase.

Table 11.1 Chemical composition of cast copper alloys for propellers

Alloy type	Chemical composition (%)							
	Cu	Al	Mn	Zn	Fe	Ni	Sn	Pb
CU1	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	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	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	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

7. Mechanical Characteristics

7.1 Standardized alloys

The mechanical characteristics must conform to the data given in Table 11.2. These values are applicable to test specimens manufactured from cast samples separately in accordance with Fig. 11.1 or in accordance with specifications of a recognized national standard.

Note :

These characteristics represent a standard for the mechanical properties of each heat; they are not, however, a binding requirement for the mechanical properties of the casting itself which may be up to 30 % lower than in the separately cast sample piece.

*The mechanical properties of integrally cast sample bars are to be subject to special agreement by **TL**.*

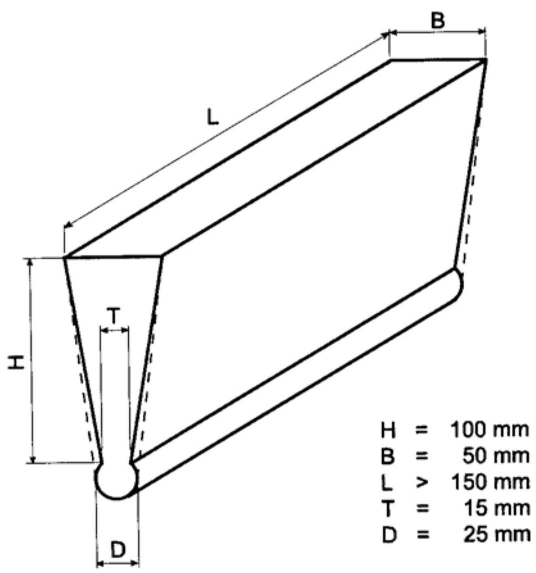


Figure 11.1 Test sample casting

7.2 Other alloys

The mechanical properties of other alloys not shown in Table 11.2 are to comply with the requirements set out in a specification which has been approved by **TL.**

Table11.2 Mechanical properties of cast copper alloys for propellers (separately cast sample pieces)

Alloy type	Proof stress $R_{p0.2}$ [N/mm^2] min.	Tensile strength R_m [N/mm^2] min.	Elongation A_5 [%] min.
CU1	175	440	20
CU2	175	440	20
CU3	245	590	16
CU4	275	630	18

8. Inspections and tests

The following inspections and tests are to be performed. The dimensions of test specimens and methods of testing are given in Section 2.

8.1 Chemical composition

The manufacturer shall define the chemical composition of each ladle.

8.2 Tensile test

8.2.1 The tensile strength, 0.2 % proof stress and elongation are to be determined by tensile test. For this purpose, at least one tensile test specimen is to be taken from each ladle charge.

8.2.2 Tensile test specimens are normally to be taken from separately cast sample pieces, see 7.1. The sample pieces are to be cast in moulds of the same moulding material as is used for the propeller casting. They must be cooled under the same conditions as the propeller itself.

8.2.3 If propellers are subjected to heat treatment, the sample pieces are to be heat treated in the same way.

8.2.4 Where test specimens are to be taken from integrally cast sample bars, this is to be the subject of special agreement with **TL**. Wherever possible, the sample bars are to be located on the blades at a point lying between 0.5 and 0.6 R, where R is the radius of the propeller. The sample material may not be removed from the propeller by thermal cutting process.

8.3 Micrographic examination

The microstructure of the casting grades CU1 and CU2 is to be demonstrated by determining the proportion of alpha phase. For this purpose, at least one specimen is to be taken from each heat. The proportion of alpha phase is to be determined as the average value from 5 counts. In this case the requirements set out in 6.2 shall be met.

8.4 Surface quality and dimensions

8.4.1 Propeller castings are to be monitored throughout all the production phases; after finish machining, the Surveyor is to carry out a comprehensive inspection of the entire surface. The inspection is also to include the bore of the boss.

8.4.2 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.

8.4.3 The Surveyor may require certain areas to be slightly etched (e.g. with iron chloride) to show up weld repairs.

9. Non-Destructive inspections

9.1 Dye penetrant inspection

9.1.1 A dye penetrant inspection is to be carried out on "Zone A" endangered areas, cf. 12. in the presence of the Surveyor. A description of the tests and a standard for evaluation purposes are contained in 13.
A dye penetrant inspection is to be performed by the manufacturer on Zones "B" and "C"; if the Surveyor requests it, in his presence.

9.1.2 Where repairs have been carried out by grinding or welding, the sites of these repairs are to be subjected to a dye penetrant inspection regardless of the location and/or danger area.

9.2 Radiographic and ultrasonic inspection

Where there is serious reason to doubt that the casting is free of internal defects, the Surveyor may require additional non-destructive tests to be carried out, e.g. radiographic and/or ultrasonic tests. In this case the following shall be noted: the standards for evaluation are to be agreed between manufacturer and **TL** in accordance with a recognized standard.

Notes on procedure:

The absorption of X and gamma rays in copper-based alloys is greater than it is in steel. In the case of propellers made of bronze, X-rays of 300 kV may normally only be used up to wall thicknesses of 50 mm, and Co 60 gamma rays only up to wall thicknesses of 160 mm. Owing to the restricted penetration thickness and other practical considerations, radiographic testing is not a suitable method for testing the thickest parts of large propellers.

Ultrasonic testing cannot, as a general rule, be performed on casting grades CU1 and CU2 due to the high absorption properties of these materials. Ultrasonic testing is possible for grades CU3 and CU4 at areas close to the surface.

9.3 Documentation on defects and tests

All defects requiring the casting to be repaired by welding are to be preferably indicated in the drawings or in special sketches, in which their location and dimensions is to be clearly identified.

The test method is also to be indicated. These documents are to be submitted to the Surveyor prior to any repair welding being carried out.

10. Identification and Marking

10.1 Identification

The manufacturer must employ a production monitoring system which enables the castings to be traced back to their heat. On request, the Surveyor is to be provided with proof of the process.

10.2 Marking

Prior to final inspection by the Surveyor, the manufacturer shall mark the castings at least as follows:

- 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,
- Specimen number,
- Date of final inspection,
- Number of **TL**'s test certificate,
- Ice class symbol, where applicable,
- Blade skew angle for high-skew propellers.

11. Certificates Issued by the Manufacturer

For each propeller the manufacturer is to submit to the Surveyor a certificate containing the following details:

- Purchaser and order number,
- Ship project number, if known,
- Description of the casting and drawing number,
- Diameter, number of blades, pitch and direction of turning,
- Grade of casting and chemical composition of each heat,
- Heat or casting number,
- Final weight,
- Results of the non-destructive tests and details of the test method, where applicable
- Proportion of alpha phase in CU1 and CU2 alloys
- Results of the mechanical tests
- Casting identification number
- Blade skew angle for high-skew propellers, cf. 12.1.

12. Definition of Skew, Severity Zones

12.1 Definition of skew

The skew of a propeller is defined as the skew angle as follows:

The maximum skew angle of a propeller blade is the angle which, in a projected view on to the blade, is formed between one connecting line from the tip of the blade to the centre of the bore of the boss and a second line from the centre of the bore of the boss as a tangent to the curve of the half widths of the blade (cf. Fig. 11.2). High-skew propellers have a skew angle of more than 25° and low-skew propellers an angle up to 25°.

12.2 Severity zones

In order to relate the scope of the tests to the effect of defects in propeller blades and avoid the risk of fatigue fractures following repairs, the blades are divided into three zones designated "A", "B" and "C".

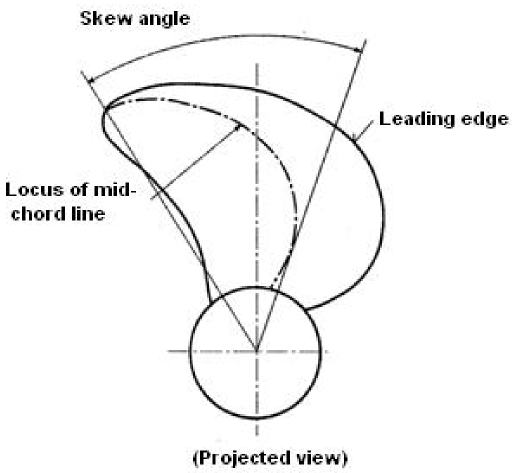


Figure 11.2 Definition of skew angle

Zone "A" is the area subjected to the greatest operating stress and requiring the most extensive testing. The blades in this area are normally at their thickest and produce the greatest resistance to expansion for welding, with the result that this leads to the highest residual stresses in and around the repair welds. High residual stresses often lead to fatigue cracks during subsequent operation so weld sites have to be subjected to heat treatment to reduce stress

Welding in Zone "A" is normally not permitted. Exceptions to this rule are only possible where **TL** has given its approval based on a special consideration. In this area, every attempt is to be made to repair a defective or damaged propeller without resorting to welding, even where this 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 **TL** has given prior approval. For approval to be granted, details about the defects or damage are to be notified for each case.

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.

12.2.1 Low skew propellers

Zone "A" is the area of the driving face of the blade between the fillet and the radius 0.4 R and is bounded on both sides by 0.15 x length of the chord C_r from the leading edge and 0.20 x C_r from the trailing edge, see Fig. 11.3.

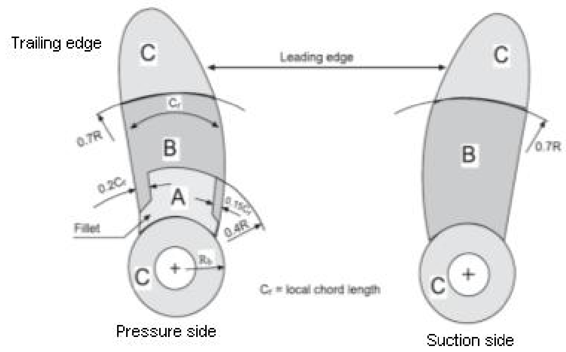


Figure 11.3 Severity zones for integrally cast low-skew propellers

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 x R_b.

Zone "A" also incorporates the areas of individually cast propeller bosses which are located in the area of the window shown in Fig. 11.5 and also the areas of flange and blade fillets of fixed or controllable pitch propellers, as described in Fig. 11.6. Further the inner taper surface of the boss is classed as Zone "A".

Zone "B" is the remaining area of the driving face up to the radius 0.7 R and on the suction face the area between the fillet and the radius 0.7 R (See Fig.11.3).

Zone "C" is the area outside the radius 0.7 R on both faces of the blade. This also incorporates the surface of a fixed-pitch propeller(Monobloc propeller) boss and the controllable-pitch propeller boss, provided this has not been classed as Zone "A".

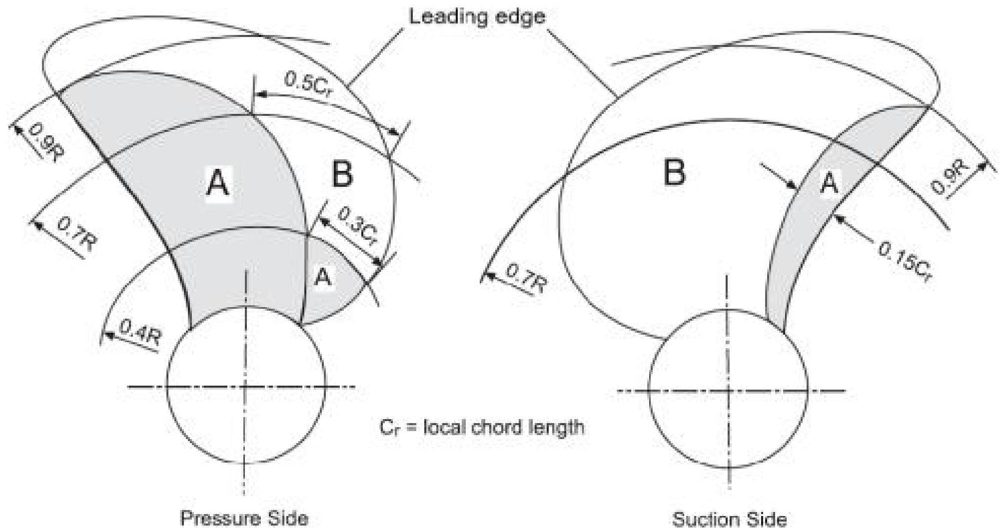


Figure 11.4 Severity zones in blades with skew angles greater than 25 º

12.2.2 High skew propellers

Zone A is the area on the pressure face contained within the blade root-fillet and a line running from the junction of the leading edge with the root fillet to the trailing edge at 0.9 R and at passing through the mid-point of the blade chord at 0.7 R and a point situated at 0.3 of the chord length from the leading edge at 0.4 R. It also includes an area along the trailing edge on the suction side of the blade from the root to 0.9 R and with its inner boundary at 0.15 of the chord lengths from the trailing edge.

Zone B constitutes the whole of the remaining blade surfaces.

Zone "A" and Zone "B" are shown in Fig. 11.4.

Note:
The remaining surface of the propeller blades is are to be divided into the severity zones as given for solid cast propellers (cf. Fig. 11.3 and Fig.11. 4)

13. Acceptance Criteria for Dye Penetrant Inspection

13.1 Inspection procedure

The dye penetrant inspection is to be executed in conformity with a standard or specification approved by **TL**.

13.2 Definitions

13.2.1 Indication

In dye penetrant inspection, an indication is classed as when bleeding of the indicating fluid is clearly visible from discontinuities in the material at least 10 minutes after the developer has been applied.

13.2.2 Forms of indication

A distinction is made between circular, linear and aligned indications, see Figure 11.7.

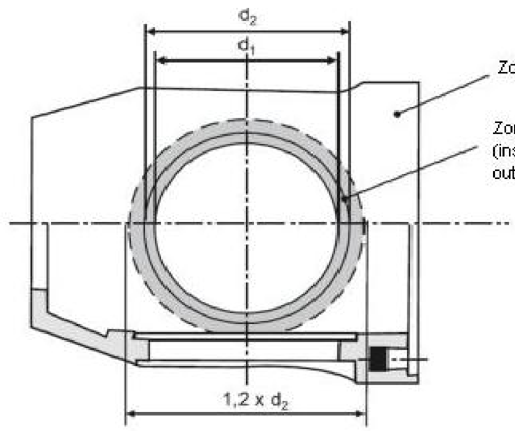


Figure 11.5 Severity zones for controllable pitch propeller boss

13.3 Acceptance standard

13.3.1 For evaluation purposes, the test surface is to be subdivided into reference areas, each being 100 cm^2, as described in the definitions given in 13.2. The number and form of the indications encountered may not exceed the values specified in Table 11.3.

The area is to be taken in the most unfavourable location relative to the indication being evaluated.

13.3.2 For welding purposes prepared areas are always to be evaluated as Zone "A" regardless of their location. The same applies for weld sites when they have been finish machined and/or ground.

14. Repair of Defects

14.1 Definition

Indications which exceed the maximum values of the acceptance standard specified in Table 11.3, such as cracks, shrinkage cavities, scabs, sand and slag inclusions or other non-metallic inclusions and also other discontinuities, where they might impair the safe operation of the propeller, is to be regarded as defects and is to be repaired.

Note :
A reference area is classed as an area of 100 cm^2 and may be either square or rectangular, the maximum edge length being no greater than 25 cm.

14.2 Repair methods

14.2.1 Defects are normally to be removed by mechanical methods such as grinding, chipping or milling. By consent of the Surveyor, repairs by welding may be performed provided that the specifications given in 14.3, 14.4 and 14.5 have been complied with.

14.2.2 After milling or chipping grinding is to be applied for such defects which are not to be welded. Grinding is to be carried out, in such a manner that the contour of the ground depression is as smooth as possible in order to avoid stress concentrations or to minimise cavitation corrosion.

14.2.3 Weld sites smaller than 5 cm^2 are to be avoided.

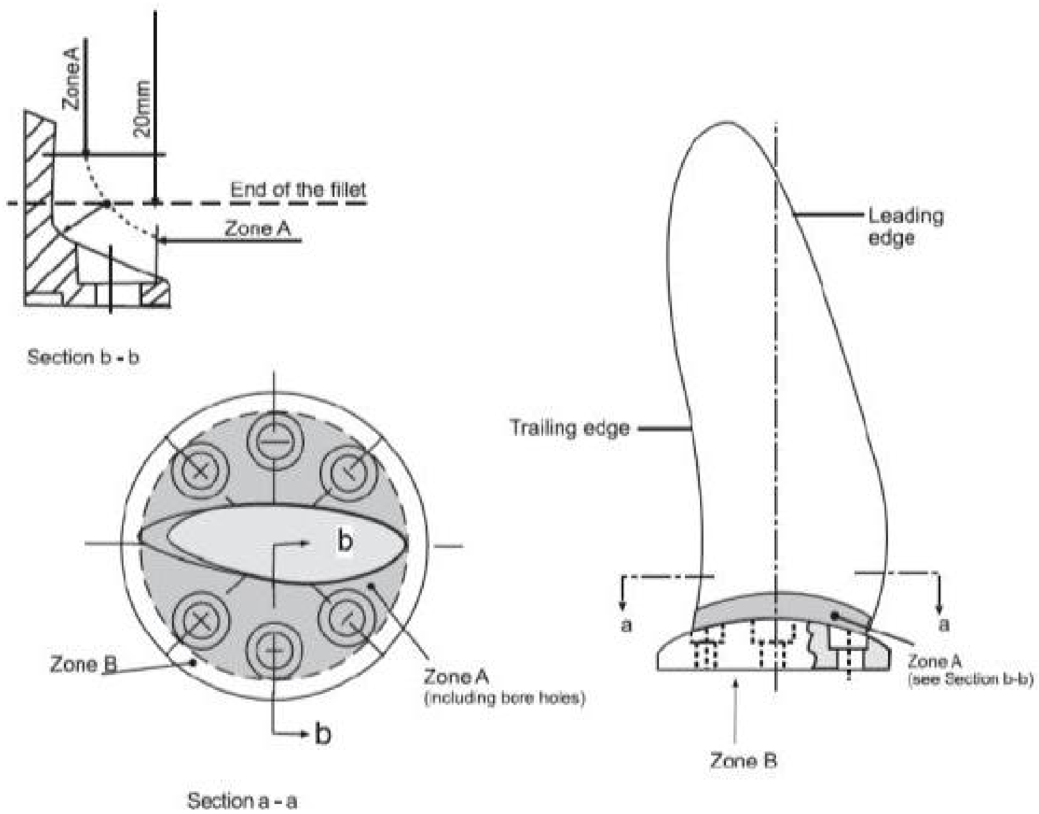


Figure 11.6 Severity zones for controllable pitch and built-up propeller

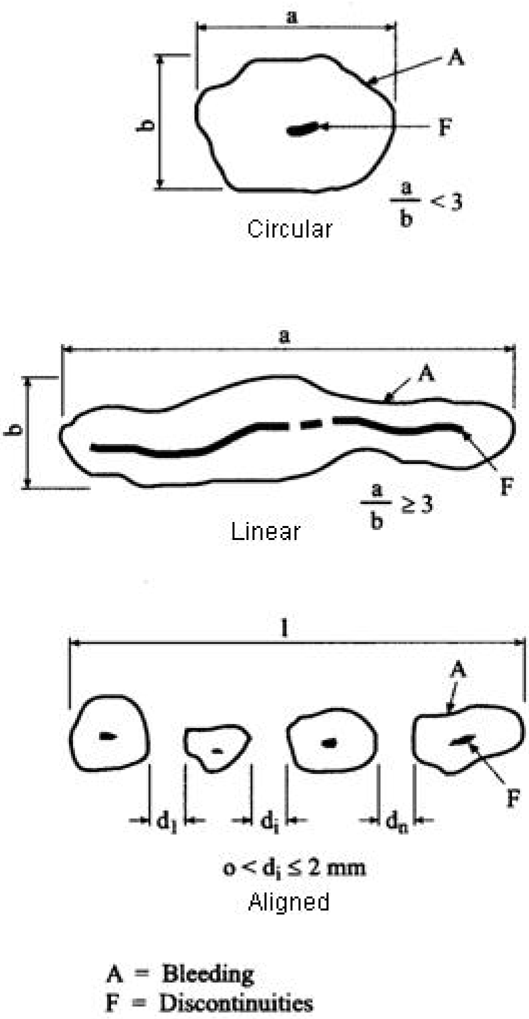


Figure 11.7 Forms of indication

14.3 Repair of defects in Zone "A"

14.3.1 Repairs by welding in Zone "A" are generally not permitted unless specially approved by **TL**

14.3.2 Grinding is permitted to the extent that the blade thickness specified in the drawing is maintained.

14.3.3 Where grinding has to be carried out more deeply than described above, this is to be inspected and approved on a case by case basis by **TL**.

14.4 Repair of defects in Zone "B"

14.4.1 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. whichever is greatest below the local thickness as specified in the Rules are to be removed by grinding.

14.4.2 Defects with a depth greater than the figure permitted for grinding may be repaired by welding.

14.5 Repair of defects in Zone "C"

Repair by welding is normally permitted in Zone "C".

15. Repair by Welding

15.1 General requirements

15.1.1 Companies wishing to carry out welding work on propellers are to have at their disposal suitable workshops, lifting gear, welding equipment, test equipment and heat treatment facilities as well as qualified welders and welding supervisors to enable them to carry out the work properly. Proof is to be furnished to the Surveyor that these requirements are satisfied before welding work begins.

15.1.2 The company in question is to prepare and submit to **TL** a specification containing all the welding details in the form of a WPS **(1)** such as preparation of weld sites, welding method, filler metals, preheating, subsequent heat treatment and test method.

15.1.3 Before welding is carried out, a welding procedure approval test is to be carried out in the presence of the Surveyor. Every welder or welding machine operator is to demonstrate that he is entirely competent to perform the specified welds, using the same procedure, fillers and positions as required for the repair. The scope of the tests required for this is given in Annex A.

15.1.4 Welding procedure approval tests and welder's qualification tests performed at the aforementioned test pieces remain valid for 3 years and include thicknesses up to 1.5 "t", with "t" being the thickness of the test piece. Welder's qualification tests performed at CU2 include CU1, those performed at CU4 include CU3.

(1) *WPS = Welding Procedure Specification.*

Table 11.3 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	Type of indication	Maximum number for each type of indicaiton (1) (2)	Maximum permitted dimension "a" or "l" of indications [mm]
A	7	circular	5	4
		linear	2	3
		aligned	2	3
B	14	circular	10	6
		linear	4	6
		aligned	4	6
C	20	circular	14	8
		linear	6	6
		aligned	6	6

(1) *Individual, circular 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 may be disregarded.*

(2) *All or some of the total number of circular indications may be increased to the maximum permitted number of all indications where there are no linear/aligned indications.*

15.2 Preparation of weld sites

Defects which are required to be removed by welding are to be ground down to the sound base material in conformity with the requirements stated in 14.2. To ensure that the defects have been completely removed by grinding, the grinding sites are to be subjected to a dye penetrant inspection in the presence of the Surveyor. The weld grooves shall be prepared so as to ensure that the base of the groove is fully fused.

15.3 Welding repair procedure

15.3.1 Arc welding is recommended for all repairs to bronze propellers.

Where the material thicknesses are less than 30 mm, gas welding (oxygen-acetylene) may be performed on casting grades CU1 and CU2 with satisfactory results.

Arc welding with coated electrodes and gas-shielded metal arc process (GMAW) are generally to be applied. Argon-shielded tungsten welding (GTAW) should be used with care due to the higher specific heat input of this process.

The recommendations applicable to filler metals, reheating and stress-relieving treatment temperatures are given in Table 11.4.

15.3.2 To avoid local overheating, the preheating temperature is to be carefully monitored, see Table 11.4.

15.3.3 All propellers are normally to be welded in the downhand (flat) position. Where this is not possible, inert gas shielding arc welding methods is to be employed.

Weld sites are to be clean and dry. Covered welding rods are to be dried before use according to the manufacturer's specifications.

To limit the risk of distortion and crack formation, the interpass temperatures are to be kept low. This is particularly applicable in the case of CU3 alloys.

Slag, undercuts and other welding defects are to be removed before the next run is performed.

Table 11.4 Recommended filler metals and heat treatments

Alloy type	Filler metal	Preheating temperature [°C] min.	Interpass-temperature [°C] min.- max.	Stress relieving heat treatment temperature [° C]	Hot straightening temperature [°C]
CU1	Al bronze **(1)** Mn bronze	150	300	350-500	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.*

15.3.4 All welding work is for preference to be performed in the workshop, shielded from draughts and the effects of the weather.

15.3.5 With the exception of CU3 alloys, all repair welds are to 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 (cf. Table 11.4).

The methods normally employed are manual arc welding using covered electrodes and metal inert gas (MIG) welding. Tungsten inert gas (TIG) welding is to be employed with care owing to the greater specific build-up of heat

15.3.6 The soaking times for the stress-relieving treatment of copper alloys for propellers shall conform to the values given in Table 11.5. The heating up and cooling down process is to 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.

16. Straightening

16.1 Application load

Only static loads are to be employed for hot and cold straightening operations.

16.2 Hot straightening

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, is to be heated up to the recommended hot straightening temperature specified in Table 11.4.

The heating up process is to be performed slowly and uniformly and point sources of heat such as oxy-acetylene or oxy-propane should not be used. Sufficient time is to be allowed to ensure that the entire thickness of the blade section is uniformly soaked. The temperature is to be maintained within the recommended temperature range throughout the entire straightening process. Thermocouple elements or temperature indicating crayons are to be used to measure temperature.

16.3 Cold straightening

Cold straightening should only be used where minor repairs are required to blade tips and edges. Stress-relieving treatment is to be performed following the cold straightening of blades made from the CUI, CU2 and CU4 grades of casting, see Table 11.4.

Table 11.5 Holding times [h] for the stress-relieving heat treatment of copper alloy propellers

Stress relieving heat treatment temperature [°C]	Alloy grade CU1 and CU2		Alloy grade CU3 and CU4	
	Hours for each 25 mm. of thickness [h]	Maximum recommended total hours[h]	Hours for each 25 mm. of thickness [h]	Maximum recommended total 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.*

B. Cast Stainless Steel Propellers

1. Scope

1.1 These rules are applicable to the manufacture of cast stainless steel propellers, blades and bosses.

1.2 Where the use of alternative alloys is proposed, particulars of chemical composition, mechanical properties and heat treatment are to be submitted for approval.

1.3 These rules may also be used for the repair of propellers damaged in service, subject to prior agreement with **TL**.

2. Foundry Approval

All propellers, blades and bosses are to be manufactured by foundries approved by **TL**. The scope of the procedure tests involved in the approval is to be agreed.

3. General Characteristics of Castings

All castings are to have a workmanlike finish and are to be free from imperfections that could be considered to impair in-service performance.

4. Chemical Composition

Typical cast steel poropeller alloys are groupped into four types depending on their chemical composition as given in Table 11.6.

5. Heat Treatment

Martensitic castings are to be austenitized and tempered. Austenitic castings should be solution treated.

6. Mechanical Characteristics

6.1 The mechanical properties are to meet the requirements in Table 11.7. These values refer to the test specimens machined from integrally cast test bars attached to the hub or on the blade.

6.2 Where possible, the test bars attached on blades are to be located in an area between 0.5 to 0.6 R, where R is the radius of the propeller.

6.3 The test bars are not to be detached from the casting until the final heat treatment has been carried out. Removal is to be by non-thermal procedure.

Table 11.6 Typical chemical composition for steel propeller castings

Alloy type	C Max. [%]	Mn Max. [%]	Cr [%]	Mo (1) Max. [%]	Ni [%]
Martensitic (12 Cr 1 Ni)	0.15	2.0	11.5 - 17.0	0.5	Max. 2.0
Martensitic (13 Cr 4 Ni)	0.06	2.0	11.5 - 17.0	1.0	3.5 - 5.0
Martensitic (16 Cr 5 Ni)	0.06	2.0	15.0 - 17.5	1.5	3.5 - 6.0
Austenitic (19 Cr 11 Ni)	0.12	1.6	16.0 - 21.0	4.0	8.0 - 13.0

(1) *Minimum values are to be in accordance with recognised national or international standards.*

Table 11.7 Mechanical properties for steel propeller castings

Alloy type	Proof stress $R_{p0.2}$ min. [N/mm^2]	Tensile strength R_m min. [N/mm^2]	Elongation A_5 min. [%]	Red. of area Z min. [%]	Charpy V-notch Energy min. (1) [J]
12 Cr 1 Ni	440	590	15	30	**20**
13 Cr 4 Ni	550	750	15	35	**30**
16 Cr 5 Ni	540	760	15	35	**30**
19 Cr 11 Ni	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 -10 ºC.*
(2) *$R_{p1.0}$ value is 205 N/mm^2.*

6.4 Separately cast test bars may be used subject to prior approval of **TL**. The test bars are to be cast from the same heat as the castings represented and heat treated with the castings represented.

6.5 At least one set of mechanical tests is to be made on material representing each casting in accordance with Section 2.

6.6 As an alternative to 6.5, 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 set of mechanical tests is to be provided for each multiple of five casting in the batch.

7. Visual Inspection

7.1 All finished castings are to be 100% visually inspected by the surveyor. The surveyor may require areas to be etched for the purpose of investigating weld repairs.

7.2 Castings are to be free from cracks, hot teats or other imperfections which, due to their nature, degree or extent, will interfere with the use of the castings.

8. Dimensions, Dimensional and Geometrical Tolerances

8.1 The dimensions are the responsibility of the manufacturer and the report on the dimensional inspection is to be handed over to the surveyor, who may require checks to be made in his presence.

8.2 Static balancing is to be carried out on all propellers in accordance with the approved drawings.

Dynamic balancing may be necessary for propellers running above 500 rpm.

9. Non-Destructive Tests

9.1 All finished castings are subject to non-destructive testing in accordance with the requirements given in 9.2 to 9.9.

9.2 In order to relate the degree of non-destructive testing to the criticality of imperfections, propeller blades are divided into three severity zones designated A, B and C. Further a distinction is made between low skew and high skew propellers (See A).

9.3 For all propellers, separately cast blades and hubs, the surfaces covered by severity zones A, B and C are to be liquid penetrant tested. Testing of zone A is to be undertaken in the presence of the surveyor, whilst testing of zone B and C may be witnessed by the surveyor upon his request.

9.4 If repairs have been made either by grinding or by welding, the repaired areas are additionally to be subjected to the liquid penetrant testing independent of their location and/or severity zone. Weld repairs are, independent of their location, always to be assessed according to zone A.

9.5 The following definitions relevant to liquid penetrant indications apply:

Indication: the presence of detectable bleed-out of the penetrant liquid from the material discontinuities appearing at least 10 minutes after the developer has been applied.

Linear indication: an indication in which the length is at least three times the width.

Non-linear indication: an indication of circular or elliptical shape with a length less than three times the width.

Aligned indication: three or more indications in a line, separated by 2 mm or less edge-to-edge.

Open indication: an indication that can be detected by the use of contrast dye penetrant.

Non-open indication: an indication that cannot be detected by the use of contrast dye penetrant.

Relevant indication: an indication that is caused by a condition or type of discontinuity that requires evaluation. Only indications which have any dimensions greater than 1.5 mm is to be considered relevant.

9.6 For the purpose of evaluating indications, the surface is to be divided into reference areas of 100 cm^2, which may be square or rectangular with the major dimension not exceeding 250 mm. The area is to be taken in the most unfavorable location relative to the indication being evaluated.

9.7 The indications detected may, with respect to their size and number, not exceed the values given in the Table 11.8.

Table 11.8 Allowable number and size of indications depending on severity zones

Severity zone	Max. total number of indications	Indication type	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 other zones may be disregarded.*
(2) *The total number of non-linear indications may be increased to the maximum total number, or part thereof, represented by the absence of linear or aligned indications.*

9.8 Where serious doubt exists that the casting are not free from internal defects, further non-destructive inspections are to be carried out upon request of the surveyor, e.g. radiographic and/or ultrasonic tests. The acceptance criteria are then to be agreed between the manufacturer and **TL**.

9.9 The foundry is to maintain records of inspections traceable to each casting. These records are to be reviewed by the surveyor. The foundry is also to provide the surveyor with a statement confirming that non-destructive tests have been carried out with satisfactory results.

10. Repair

10.1 Defective castings are to be repaired in accordance with the requirements given in 10.2 to 10.7 and, where applicable, the requirements of item 11.

10.2 In general the repairs are to be carried out by mechanical means, e.g. by grinding or milling. The resulting grooves are to be blended into the surrounding surface so as to avoid any sharp contours. Complete elimination of the defective material is to be verified by liquid penetrant testing.

10.3 Weld repairs are to be undertaken only when they are considered to be necessary and have prior approval of the surveyor. All weld repairs are to be documented by means of sketches or photographs showing the location and major dimensions of the grooves prepared for welding. The documentation is to be presented to the surveyor prior to repair welding.

10.4 The excavation are to be suitably shaped to allow good access for welding. The resulting grooves are to be subsequently ground smooth and complete elimination of the defective material is to be verified by liquid penetrant testing. Welds having an area less than 5 cm^2 are to be avoided.

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

10.6 Defects in severity zone B that are not deeper than t/40 mm (“t” is the minimum local thickness according to the rules) or 2 mm, whichever is greatest, are to be removed by grinding. Those defects that are deeper may be repaired by welding subject to prior approval from **TL**.

10.7 Repair welding is generally permitted in severity zone C.

11. Weld Repair Procedure

11.1 The sope of the procedure tests involved in the qualification is given in Annex B.

Before welding is started, a detailed welding procedure specification is to be submitted covering the weld preparation, welding positions, welding parameters, welding consumables, preheating, post weld heat treatment and inspection procedures.

11.2 All weld repairs are to be made by qualified welders using qualified procedures.

11.3 Welding is to be done under controlled conditions free from draughts and adverse weather.

11.4 Metal arc welding with electrodes or filler wire used in the procedure tests is to be used. The welding consumables are to be stored and handled in accordance with the manufacturer’s recommendations.

11.5 Slag, undercuts and other imperfections are to be removed before depositing the next run.

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

11.7 On completion of heat treatment the weld repairs and adjacent material are to be ground smooth. All weld repairs are to be liquid penetrant tested.

11.8 The foundry is to maintain records of welding, subsequent heat treatment and inspections traceable to each casting repaired. These records are to be reviewed by the surveyor.

12. Identification

12.1 Prior to final inspection by the surveyor, each casting is to be suitably identified by the manufacturer with the following:

- Heat number or other marking which will enable the full history of the casting to be traced,
- **TL**'s certificate number,
- Ice class symbol, where applicable,
- Skew angle for high skew propellers,
- Date of final inspection.

12.2 **TL**'s stamp is to be put on when the casting has been accepted.

13. Certification

13.1 The manufacturer is to provide the surveyor with an inspection certificate giving the following particulars for each casting which has been accepted:

- Purchaser's name and order number,
- Vessel identification, where known,
- Description of the casting with drawing number,
- Diameter, number of blades, pitch, direction of turning,
- Skew angle for high skew propellers,
- Final mass,
- Alloy type, heat number and chemical composition,
- Casting identification number,
- Details of time and temperature of heat treatment,
- Results of the mechanical tests.

13.2 The manufacturer is to provide a statement regarding non-destructive tests as required by 9.9 and, where applicable, records of weld repairs as required by 11.8.

ANNEX A

WELDING PROCEDURE AND WELDER'S QUALIFICATION TESTS FOR PROPELLERS MADE OF CAST COPPER ALLOYS

1. General

Testing is to be carried out using the same welding method, filler metal, the same preheating and stress-relieving heat treatment as is to be employed for the actual repair.

2. Test Sample

A test sample at least 30 mm. thick is to be welded in the down-hand (flat) position (see Fig. 11.A.1). The dimensions of the test specimens to be taken from said test piece are given in Figure 11.A.2 and Section 2 Figure 2.6.

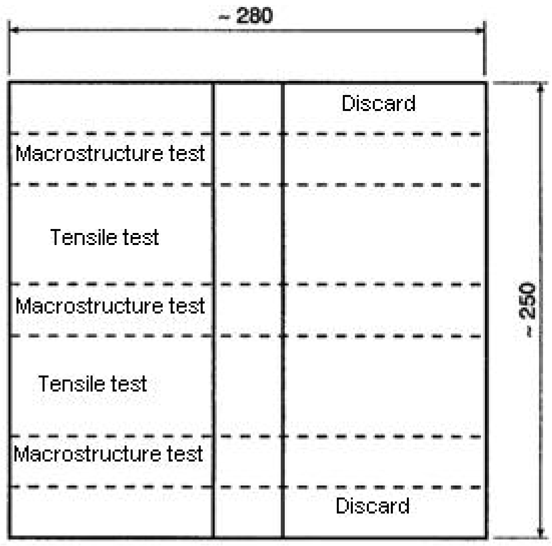


Figure 11.A.1 Test piece

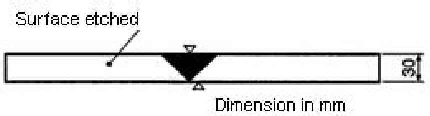


Figure 11.A.2 Macrostructure test specimen

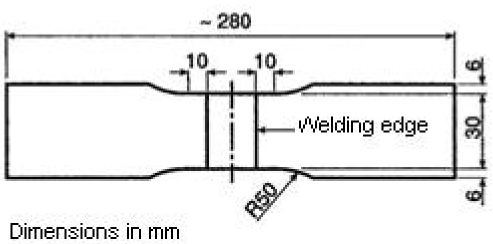


Figure 11.A.3 Tensile test specimen

3. Tests

3.1 Non-destructive test

Following welding, the joint is to be subjected to a 100 % dye penetrant test. Cracks are not allowed. The evaluation standard for zone "A" given in Table 11.3 is to apply.

3.2 Macrostructure test

Three macrostructure test specimen must be prepared and etched as shown in Figure11.A.2. An etching medium with the following constitule would be suitable for this purpose:

5 g. Ferric (III) – Chloride

30 ml. Hydrochloride acid

100 ml. Distilled water

Pores larger than 3 mm. and cracks are not permitted.

3.3 Mechanical test

Two tensile test specimen shall be prepared as shown in Chapter 2 material Rules Section 2 Figure 2.6.

During testing, the requirements set out in Table 11.A.1 must be satisfied. Other forms of tensile test specimen conforming to recognized standards may be used.

Table 11.A.1 Tensile strength requirements

Alloy type	Tensile strength [N/mm^2] min.
CU1	370
CU2	410
CU3	500
CU4	550

ANNEX B

WELDING PROCEDURE QUALIFICATION TEST FOR PROPELLERS MADE OF CAST STAINLESS STEEL

1. Preparation of Test Assembly

A test assembly of minimum 30 mm thickness is to be welded. The types of specimens to be prepared are shown in Figure 11.B.1.

2. Non-Destructive Testing

Prior to sectioning, the test assembly is to be visually inspected and liquid penetrant tested. İmperfections are to be assessed in accordance with B.9.

3. Macro-Examination

Two macro-sections are to 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 heat affected zone. Cracks or crack-like imperfections, slag inclusions and pores greater than 3 mm are not permitted.

4. Tensile Testing

Two flat transverse tensile test specimens are to be prepared. Testing procedures are to be in accordance with Annex A-2(Ref. IACS UR W2.4.2.8.b).

The tensile strength is to meet the specified minimum value of the base material. The location of fracture is to be reported, i.e. weld metal, heat affected zone or base material.

5. Bend Testing

Two transverse side bend test specimens are to be prepared in accordance with Section 2. The former diameter is to be 4 x thickness except for austenitic steels, in which case the former diameter is to be 3 x thickness.

The test specimen, when visually inspected after bending, is to show no surface imperfections greater than 2 mm in length.

6. Charpy V-notch testing

Impact test is not required, except where the base material is impact tested. Charpy V-notch test specimens are to be in accordance with Section 2. Two sets are to be taken, one set with the notch positioned in the center of the weld and one set with the notch positioned in the fusion line, respectively.
The test temperature and impact energy are to comply with the requirement specified for the base material.

7. Hardness Testing

One of the macro-sections is to be used for HV5 hardness testing. Indentations are to traverse 2 mm below the surface. At least three individual indentations are to be made in the weld metal, the heat affected zone (both sides) and in the base material (both sides). The values are to be reported for information.

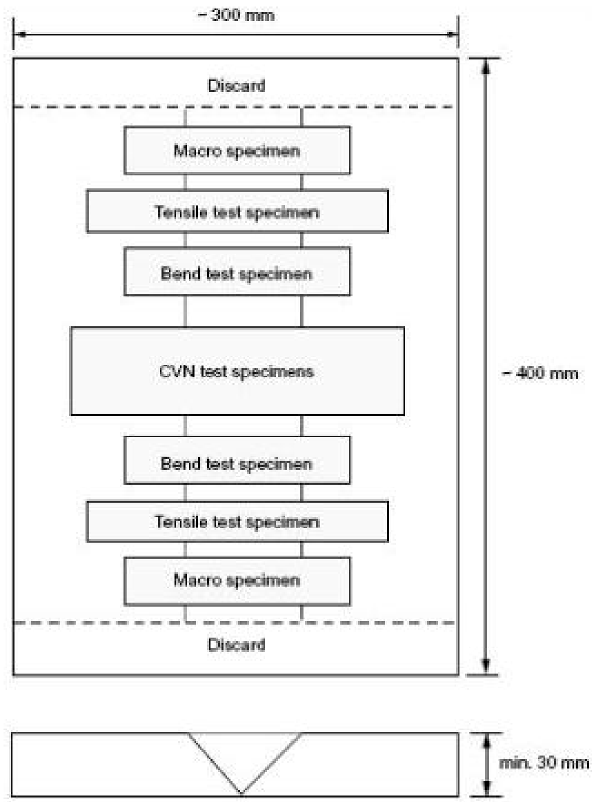


Figure 11.B.1 Weld test assembly

SECTION 12

WOODEN MATERIALS

A. General

1. Classification According to the Field of Application

1.1 Only proven boatbuilding wood is to be used for all timber components exposed to water and weather, i. e. timber with good resistance to water and weather, fungal attack and insect infestation, as well as with good mechanical properties that are also suitable for the particular application. Furthermore, it shall have a low swelling and shrinkage properties

1.2 For components not exposed to water or weather, and not requiring strength, timber of lower durability may be used.

2. Quality

The timber used in boatbuilding is to be straight and of the best quality, i. e. be free from sap, shakes, objectionable knots and other defects. Twisted-grown or rough saw cut wood is not to be used.

3. Drying

3.1 The timber used is to be well seasoned and sufficiently dried, or is to be correctly dried in a suitable drying kiln.

3.2 For this purpose, the timber is to be stacked in piles which are as small as possible, so that uniform drying is guaranteed.

3.3 In the case of forced drying, the residual moisture content is not to be more than 10 %. When processing, this content is not to exceed a maximum of 15 % as a result of hygroscopic behaviour.

3.4 The moisture content is to be determined by establishing the loss of mass of a sample between its state at the time of draw-off and its state after drying, based on constant weight at 103 ±2 °C and the calculation of the weight loss as a percentage of the dry mass. This is to be done in accordance with ISO 16979.

B. Types of Wood and Classifications

1. Solid Wood

1.1 Radially sawn timber is mainly to be used for boatbuilding. The angle of the annual rings to the lower sawn edge is not to be less than 45°.

1.2 Table 12.2 shows the number of different types of timber and their most important properties, such as durability, specific gravity, as well as bending, tensile and compressive strength. Since these properties can vary in the case of timber of the same type, or even within the same trunk, no absolute values are indicated in the table, but rather reference values. The timber listed is divided into durability groups from I to V, whereby:

I = Very good

II = Good

III = Average

IV = Moderate

V = Poor

1.3 The timber used in boatbuilding shall, if exposed to the weather or used for the primary structural components of a boat, belong to at least durability group III.

1.4 In place of the timber listed in Table 12.2, other types can be used if the durability and the technological values are verified and are equivalent. The manufacturer is always to be responsible for the correct selection of the quality and type of wood.

1.5 Since wood has anisotropic material properties, these are to be taken into account during the design of the components. It is to be ensured that the main direction of stress lies in the direction of the greatest strength of wood, and that no impairment of function of the component is caused through the directional moisture coefficient of expension.

1.6 The safety factors used in the strength calculations is to be agreed on in each case with **TL**.

2. Plywood

2.1 General

2.1.1 Plywood consists of individual layers which are bonded together. In general, the layers can comprise veneers, wooden slats or small wooden slats. The panels described in these rules as plywood are to consist exclusively of veneer layers.

2.1.2 The plywood panels consist of at least three veneers bonded transversely to each other (Table 12.1) by means of curable synthetic resin adhesives. The resistance of the adhesives to water and weather is to be demonstrated by long-term and outdoor testing. The number of veneer layers is dependent on the thickness and is defined in C. and D.

2.2 Grades

2.2.1 The plywood panels are divided into two grades TL 1 and TL 2.

2.2.2 Both grades are identical with regard to required strengths, including resistance to adhesives. The only distinction is that the panels of grade TL 1 are suitable for use in one piece, whilst those of grade TL 2 may, because of non-permissible defects in the middle and outer layers, only be used separately after removal of the defects.

2.3 Panel dimensions

2.3.1 The dimensions of the plywood panels are to be specified by the customer, if standard dimensions in accordance with DIN EN 313-1 are not used.

2.3.2 The length of the panels is measured parallel to the grain of the outer layer, and is always specified first. The longitudinal and transversal tolerances are ±5 mm.

2.3.3 The permissible thickness deviation is:

up to 3 mm : ±10 %

over 3 mm : ±5 %, but maximum ±0.5 mm.

2.4 Bonding

2.4.1 The plywood panels are to be bonded without flaws For this purpose, compliance with all decisive factors such as wood moisture content, pressing power, pressing temperature, pressing duration, glue characteristics, charging etc. is to be observed continually and carefully.

At present, the following synthetically-based adhesives are approved by **TL** for plywood production:

- Phenolic adhesive (including phenolic adhesive film),
- Melamine resin adhesives,
- Resorcinol resin adhesives.

2.4.2 If a new glue is used, then faultless, error-free handling and bonding is to be demonstrated to **TL** as well as absolute resistance to water and boiling.

2.5 Structure and requirements

Different requirements apply to the structures and plywood panels used in boatbuilding and aviation, as listed in C. and D. respectively.

2.6 Certificates

2.6.1 **TL** issues certificates for tested and approved plywood panels, and these are handed over to the manufacturer and/or customer.

2.6.2 The certificate specifies, among other things, the plywood type, the number of plywood panels inspected, the stamping and, if requested, the average values of the test results.

2.6.3 Independent of the testing by **TL,** the manufacturer is obliged to continually carry out his own shop-based quality control during all working steps, the selection of the wood and its processing during production of the plywood panels.

2.7 Storage of the plywood panels

2.7.1 Finished plywood panels which are placed in storage are to be kept in closed rooms and stored horizontally.

2.7.2 The plywood panels are only to be placed in horizontal stores that are at least 30 cm above the ground and from the walls, in order to avoid the effects of moisture.

2.7.3 The individual piles are to be protected against moisture from one side by covering panels.

2.7.4 Non-compliance with these storage requirements can lead to previous tests being declared invalid.

2.8 Strength calculations

The safety factors used in the strength calculations are to be agreed on, in each case, with **TL**.

C. Boatbuilding Plywood

1. General

1.1 All plywood components exposed to water and weather, or used in primary structural components (such as the deck, shell and bulkheads), are to be produced from boatbuilding plywood that has been tested and in compliance with 10.6.

1.2 Boatbuilding plywood consists of at least three veneers bonded crosswise together (Table 12.1) by means of curable synthetic-resin adhesives. The resistance of these adhesives to water and weather is to be demonstrated by long-term and outdoor testing.

1.3 As plywood can also be destroyed in suitable conditions by animal or plant pests, timber is to be used which offers a natural resistance.

1.4 Independent of the testing by **TL,** the manufacturer is obliged to continually carry out his own shop-based quality control of all working steps, the selection of the wood and its processing during production of the plywood panels.

1.5 The points listed under B.2 are to be taken into account.

Table 12.1 Minimum number and thickness of the veneer layers

Plywood thickness [mm]	Minimum number of veneer layers	Minimum thickness of the outer layers	Greatest thickness of the inner layers
Up to 6 Over 6 to 10 Over 10 to 15	3 5 7	1.5 mm	2.6 mm
Over 15 to 20 Over 20 to 26 Over 26 to 34 Over 34 to 40 Over 40 to 48 Over 48 to 55	7 9 11 13 15 17	1.5 mm	3.8 mm

2. Structure

2.1 The selection of timber and the structure of the panels (number of veneer layers) are to be appropriate for the field of application. Depending on the application, strong, durable timber - e.g. makoré and the hard, durable mahogany types of strength group F1 (Table 12.2) - with several thin inner layers of veneer is to be selected for load-carrying components subject to high stresses. On the other hand, plywood panels of lighter, less strong, and less durable timber of strength group F2 - e.g. khaya mahogany, okumé - with thicker and fewer inner layers of veneer and good surface protection are suitable for linings.

2.2 In general, veneers of 1.5 mm thickness are used for the outer layers. However, efforts are to be made to use thicker outer layers because of the later reworking necessary in boatbuilding. However, their thickness is not to exceed 2.6 mm because of increased danger of shakes in the veneers. In the case of inner layers, veneer layers in plywood panels up to 15 mm thick may not have a thickness in excess of 2.6 mm because of potential defects. For plywood panels thicker than 15 mm, veneer layers thicker than 3.8 mm may not be used.

Table 12.2 Plywood strength groups

Timber type	Botanical name	Density, air-dried approx. [g/cm^3]	Durability	Mean tensile strength of plywood	
				Longitudinal [N/mm^2]	Transverse [N/mm^2]
Strength group: F1 (for load bearing components)					
Teak	Tectona grandis	0.64	I	⩾ 40	⩾ 30
Macore	Dumoria hekelii	0.62	I	⩾ 40	⩾ 30
Douka	Dumoria africana	0.62	I	⩾ 40	⩾ 30
Utile	Entandrophragma utile	0.57	II	⩾ 40	⩾ 30
Sapele-Mahogany	Entandrophragma cylindricum	0.59	III	⩾40	⩾ 30
Oak	Quercus sp.	0.63	II	⩾ 40	⩾ 30
Strength group F2 **(1)**					
Echtes Mahagoni	Switenia macrophylla	0.49	II	< 40, but > 30	< 30, but > 20
Khaja Mahagoni	Khaja ivorensis	0.45	II - III	< 40, but > 30	< 30, but > 20
Okume (Gaboon)	Aucoumea - Klaineana	0.41	IV - V	< 40, but > 30	< 30, but > 20
(1) *Only for non-load bearing components.*					

2.3 Only in special cases and with the explicit permission by **TL** this restriction can be waived. Such plywood panels are then assigned to the strength group F2 and marked accordingly in the **TL** stamp.

2.4 A list of the required minimum number and thickness of the veneer layers is given in Table 12.3.

2.5 The veneer layers are to be symmetrical around the middle layer, both with respect to the grain as well as to the thickness of the layers.

2.6 The strength of the plywood panel can be increased, or its property adapted to specific requirements, through an increased number of veneer layers, addition of extra glue and increased pressing power, as well as through insertion of fabric layers.

2.7 For the production of boatbuilding plywood panels, only wood which is of the best quality, flawless, healthy, free from sap and spring wood is to be used for the outer and inner layers.

3. Veneer Joints

3.1 The joints are to be sealed perfectly and bond the veneers to each other by butt joints. The joints are to be glued on a suitable joint bonding machine.

3.2 The strips of veneer of the outer layers are to be put together so that they match with regard to timber and color.

3.3 Sealed joints between all layers are a precondition for boatbuilding plywood panels.

3.4 Paper or plastic adhesive strips may not be used to secure or repair inner veneer layers.

3.5 The joints of the different veneer layers are to be staggered.

3.6 Metal clamps used for securing purposes may only be positioned on the edges of the panels. They are on no account to remain on the panels when they are cut to standard dimensions.

4. Strength Groups

4.1 With regard to their suitability for the production of boatbuilding plywood, the types of timber listed in Table 12.2 are currently approved. The timber is subdivided into two strength groups. Also shown is the natural durability and weathering resistance of the mentioned types of timber.

4.2 The plywood panels may be manufactured from one or several of the approved kinds of timber. If panels comprise different types of timber of both strength groups, then all panels are assigned to the group with the lower strength.

4.3 All boatbuilding plywood panels which are manufactured according to special specifications and conditions of the customer, or deviate from **TL** requirements, are assigned to the appropriate group and stamped according to the plywood type.

4.4 Other types of wood may only be used for making plywood panels upon agreement with **TL**. The manufacturer is always to remain responsible for the correct selection of the quality and type of wood.

5. Plywood Grades

5.1 Boatbuilding plywood of the two strength groups is subdivided into two grades after inspecting its external and internal quality. In relation to their respective groups, grades I and II are identical with regard to type of wood, strength, production and bonding. They differ insofar that the panels of grade I can be used completely, while the panels of grade II are restricted to partial use because of local manufacturing defects or timber flaws.

5.2 The defects of grade II are to be limited to one third of the area of the panel. Two thirds of the panel is to be free of defects and suitable for use. The defects are identified during inspection by marking.

5.3 The visible side of the plywood panel is to be manufactured virtually without any defects and, furthermore, the quality, color and grain is to be combined in such a manner that they match. The hidden surface may have small color differences or slight blemishes which do not influence the strength of the panel.

6. Defects

6.1 The following wood and production defects are not permissible in the outer and inner veneer layers:

6.1.1 Any bonding defects,

6.1.2 Loose contra-shaving wood; strongly curly-grained, short-fibred wood growth at right angles to the run of the grain; cross-cut timber,

6.1.3 Larger, more prominent wood discoloration or mould stains which tend to cause rot and all other defects which could have a noticeable affect on the strength of the panel,

6.1.4 Wood discoloration on both sides, or strong glue bleeding on both sides,

6.1.5 Loose black (dead) knots, holes, loose joints or blocking cracks in the veneer layers,

6.1.6 Overlapping of the veneer layers (folding).

The following can be permitted:

6.1.7 Up to three healthy tight knots of 15 mm diameter maximum for each side of the panel,

6.1.8 Up to three knots of 25 mm diameter maximum on each side of the panel which have been perfectly repaired,

6.1.9 Up to three cracks of the veneer edge which have been perfectly repaired. The cracks may be up to 1/10 of the panel length and on each side of the panel,

6.1.10 Small local edge flaws up to 3 cm length do not have to be considered.

Only one of the defects mentioned in 6.1.7, 6.1.8 and 6.1.9 can be present.

7. Repairs

7.1 Repairs may be carried out on the finished, pressed boatbuilding plywood panels to a limited extent, provided that the quality of the panel is not impaired in any way. The repairs are to be carried out at the appropriate temperature under pressing power with a glue which is resistant to water and weather.

7.2 Shakes of up to 1/10 of the panel length and 1 mm width, and small knot holes up to 5 mm, may be repaired with wood putty of the same color.

7.3 Wider shakes and defects of up to 1/10 of the panel length are to be bonded so that they are weather-resistant. In doing so, care is to be taken when fitting and selecting the strips such that they are from appropriate timber and have the same color. The repair work is to be carried out under pressure in accordance with DIN 68705-2 BFU 100.

8. Surface treatment

8.1 After pressing, the plywood panels are to be subjected to sufficient soaking to ensure that their moisture content again rises to 6 - 12 %. The plywood panels may either remain unsanded or be lightly sanded.

8.2 The outer layers of the plywood panels cut to their final dimensions are to be at least 1.0 mm (after the pressing and sanding) at the thinnest point. When sanding the panels, special care is to be taken to ensure that this requirement is met.

9. Panel dimensions

9.1 The dimensions of the plywood panels are specified by the customer if standard dimensions are not used (see B.2.3).

10. Testing

10.1 General

10.1.1 In general, the finished boatbuilding plywood panels are tested and approved at the manufacturing shop by surveyor of **TL.**

10.1.2 The inspection of finished plywood panels outside of the manufacturing shop is carried out by **TL** only by way of exception and under stricter test conditions.

10.1.3 **TL** reserves the right to also monitor the production of the plywood panels in the manufacturing shop.

10.2 Inspection of the plywood panels

10.2.1 The condition of all boatbuilding plywood panels is inspected and tested by **TL** surveyors after their completion. In particular, attention is paid to bonding. The panels are allocated to the appropriate plywood strength group and grade, depending on the type of plywood and the quality and stamped.

10.2.2 The plywood panels submitted to **TL** for inspection is to be examined, pre-graded, finished and then divided into test batches or orders by the manufacturer prior to inspection by the **TL** surveyor. Panels with faulty gluing are examined more closely to determine whether the faults are locally or present over the whole panel. If the latter is true, the entire test batch is tested with special care. If there are several such panels in a test batch, then the entire batch is rejected. If leaky joints or blocking cracks are found at the plywood edges of the inner layers, then these defects are not to be plugged before the **TL** inspection. The **TL** surveyor will decide whether these defects can be corrected, or whether the panel is to be rejected or assigned to grade II.

10.3 Grading of the plywood panels

Grading of the panels are to be in accordance with the differences between grades I and II stipulated in C,5. The panels are marked with the appropriate grade stamp.

10.4 Sampling

10.4.1 For the inspection of boatbuilding plywood panels, sample panels are taken from test batch intended for inspection and provided with a sample number.

10.4.2 Test pieces of approx. 25 cm length and 100 cm width are removed from these sample panels and provided with the sample number of the test panel.

10.4.3 The required samples are prepared from these sample pieces, and again provided with the sample numbers of the test panel.

10.4.4 If only a few panels of a particular plywood type, or very thick and large panels, are submitted for inspection, and if the effort involved in cutting these panels appears to be too great, then samples can also be taken from pieces cut off the edge of these panels. For this purpose, it is necessary, when trimming these panels, to put the edge cuttings aside.

10.4.5 The number of test panels is determined according to the following factors:

10.4.5.1 If continuous inspections by **TL** in the manufacturing shop show that the production of the boatbuilding plywood panels appears to be reliable, and if the production is monitored continuously by suitable, automatic facilities or supervision, then it is not necessary to take test panels from each test batch.

10.4.5.2 It is sufficient to select approximately 2 % (by number) of the panels from the current production to be used as samples.

10.4.5.3 It is to be ensured that the test panels cover all plywood thicknesses and types.

10.4.5.4 If production problems occur, or if the **TL** surveyor has the impression that the production is not always reliable, then the surveyor can insist on the selection a greater number of test panels.

10.4.5.5 If one or several test panels should exhibit inadequate values during the inspection, then an additional two panels from the same test batch are to be tested. If, once again, the minimum requirements are not satisfied during this inspection, then the complete test batch is to be rejected.

10.5 Sample type and quantity

From every test panel (or test strip) to be tested, the following samples are to be taken and prepared:

10.5.1 Two samples for the delamination test in order to determine, in accordance with DIN 53255, the bonding strength of the glue.

10.5.2 Eight samples in accordance with DIN 53255 for the adhesive tensile lap-shear test to check the delamination test. Simple tensile lap-shear samples are to be used in accordance with Fig. 12.1.

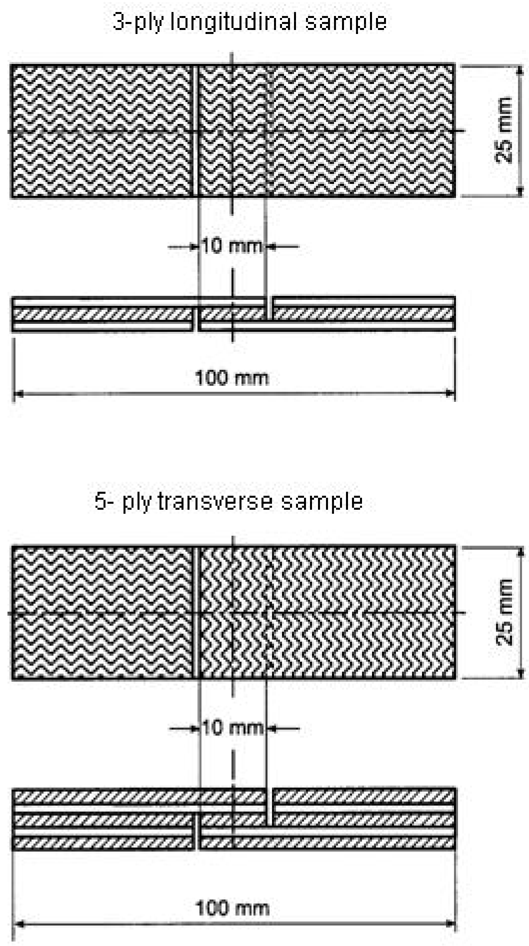


Fig. 12.1 Typical representation of a 3-ply longitudinal and a 5-ply transverse tensile lap-shear sample

10.5.3 Six samples for the longitudinal strength test and six samples for the transverse strength test to determine the plywood tensile strengths in accordance with DIN 52377.

10.5.4 Two kiln-dried samples for the determination of the moisture content of the plywood and the specific weight (apparent density) in accordance with ISO 16979.

10.6 Pre-treatment and testing of the samples

10.6.1 Glue bonding strength samples

10.6.1.1 Two delamination samples and eight tensile lap-shear samples are used for testing the bonding strength of the glue.

10.6.1.2 Before testing, these samples are to be subject to a boiling/drying alternation test and a short-time test BFU 100 in accordance with DIN 68705-2 and is to satisfy the following test conditions.

10.6.1.3 Storage of the samples in boiling water with intermediate drying at 60 °C in the following cycle:

4 hours boiling
16 hours drying
4 hours boiling
2 hours cooling under water at 20°C

10.6.1.4 The two delamination samples are to be subjected to a delamination test after this pre-treatment. The bonding is to offer considerable resistance to the forceful delamination of the veneers by means of a delamination tool, and the fracture area is to exhibit wood fracture and flawless bonding.

10.6.1.5 The eight tensile lap-shear samples are to be tested in a wet condition in the testing machine and shall satisfy the following minimum values:

For timber of the strength group F1:
at least 1.5 N/mm^2

For timber of the strength group F2:
at least 1.2 N/mm^2

10.6.2 Plywood strength test

10.6.2.1 The six longitudinal tensile-strength samples and the six transverse tensile-strength samples are to undergo acclimatization prior to testing in the testing equipment and their moisture content is to be adjusted to 12 - 15 %.

10.6.2.2 From each of the six samples, three longitudinal and three transverse samples are to be tested in the testing machine and the average strength value determined for these three samples.

10.6.2.3 The two batches of three remaining samples serve as replacement samples for those samples which exhibit fractures at the clamping device with insufficient values. The fractured samples are then not to be used for evaluation purposes.

10.6.2.4 The samples are to have the minimum plywood strengths as specified in Table 12.2.

10.6.2.5 Plywood made from other types of timber is to be included in the strength group with which its properties comply.

10.6.2.6 If the production and the plywood strength at a manufacturing shop is continually monitored by **TL** and if the determination of the plywood strength of individual test batches is considered to be irrelevant, then the inspection and determination of the plywood strengths of these test batches can be waived.

10.6.2.7 If plywood panels of the timber and strength group F1 do not achieve the required minimum plywood strength values of this group, then these panels can be assigned to the plywood strength group F2 and stamped accordingly.

10.6.2.8 All boatbuilding plywood panels which are manufactured according to special specifications and conditions of the customers, or which deviate from **TL** rules, are stamped according to their plywood type and strength group. The deviations or special features of such plywood panels are to be recorded in the test certificate.

10.6.3 Moisture test

10.6.3.1 The two kiln-dried samples are used for determining the moisture content of plywood. They shall be examined in accordance with ISO 16979. The moisture content of the plywood is to be 5 - 12 % ex works.

10.6.3.2 Measurements of the moisture content of plywood by means of electrical measuring instruments can only be approved if check measurements using the kiln-dried samples have shown approximately identical values.

10.6.4 Determination of specific weight

10.6.4.1 For the determination of the specific weight of the plywood panels, the two kiln-dried samples are to be measured and weighed as precisely as possible in dry-air conditions before the kiln-drying.

10.6.5 Inspection of the plywood scarf jointing

The plywood scarf jointing is to be carried out in accordance with the conditions specified in E.2. and bonded with glues approved by **TL** under pressing power and pressing temperature without any flaws. The bonding of the scarf joint is to be checked by bending the panels over a test frame or a roller. If the scarf joints appear to be of doubtful quality, then this bending test is to be performed for both sides of the panels.

10.6.6 Additional tests

If for any reason the **TL** surveyor has any doubts regarding the production and in particular the bonding of the plywood panels and its scarf jointing, then he is to be entitled to subject the test batch to additional tests of his choice, e. g. prising-open tests, knocking-off tests, bending tests, warping tests, soaking tests etc.

11. Marking and stamping

11.1 All boatbuilding plywood panels inspected by **TL** surveyors and found to be in order are to be provided with the following stamping to identify the plywood type, grade and production:

- Stamping by the manufacturer:
  - Sign or mark of the manufacturing shop
  - Size and thickness of the panel the plywood thickness is given in mm, the length and width of the panel in cm. The first dimension indicates the length of the panel in the longitudinal fibre direction of the outer layers.
  - Timber used for the outer and inner layers (separated by a dash).
  - Bonding type: "BFU 100"

The panels may be stamped neutrally, i. e. without the manufacturer's details, if explicitly so required by the customer.

- Stamping by **TL**:
  - A rectangular **TL** stamp, with the following details
  - Boatbuilding plywood
  - Strength group
  - Plywood grade I (or II)
  - Türk Loydu
  - Testing date
  - Respective certificate

As a rule, the stamping is to be applied on the bottom right of that side of the panel which is of lesser quality (i. e. on the back).

11.2 In the case of long scarf-jointed panels, the **TL** stamp is to be made on both ends of the panel.

11.3 Since inspection is only carried out randomly, the inspector is entitled to reject panels which have already been stamped, if they should prove to be defective.

12. Certificates

12.1 Türk Loydu issues certificates for boatbuilding plywood panels which have been tested and approved, and these certificates are given to the manufacturer or customer.

12.2 The certificate shows, among other things, the plywood types, the number of plywood panels inspected, the stamp and, if requested, the average values of the test results.

13. Storage of the plywood panels

13.1 Finished plywood panels which are placed in storage is to be kept in closed rooms and stored horizontally.

13.2 The plywood panels are only to be placed in horizontal stores that are at least 30 cm above the ground and from the walls, in order to avoid the effects of moisture.

13.3 The individual stacks are to be protected against moisture from one side by covering panels.

13.4 Non-compliance with these storage requirements can lead to previous tests being declared invalid.

D. Plywood for Aircraft

1. General

1.1 The plywood consists of at least three transversely veneer layers (Table 12.3). The bonding is with curable synthetic resin adhesives. The resistance of the adhesives to water and weather is to be demonstrated by long-term and outdoor testing.

1.2 Independence of the testing by Türk Loydu, the manufacturer is obliged to carry out his own shop-based quality control of all working steps continually, the selection of the wood and its processing during production of the plywood panels.

1.3 The points listed under B.2 are to be taken into account.

Table 12.3 Minimum number and thickness of the veneer layers

Plywood thickness [mm]	Minimum number of veneer layers	Remarks
Up to 2	3	No layer is to be thicker than 2 mm
From 2 to 6	5	
From 6 to 14	7	
Over 14	⩾9	

2. Structure

2.1 The selection of the timber and the structure of the panels (number of veneer layers) are to be appropriate for the field of application.

2.2 The veneer layers are to be symmetrical around the middle layer, both with respect to the grain as well as to the thickness of the layers.

2.3 The thicknesses are to be selected in such a way that, as far as possible, the same strength is ensured in the longitudinal and lateral direction. **TL** reserves the right to exclude any panels with an unsuitable structure from the testing.

2.4 Table 12.3 gives a list of the required minimum number and thickness of the veneer layers

2.5 Birch, beech, alder, okume (gaboon) or other timber may be used, provided that the properties of the respective timber strength group are ensured.

2.6 Only binding agents (adhesives) authorized by **TL** may be used.

2.7 Surface treatment

2.7.1 The panels may be manufactured as unsanded, lightly sanded, scoured, smoothed, resined or unresined.

2.7.2 The outer layers are stil to be thick enough after processing so that reliable subsequent processing is ensured.

3. Veneer Joints

3.1 Unless otherwise agreed between contractor and manufacturer, panels bonded with synthetic-resin adhesive may have veneer joints parallel to fibre direction in the middle and outer layers.

3.2 The joints are to be sealed perfectly and bond the veneers to each other by butt joints. The joints are to be glued on a suitable joint bonding machine.

3.3 The joints of the various veneer layers are to be staggered.

3.4 The strips of veneer of the outer layers are to be put together so that they match with regard to timber and color.

3.5 Paper or plastic adhesive strips may not be used to secure or repair inner veneer layers.

3.6 Metal clamps used for securing purposes may only be positioned on the edges of the panels. They are on no account to remain on the panels when they are cut to standard dimensions.

4. Strength Groups

4.1 With regard to their suitability for the production of aviation plywood, the timbers listed in Table 12.4 currently approved; these have been divided into two strength groups.

4.2 In the case of panels over 3 mm thick, these values may be reduced by a maximum of 10 %.

4.3 Other types of wood may only be used for making plywood panels upon agreement with **TL**. The manufacturer is always to remain responsible for the correct selection of the quality and type of wood.

5. Plywood Grades

5.1 Plywood of the two strength groups is subdivided into two grades after inspecting its external and internal quality. In relation to their respective groups, grades I and II are identical with regard to type of wood, strength, production and bonding. They differ insofar that the panels of grade I can be used completely, while the panels of grade II are restricted to partial use because of local manufacturing defects or timber flaws.

5.2 The defects of grade II are to be limited to one third of the panel area. Two thirds of the panel area to be free of defects and suitable for use. The defects are identified during inspection by marking.

5.3 The visible side of the plywood panel is to be manufactured virtually without any defects and, furthermore, the quality, color and grain is to be combined in such a manner that they match. The hidden-surface may have small color differences or slight blemishes which do not influence the strength of the panel.

Table 12.4 Strength groups

Timber	Strength group	Mean tensile strength of plywood MPa [N/mm^2]		
		Longitudinal	Transverse	Long. + transv. (added)
Birch	F1	⩾ 70	⩾ 45	⩾ 140
Beech		⩾ 70	⩾ 45	⩾ 140
Alder		⩾ 70	⩾ 45	⩾ 140
Okume (Gaboon)	F2	⩾ 45	⩾ 30	⩾ 90
Poplar		⩾ 45	⩾ 30	⩾ 90

6. Defects

6.1 The following wood and production defects are not permissible in the outer and inner veneer layers:

- Loose, pith knots, rotten knots, holes in the middle layers,

- Firm knots over 6 mm diameter,

- In the case of three-ply panels, more than four knots per m^2 in one layer,

- A distance of less than 200 mm between the knots,

- In the case of five- or multi-ply panels, more than six knots in one layer and less than 150 mm distance between the knots.

  If the panel sizes are different to those specified above, the number of the permissible knots changes in accordance with the area. Knots up to 30 mm from the edge do not have to be taken into consideration.

- Short-grained, curly-grained and cross-grained wood, variegated appearance and discolorations, and mould stains if they decrease the strength and bending capability significantly.

  Small signs of mould stains as well as bark specks do not have to be taken into consideration.

  Short-grained or curly-grained wood covers such wood whose grain is interrupted and which has different growth directions.

- Knot and shake scars and intergrown knots.

Furthermore, the following manufacturing errors are not allowed:

- Joints which transgress the defined type, and inserted pieces (shims)

- Unbonded, open and badly closed joints

- Folds and shakes, breaks, peeling defects and bubbles as well as other such defects which decrease the strength of the panel.

  (Up to three instances of damage, folds or shakes less than 30 mm from the edge of the panel do not have to be taken into consideration if they are not on opposite sides of the panel.)

- Corrugated or bent panels

- Areas without binding agent, e.g. damage to the film of glue, insofar as these areas were not covered

- Heavy glue bleeding on more than one side of a panel

7. Testing

7.1.1 In general, the finished plywood panels are tested and approved at the manufacturing shop by a surveyor of **TL**.

7.1.2 The inspection of finished plywood panels outside of the manufacturing shop is carried out by **TL** only by way of exception and under stricter testing conditions.

7.1.3 **TL** reserves the right to also monitor the production of the plywood panels in the manufacturing shop.

7.2 Inspection of the plywood panels

7.2.1 With respect to structure, and in particular bonding, all plywood panels are examined by **TL** and carefully tested after their completion by a **TL** surveyor. The panels are assigned, depending on the plywood type and quality, to the appropriate plywood strength group and grade. They are then graded and provided with the appropriate group and grade stamp.

7.2.2 The plywood panels submitted to **TL** for inspection shall be examined, pre-graded, finished and then divided into test batches or orders by the manufacturer prior to **TL** inspection. Panels with faulty gluing are examined more closely to determine whether they are only limited locally or are present over the whole panel. If the latter is true, the entire test batch is tested with special care. If there are several such panels in a test batch, then the entire batch is rejected. If leaky joints or blocking cracks are found at the plywood edges of the inner layers, then these defects are not to be plugged before the **TL** inspection and decision of the **TL** surveyor as to whether these defects can be corrected, or whether the panel is to be rejected or assigned to grade II.

7.3 Grading of the plywood panels

7.3.1 Grading the panels are to be in accordance with the differences between grades I and II specified in D,5. The panels are marked with the appropriate grade stamp.

7.4 Sampling

7.4.1 For the inspection of the plywood panels, test panels are taken from the test batch submitted for inspection and provided with a sample number.

7.4.2 Test pieces of approx. 25 cm length and 100 cm width are removed from these sample panels and provided with the sample number of the test panel.

7.4.3 From these test pieces, the required samples are prepared and again provided with the sample number of the test panel.

7.4.4 If only a few panels of a particular plywood type, or very thick and large panels, are submitted for inspection, and if the effort involved in cutting these panels appears to be too great, then samples can also be taken from pieces cut off the edge of these panels. For this purpose, it is necessary, when trimming these panels, to put the edge cuttings aside.

7.4.5 The number of test panels is determined according to the following factors:

7.4.5.1 If continuous inspections by **TL** in the manufacturing shop show that the production of the plywood panels appears to be reliable, and if the production is monitored continuously by suitable, automatic facilities or supervision, then it is not necessary to take test panels from each test batch.

7.4.5.2 It is sufficient to select approximately 2 % (by number) of the panels from the current production to be used as samples.

7.4.5.3 It is to be ensured that test panels cover all plywood thicknesses and types.

7.4.5.4 If production problems occur, or if the **TL** surveyor has the impression that the production is not always reliable, then the surveyor can insist on the selection of a greater number of test panels.

7.4.5.5 If one or several test panels should exhibit inadequate values during the inspection, then an additional two panels from the same test batch are to be tested. If, once again, the minimum requirements are not satisfied during this inspection, then the complete test batch is to be rejected.

7.5 General quality of the panels

7.5.1 The general quality at the panels are to be determined by an external examination.

7.5.2 The internal quality is to be examined against the light provided by a suitable source of illumination of sufficient intensity in a well darkened room.

7.5.3 All panels up to a thickness which allows examination against light are to be subject to this inspection:

- Light timber, e.g. birch: up to 3.0 mm thickness,
- Darker timber, such as beech or okumé (gaboon): up to 1.5 mm thickness.

7.6 Thickness deviations

Deviations in production, especially with regard to the thickness, are to comply with the requirements of the customer. If no other specifications exist, then the values listed in B.2 are to be used.

7.7 Moisture test

7.7.1 Two kiln-drying samples are used for determining the moisture of plywood. This is to be done in accordance with EN 322. The moisture content of the plywood is to be 5 - 12 % ex works.

7.7.2 Measurements of the moisture content of plywood by means of electrical measuring instruments can only be approved if check measurements using the kiln-dried samples have shown approximately identical values.

7.8 Tensile strength

7.8.1 The strength of at least three samples parallel to and three samples at right angles to the fibre direction of the outer layers of each test panel is to be determined by means of tensile testing in a calibrated testing machine.

7.8.2 The tensile strength is to be determined in accordance with DIN 52377, using the test pieces specified therein.

7.8.3 The average value of the results for the same test panel is taken as the result of the test.

7.9 Tensile lap-shear test

7.9.1 The tensile lap-shear test is to be carried out in accordance with DIN 53255.

7.9.2 The tensile lap-shear strength is to be determined with at least five samples from each test panel in a wet condition by shearing off the bonded area in a calibrated testing machine, as well as with two boiling samples of 10 cm x 10 cm dimensions:

- Samples for 3-ply panels in accordance with Fig. 12.2.
- Samples for 5-ply panels in accordance with Figs. 12.3 and 12.6.
- Samples for 7-ply panels in accordance with Figs. 12.4 and 12.7.
- Samples for 9-ply panels in accordance with Fig. 12.5.

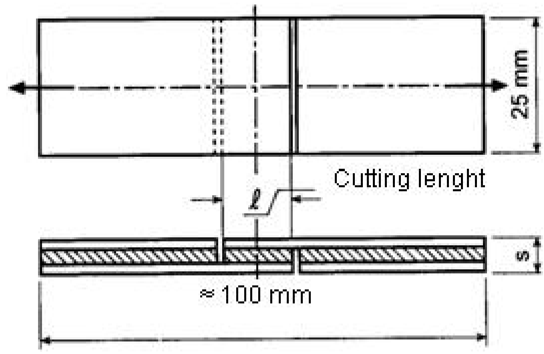


Fig. 12.2 Longitudinal sample for a 3-ply plywood panel

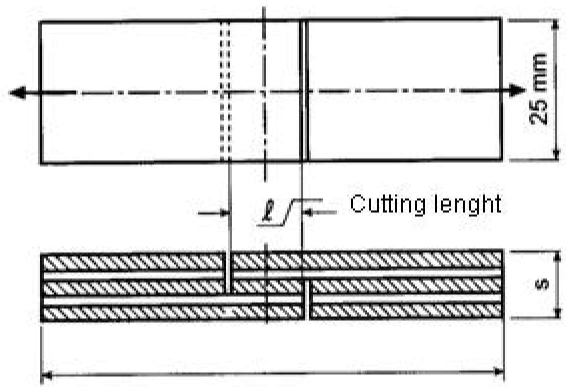


Fig. 12.3 Transverse sample for a 5-ply plywood panel

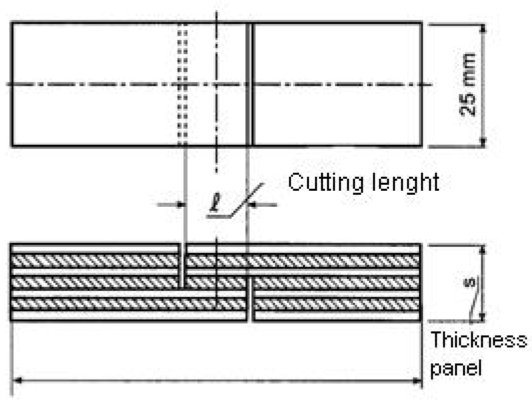


Fig. 12.4 Longitudinal sample for a 7-ply plywood panel

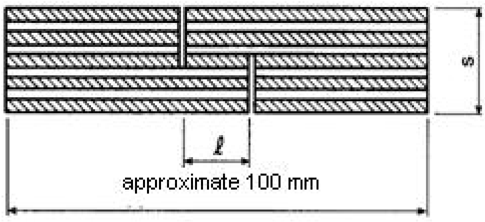


Fig. 12.5 Transverse sample for a 9-ply plywood panel

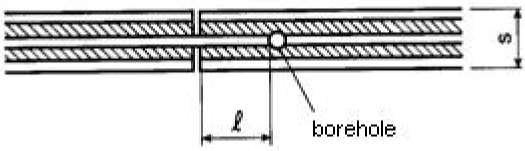


Fig. 12.6 Longitudinal sample for a 5-ply plywood panel

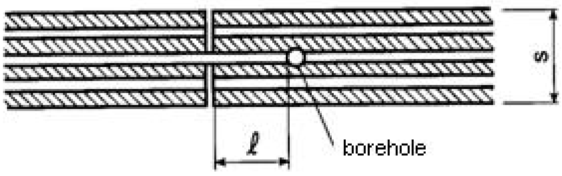


Fig. 12.7 Transverse sample for a 7-ply plywood panel

7.9.3 Recommended values for the routing lengths of the adhesive samples

The tested bonding area is to be small enough so that no wood shake occurs, and on the other hand is to be large enough so that the layers do not detach themselves too easily. See Table 12.5 for recommended lengths.

7.9.4 Adhesive samples of 5-ply and multi-ply panels having thin veneer thickness which cannot, or cannot easily, be penetrated in accordance with Figs. 12.6 and 12.7, is to be prepared in accordance with Figs. 12.3, 12.4 and 12.6; however, the fibres of the outer layers are to be in the transverse direction in the case of 5-ply panels, and parallel to the longitudinal direction of the sample in the case of 7-ply panels. Routing of three or four layers is to be performed on each side.

7.9.5 The samples shall have been immersed in water prior to the test for a sufficient period of time to ensure complete soaking.

Recommended values for soaking at room temperature (15 - 20 °C):

- 24 hours for samples up to 2 mm thickness,
- For thicknesses greater than 2 mm, the required time is determined by linear extrapolation.

Soaking of the samples may be substituted by three hours of boiling (three-hour immersion in boiling water).

7.9.6 The strength after soaking or after boiling of the samples is to be determined in a wet state and shall be at least 2 N/mm^2.

7.9.7 Isolated values may be up to 10 % below this requirement.

Table 12.5 Recommended values for routing lengths

Panel thickness = s in mm	Up to 0.8	12	1.5	3	4	5	6	8	10-14	16-20
Cutting length = ℓ mm	3	4	5	5	6	7	8	9	10	12
Glue surface for the samples acc. Fig. 12.2, 12.3, 12.4 and 12.5 = Cutting length 1 x width of sample, Glue surface for the samples acc. Fig. 12.6 and 12.7 = 2 x cutting length 1 x width of sample.										

7.9.8 In addition, a three-hour boiling test is to be performed twice on two 10 cm x 10 cm samples from each test panel. The samples are to be first boiled for three hours in water and then dried at 60 °C. After this, they are again to be boiled for three hours, cooled in warm water for two hours at 20 °C and then, in a wet state, is to either be manually or with suitable equipment bent several times back and forth until they break. In doing so, there shall be no sign of loosening of the individual veneer layers, no embrittlement or unfavourable appearance of the glue joint.

7.9.9 If the **TL** surveyor notices anything unusual in this respect, the Surveyor is then to increase the number of the tests and carry them out on the panels in question.

7.9.10 In the case of bonding with phenolic resin, boiling tests may be omitted at the discretion of the **TL** surveyor.

7.10 Additional tests

7.10.1 If the **TL** surveyor has any doubts regarding the production and, in particular, the correct bonding of the plywood panels and its scarf jointing, then the Surveyor is authorized to subject the test batch to additional tests.

For example: prising-open tests, knocking-off tests, bending tests, warping tests, soaking tests etc.

8. Marking and Stamping

8.1 Each panel which satisfies these Rules and is approved is to be provided with the following stamp:

8.1.1 Stamping by the manufacturer:

- Sign or mark of the manufacturer,
- Thickness of the panel in mm and the timber used.
- Letters which identify the type of bonding e.g.

T = Bonded with Tego film

PH = Bonded with phenolic resin

M = Bonded with melamine resin

R = Bonded with resorcinol resin

As an alternative, the type of bonding can be identified by "BFU 100".

8.1.2 Stamping by Türk Loydu

- A stamp that identifies the grade TL 1 or 2, the number of the test batch and the year of testing
- The stamps are to be applied by means of a roller stamp diagonally across the panel on the side of lesser quality.

8.2 Since inspection is only carried out randomly, the surveyor is entitled to reject panels which have already been stamped, if they should prove to be defective.

8.3 **TL** is entitled to stop providing stamps if production defects occur continually.

9. Certificates

9.1 Türk Loydu issues certificates for tested and approved plywood panels, and these certificates are handed over to the manufacturer or customer.

9.2 The certificate specifies, among other things, the plywood type, the number of plywood panels inspected, the stamping and, if requested, the average values of the test results.

10. Storage of the Plywood Panels

10.1 Finished plywood panels placed in storage are to be kept in closed rooms.

10.2 The plywood panels are only to be placed in horizontal stores that are at least 30 cm above the ground and from the walls, in order to avoid the effects of moisture.

10.3 The individual stacks are to be protected against moisture from one side by covering panels.

10.4 Non-compliance with these storage requirements can lead to previous tests being declared invalid.

E. Joining of Wood Materials

1. Laminated and Multilayered Components

1.1 In order to reduce variations in the characteristic values of wood and therefore to arrive at reasonable safety factors to be applied in designing structural elements, the wood is homogenized by means of lamination. Laminated components are bonded components consisting of individual layers (at least three) of sawn timber which have the same grain direction.

1.2 Multilayered components are bonded components in which the individual layers (at least three) consist of sawn timber and have different grain directions. The thickness of the individual laminates depends on the shape of the components to be laminated. However, the laminate thicknesses shall not, if possible, be less than 5 mm and are to not exceed 25 mm in the case of curved parts. In the case of straight parts, the laminate thickness is not to be more than 40 mm.

1.3 Adhesives may only be used that are resistant to cold and boiling water and that in the bonded joint have the same strength as that of the wood (see also C. and D.). A precondition for the carrying out of gluing procedures is the availability in the workshops of temperature and humidity controls as well as clamping facilities.

1.4 The moisture of the wood is to be 12 -15 % at the time of bonding; but must not exceed 18 %. Efforts are to be made to keep the glued joint as thin as possible (0.1 - 0.2 mm).

1.5 Since transverse compressive stresses during subsequent swelling of the wood are less damaging than transverse tensile stresses brought about by subsequent volume contraction, it is recommended that the timber be dried to an average moisture content that is the same as, or just below, the average moisture content of the component,

1.6 If adhesives on a formaldehyde basis are used (e.g. for boatbuilding timber), then a pre-drying time for the moist joining surface for 5 - 10 minutes may be necessary to enable low-molecular substances to escape.

1.7 Sufficiently long clamping times is to be adhered to, depending on the bonding temperature. In the case of curved or welded parts, the clamping time shall be extended accordingly.

2. Scarf Jointing

2.1 The joint ends are to be precisely joined in order to avoid faulty gluing or other defects.

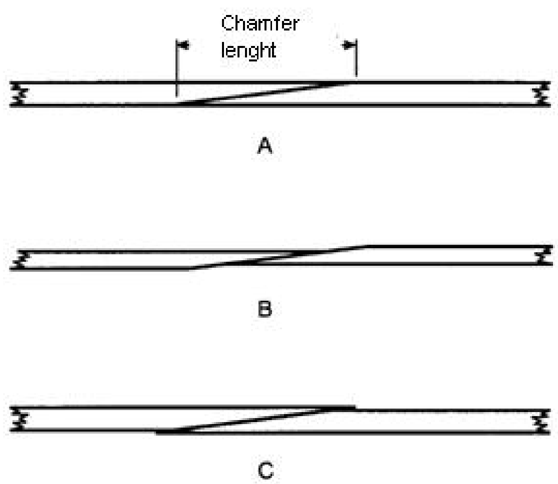


Figure 12.8 Scarf joints across the thickness

2.2 Fig. 12.8.A illustrates the correct method. Fig. 12.8.B depicts the incorrect method; it is especially unsuitable, as faulty gluing occurs frequently because of insufficient pressing power. The method illustrated in Fig. 12.8.C is also wrong and causes a variety of defects. In this case, particularly when sanding plywood panels down until they are smooth, the outer layers are sanded away excessively.

2.3 The minimum pressing power is not to fall below 4 kg/cm^2.

2.4 Glued scarf-jointing of solid wood is to have a chamfer length which is eight times the panel thickness.

2.5 For glued scarf-jointing of plywood, the ratio of the plywood thickness to chamfer length is to be as follows.

- For panels up to 10 mm: at least 1:10

- For panels over 10 mm: at least 1:8

2.6 Further information for other bonding methods see related standards.

F. Wood Protection

1. All timbers (with the exception of the timber of the durability group I, Table 12.2) are to be protected by several coats of suitable protective paint, or by means of impregnation with a proven wood preservative, against fungi and insect infestation. Impregnation is the preferred method for interior surfaces of the boat's components which are exposed to water or weather (outer e.g. skin, deck, superstructure) and which have received a coat of paint impervious to vapor pressure.

2. All plywood parts are to be protected by several coats of paint or varnish. Special attention is to be paid to plywood edges and drill-holes by pretreating them with recognized and proven edge protection coatings.

G. Requirement for the Core Materials of Sandwich Laminates Cross-Cut Balsa Wood (1)

1. General

1.1 For material approval, the basic conditions listed in Section 13, is to apply.

1.2 A general description of the core material is to be provided. The basic properties are to be verified through the test certificate of a recognized testing body

2. Specification

2.1 The following details are required for a general description:

- Commercial name,

- Treatment of the wood,

- Storage conditions

2.2 Through the test certificate of a recognized testing body, the following values are to be verified:

- Raw density (DIN 52182), 3 samples

- Moisture content (ISO 16979), 3 samples

- Compressive strength II, ⊥ (DIN 52185) 6 samples

- Modulus of elasticity (compression) II, ⊥ (DIN 52185), 6 samples

- Shear strength (DIN 53294), 6 samples

- Shear modulus (DIN 53294), 6 samples

II is parallel to the grain, and

⊥ is perpendicular to the grain of the wood)

2.3 The following is to apply as minimum properties:

- Apparent density	96 kg/m^3
- Compressive strength II	5.0 MPa
- Compressive strength ⊥	10.4 MPa
- Modulus of elasticity (compression) II	2275MPa

(1) *Cross – cut or cross-grained wood is timber which has been cut cross the grain.*

- Modulus of elasticity (compression) ⊥ 35 MPa
- Shear strength 1.1 MPa
- Shear modulus 105 MPa

2.4 The moisture content is to be 12 ±2 %.

2.5 The tests are to be performed on samples which exhibit none of the flaws which are still permissible for processing. The surfaces must be plane and sanded. As the testing environment, the standard climate 23/50 (23 °C / 50 % relative humidity) is to be used.

SECTION 13

FIBRE REINFORCED PLASTICS

A. Requirements for Materials and Production

1. Definitions

1.1 Fibre-reinforced plastics (FRP)

Heterogeneous materials, consisting of a thermosetting resin as the matrix and an embedded reinforcing material.

1.2 Thermosetting resin

Two-component mixture consisting of resin and hardener as well as possible additives.

1.3 Reinforcing materials

Materials generally in the form of fibre products which are embedded in a matrix in order to improve certain properties. In doing so, fibres of different materials displaying isotropic or anisotropic properties are processed in the form of semi-finished textile products (mats, rovings, fabrics, non-wovens). For special requirements, mixtures of different fibre materials are also used (hybrids).

1.4 Prepreg

Reinforcing material which is pre-impregnated with a thermosetting resin which can be processed without any further addition of resin or hardener.

1.5 Laminate

A moulded part which is manufactured by placing layers of reinforcing material on top of each other together with the thermosetting resin.

1.6 Sandwich laminate

Two laminate layers connected together by means of an intermediate core of a lighter material.

2. Materials

2.1 Thermosetting resin

Depending on the purpose, and consequently the requirement, a distinction is made between laminating resin and coating resin. Compatibility shall be demonstrated for the combination of gelcoat and laminating resin if the basic formulation of the resins are not the same.

2.1.1 Gelcoat and topcoat resin

Gelcoat and topcoat resins is to protect the surface of the laminate from mechanical damage and environmental influences.

Therefore, in a cured stage, the resin is to have a high resistance to existing media (e.g. fuel, river and sea water), to maritime and industrial environments), and to abrasion, in addition to low water absorption capabilities. Thixotropic agents and coloring pigments are the only permitted additives for gelcoat resins. In topcoat resins, additives for low styrene evaporation are also permitted.

2.1.2 Laminating resin

Laminating resins are to have good impregnation characteristics when being processed. In a cured stage, they are to be resistant to fuels, river and sea water, and exhibit a high resistance to ageing. Furthermore, adequate resistance to hydrolysis is to be ensured when used with permissible additives and filling materials. When using unsaturated polyesters (UP) as the resin, the resistance to hydrolysis is to be significantly higher than that of standard UP resin (for example through the use of a resin with an isophtalic acid basis).

2.1.3 Additives

2.1.3.1 All additives (catalysts, accelerators, filling materials, coloring pigments etc.) are to be suitable for the thermosetting resin and are to be compatible with it as well as the other additives, such that a complete curing of the resin can be ensured. The additives are to be dispersed carefully throughout the resin, in accordance with the guidelines of the manufacturer.

2.1.3.2 Catalysts, which initiate the hardening process, and accelerators, which control the working time (pot life, gel-time) and the cure time, are to be used in accordance with the processing guidelines provided by the manufacturer. For cold-setting systems, catalysts are to be proportioned in such a way that complete curing is ensured between temperatures of 16 °C and 25 °C. Cold-setting systems that are to cure at temperatures outside of this range, as well as warm-curing systems, may be used after consultation with **TL.**

2.1.3.3 Filling materials are not significantly to impair the properties of the cured resin. The type and quantity of the filling materials s to be approved by **TL** and is not to lead to non-compliance with the minimum properties of the resin In general, the proportion of filling materials in the laminating resin compound is not to exceed 12 % by weight (including a maximum of 1,5 % by weight of the thixotropic agent). If a smaller value is specified by the manufacturer, this value is to apply. The proportion of thixotropic agent in the gelcoat resin compound is not to exceed 3 % by weight. Laminates used for fuel and water tanks are not to contain filling materials.

2.1.3.4 Coloring pigments are to be climate-proof and consist of inorganic or non-fading organic dyes. The maximum permissible proportion is not to exceed the value specified by the manufacturer; if no value is specified, then it is not to exceed 5 % by weight.

2.2 Reinforcing materials

2.2.1 Various types of reinforcing materials with filaments of glass or carbon are available:

Roving: A large number of parallel filaments placed together with or without twisting.

Mat: Irregular layering of continuous filaments (fleeces), or chopped rovings (minimum 50 mm long) which are joined together by means of a binder.

Fabric: Rovings woven together by means of the weaving techniques used in the textile industry, such as binding cloth, satin, body, atlas etc. Different materials and/or filament thicknesses are possible for warp and weft.

Non-woven fabric: Unidirectional layers of fibres which are laid on each other in an arbitrary manner. The layers are fixed by thin fibre strands, either together or on mats. Different materials and/or filament thicknesses are possible in the individual layers.

2.2.2 Fibre surface treatment with sizing, coupling agents or finish is to be matched to the thermosetting resin, in order to ensure adequate material properties, also under the influence of media.

2.2.3 Only low-alkaline aluminium boron silicate glass may be used for glass fibres (alkali oxide content ≤ 1%), e.g. E-glass in accordance with VDE 0334/Part 1, 9.72, Section 4.

2.3 Core materials for sandwich constructions

2.3.1 It is to be demonstrated that the core materials used are suitable for the intended purpose. They are not to impair the curing of the laminating resin.

2.3.2 The joining surfaces of local reinforcements made of metallic materials (e.g. inlets, connections) are to be cleaned in the same manner as for a gluing process, in order to ensure optimal bonding (cf. DIN 53281).

2.3.3 Core materials other than those listed below may be used, provided that they are suitable for the intended purpose and that this is accepted by **TL** beforehand.

2.3.4 Rigid foam materials

Rigid foam materials which are used as core material for sandwich laminates, or as shear webs, are to be of a closed-cell type and have high resistance against the laminating resin or the adhesive, as well as against ageing, fuels, river and sea water. A low water absorption capability is required, together with a minimum apparent density of 60 kg/m^3.

It is to be ensured that the allowable temperature of foam material is not exceeded during the curing reaction (exothermic reaction).

2.3.5 End-grained balsa wood

End-grained balsa wood used as core material for sandwich laminates are to fulfill the following requirements. It is to

- have immediately been treated after felling against attack by fungi and insects,
- be sterilized and homogenized,
- be kiln-dried within 10 days after felling, and
- have an average moisture content of maximum 12 %.

2.4 Prepregs

Fibre reinforcements pre-impregnated with laminating resin shall satisfy the requirements placed on their components. In addition, a minimum resin content of 35 % by volume is to be ensured, as well as adequate tack at the processing temperature.

2.5 Adhesives

2.5.1 When bonding fibre-reinforced plastics together, or with other materials, only solvent-free adhesives are to be used. Preference is to be given to two-component reaction adhesives, if possible with the same basis as the laminating resin.

2.5.2 Laminates are only to be bonded in the cured state. Hot-setting adhesives generally attain a higher strength; however, the maximum allowable temperature of the materials to be bonded is not to be exceeded. This applies especially when using single-component hot-melt adhesive.

2.5.3 The adhesives are to be used in accordance with the processing guidelines issued by the manufacturer. They are not to affect the materials to be bonded and exhibit a high resistance to humidity and ageing. The influence of the operating temperature on the adhesive strength is to be small.

2.5.4 Adhesives are to be usable within a minimum temperature range of -20° to +60°C.

3. Approval of Materials

3.1 All materials to be used during production of components from FRP are first to be assessed and approved by **TL**. Approval by other organizations can be recognized following agreement by **TL**, provided that the tests required for approval are in accordance with o **TL** requirements.

3.2 The manufacturer and/or supplier of the material is to apply to **TL** for approval

3.3 Approval is granted if the material fulfils the requirements of **TL**. For this purpose, specific tests are necessary, and they are either to be carried out under supervision of **TL** or the results are to be documented in the report of a recognized testing institute.

3.4 Before production starts, the required material approvals are to be submitted to **TL.** If no approvals, or not all required approvals have been obtained, then as an exception and following agreement with **TL**, proof of the properties of the basic material can be demonstrated as part of material testing of the component laminate.

3.5 The packaging or wrapping material is to bear a reference to the approval.

4. Requirements for Manufacturers

4.1 General

4.1.1 Manufacture of FRP-components is only to be performed by workshops which are approved by **TL** for the manufacture of components made from fibre-reinforced thermosetting resins.

4.1.2 The manufacture of FRP-components is only to be carried out by persons with sufficient professional knowledge. This professional knowledge is in general to be verified by certificates of the corresponding training courses. If such certificates are not available, the minimum requirement is to consist of training completed for a technical profession, in conjunction with internal training and several months of experience.

4.1.3 The shop approval is granted by **TL** on the basis of the written application and the report submitted by the **TL** surveyor. The report deals with the following points:

- General information on the shop,
- Personnel,
- Internal quality management,
- Incoming inspection,
- Storage of the materials in the shop and during field work,
- Mechanical processing capabilities,
- Production equipment.

4.1.4 All manufacturing facilities, store-rooms and their operational equipment are to fulfill the requirements of the responsible safety authorities and professional employers liability insurance associations. The manufacturer is exclusively responsible for compliance with these requirements.

4.1.5 The danger of contamination of laminating materials is to be minimized through separation of production facilities from store-rooms.

4.1.6 During laminating and bonding in the laminating shop, no dust-generating machinery is to be operated nor any painting or spraying operations carried out. As a matter of principle, such work is to take place in separate rooms.

4.2 Laminating workshops

4.2.1 Laminating workshops are to be closed spaces capable of being heated and having supply and exhaust ventilation. During laminating and curing, a room temperature of between 16 °C and 25 °C and a maximum relative humidity of 70 % is to be maintained, provided that the manufacturer of the laminating resin compound does not specify otherwise.

4.2.2 In order to control the climatic conditions, thermographs and hydrographs are to be provided. The equipment is to be set up following agreement with **TL**, their number and arrangement depending on operational conditions. The equipment is to be calibrated in accordance with statutory regulations. The recordings are to be kept for at least 10 years and submitted to **TL** on request.

4.2.3 Ventilation facilities are to be arranged in such a manner that no inadmissible amounts of solvents are removed from the laminate, and also that no inadmissible workplace concentrations (MAK values) occur.

4.2.4 The workplaces are to be illuminated adequately and suitably, but at the same time precautionary measures shall be taken to ensure that the controlled curing of the laminating resin compound is neither impaired through sunlight nor lighting equipment.

4.3 Storage-rooms

4.3.1 Laminating resins are to be stored in accordance with the manufacturer's instructions. If no such instructions are provided, then they are to be stored in dark, dry rooms at a temperature between 10 °C and 18°C. The temperature of the storage-rooms is to be recorded continuously by means of thermographs.

4.3.2 Prepregs are to be stored in special cold-storage rooms in accordance with the manufacturer's instructions.

4.3.3 Hardeners, catalysts and accelerators are to be stored separately in well-ventilated rooms in accordance with the manufacturer's instructions. If no instructions are provided, they are to be stored in dark, dry rooms at temperatures between 10 °C and 18 °C.

4.3.4 Reinforcing materials, fillers and additives are to be stored in closed containers, in dry and dustfree conditions.

4.3.5 Storage is to be arranged in such a way that the identification of the materials, their storage conditions and maximum period of storage (expiry date) as prescribed by the manufacturer are clearly visible. Materials whose duration of storage exceeds the expiry date are to be removed immediately from the stores.

4.3.6 Quantities of materials due to be processed are to be brought to the production shops as early as possible to ensure complete adjustment to the processing temperature (Δt≤2°C), with the containers remaining closed.

4.3.7 Materials taken from the stores and partially used are only to be replaced in the stores in special cases (e.g. hot-curing prepregs) and with the consent of **TL**.

5. Guidelines for Processing

5.1 General

5.1.1 As a matter of principle, only materials approved by **TL** are to be used. In addition to the choice of suitable and approved materials, special care is to be taken when working with them because of the great influence on the properties of the product.

5.1.2 For the preparation and processing of the resin compounds and reinforcing material, these rules, the instructions issued by the material manufacturers and the regulations of the local authorities are also to be observed.

5.1.3 Resin, hardener and resin additives are to be mixed in such a way as to ensure a uniform distribution and to minimize the amount of air introduced into the mixture as far as possible. A degassing of the resin compound may be necessary in individual cases.

5.1.4 During lamination, the processing time of the prepared resin compound specified by the manufacturer is not to be exceeded. If such a time is not specified, the pot-life is to be determined by means of a preliminary test and the processing time then established in consultation with **TL**.

5.1.5 It is not possible to cover all types of moulds and processing methods in detail. Deviations are therefore possible for special cases with the consent of **TL**.

5.2 Requirements for moulds

5.2.1 The moulds are to be made of a suitable material that, on the one hand, has adequate stiffness to prevent inadmissible deformations while laminating or curing, and on the other hand has no influence on the curing of the laminate. Moulds made of FRP may be used only after complete curing and subsequent tempering.

5.2.2 In the case of moulds for products which are made using vacuum bags, absolute air tightness of the mould is additionally to be ensured.

5.2.3 The surface of the moulds is to be as smooth as possible and shall have no sharp edges. The mould is to be designed in such a way as to permit flawless removal of the product from the mould.

5.2.4 Before commencing with the laminating, the surface of the components is to be treated with a sufficient quantity of a suitable release agent and brought up to the temperature required for lamination. The surfaces are to be dry and free of dust. It is not permissible to use release agents with a silicon base.

5.3 Building up the laminate

5.3.1 If the surface protection is to be achieved by providing a gelcoat, then the gelcoat resin compound is to be applied with a uniform thickness of between 0,4 and 0,6 mm, using a suitable process.

5.3.2 The first laminate layer is to be applied as soon as possible after application of the gelcoat. A fibre mat or fabric with low weight per unit area and a high resin content is to be used (e.g. for glass fibres: a maximum of 450 g/m^2 and a maximum of 30 % glass by weight).

5.3.3 The laminate is to be built up in accordance with the approved technical documentation, whereby **TL** is to be consulted about the method.

Air is to be removed adequately from the reinforcing layers and these layers are to be compacted in such a manner to ensure that the required proportion of resin is achieved. Resin enrichment is to be avoided.

5.3.4 The maximum thickness of the material that can be cured at one time is determined by the maximum permissible heat development. In the case of vacuum bagging, as a rule, the decisive factor is the maximum number of layers from which air can still be totally removed.

5.3.5 If a laminating process is interrupted for a period causing the base laminate resin to exceed the point of gelation, a test is to be performed to verify adhesion between the base laminate and the top laminate.

For each resin system, under the given processing conditions, the permissible period of interruption of the laminating process is to be determined. In the event of this period being exceeded, the laminate is to be thoroughly ground in order to provide a surface exhibiting adequate adhesion properties after removal of the dust. For UP resins on an orthophthalic acid and standard glycol basis not containing any skin-forming agents a 48 h interruption on the laminating process may, without any further proof being furnished, be considered uncritical with respect to lamination.

5.3.6 When grinding laminates containing resins with low styrene evaporation as the matrix system, the surface is to be removed down to the mat layer. In order to ensure that no skin-forming agent elements (e.g. paraffins) will be left on the surface, the surface is finally to be polished using new abrasive paper. The same procedure is also to be applied when treating the surfaces of materials to be bonded.

5.3.7 Transitions between different thicknesses of laminate is to be made gradually. A minimum value (for glass fabric in the fibre direction) of 25 mm per 600 g/m^2 reinforcing material can be used. In the transition region from a sandwich construction to a solid laminate, the core material is to be tapered with a gradient of not more than 1 : 3.

5.3.8 If cutting of reinforcing layers is unavoidable in the case of complicated mouldings, then the cut edges is to overlap, or reinforcement strips are to be provided. In the butt or seam region of laminates, every reinforcing layer is to overlap by at least 25 mm. per 600 g/m^2.

5.3.9 Different components may be laminated together only while they are not fully cured. Special attention is to be paid to crossings of laminates.

5.3.10 Parallel or insert linings are to be free of all moisture and pollution (dirt). Their bonding surfaces with the laminate are to be prepared in a suitable manner (roughening, coupling agent or similar).

5.4 Glass-fibre resin spraying

Glass-fibre resin spraying, a partly mechanical method of lamination by hand, requires fulfilment of the following specific requirements:

5.4.1 The equipment to be used is to be demonstrated before use and its suitability proven.

5.4.2 The qualification of the fibre-resin sprayer, and where appropriate his assistant, is to be demonstrated to **TL** by means of procedure test.

5.4.3 The equipment is to be calibrated in accordance with the guidelines of the manufacturer.

Calibration is to be checked regularly before fibre-resin spraying, but the very least at the beginning of every production day.

5.4.4 The length of a roving cut is to be between 25 mm. and 50 mm.

5.4.5 A powder-bound textile glass mat of maximum 450 g/m^2 is to be used for the first laminate layer. The glass part of this layer (to be applied manually) is to be less than 30 % by weight.

5.4.6 The glass weight per unit area of the spray laminate layer of a combined laminate is to not exceed 1150 g/m^2.

5.4.7 After a maximum of 1150 g/m^2 of fibres have been sprayed, air is to be removed and the composite is to be compacted.

5.4.8 Tests are to be performed on a regular basis to check whether a uniform laying up of the reinforced layers as well as a uniform distribution of percentage glass weight has been achieved. **TL** reserves the right to demand test pieces to check the resulting mechanical properties.

5.5 Curing and tempering

5.5.1 Completed components may only be taken from the moulds after adequate curing of the thermosetting resin compounds. The required cure time generally depends on the manufacturer's instructions. Otherwise, a minimum cure time of 12 hours at 20 °C shall be observed for cold-setting systems.

5.5.2 Resin systems which cure under pressure, UV radiation and/or increased temperature are to be treated in accordance with the manufacturer's instructions.

5.5.3 Immediately after curing, the components should receive post-treatment at increased temperature (tempering). The tempering time depends on the resin in question and the temperature attained within the component during tempering, whereby this is to be below the temperature for dimensional stability under heat and is to be agreed on with **TL**. Cold-setting systems which are not subsequently tempered is to be stored for 30 days at a temperature of 16 °C, and for correspondingly shorter periods at temperatures up to 25 °C. This period can be shortened with the consent of **TL**, provided the relevant manufacturer's specifications regarding post-curing are available, or post-curing values exist which are supported by experimental results. If such values are not available, then in general the following tempering conditions can be used (polyester/epoxy resin):

at least 16 h at 40 °C / 50 °C or
at least 9 h at 50 °C / 60 °C

5.6 Adhesive bonding

5.6.1 Adhesive joints

5.6.1.1 Adhesive joints for load-bearing parts are generally to be verified by tests to be agreed on for each individual case, unless comparable experience is available.

Note :
Particularly in the case of highly thixotropic adhesives, prior proof of their suitability is to be given with due consideration of the production process.

5.6.1.2 A specification for production and testing is to be compiled for the adhesive joints of load-bearing structures. In particular, the nominal values and tolerances of adhesive-layer thicknesses as well as the maximum size and extent of permissible flaws is to be defined. The adhesive layer thicknesses, tolerances and the maximum size and extent of permissible flaws is to be considered during the computational verification of the adhesive joint.

5.6.1.3 Only adhesives with confirmed properties may be used for bonding. The adhesives may not have any negative effects on the materials to be joined.

5.6.1.4 The possibility of contact corrosion (bond-line corrosionis to be countered by suitable means.

5.6.1.5 If FRP components are to be bonded and a resin system differing from the laminating system is used, the components are to be totally cured before bonding.

5.6.2 Assembly process

5.6.2.1 The various surface pretreatments for synthetic materials and metals are for example compiled in VDI 2229 and VDI 3821.

5.6.2.2 The surfaces of the materials to be bonded together are to be dry and free of release agents (wax, grease, oil etc.), impurities (dust, rust etc.) and solvents. Especially when using solvents for cleaning purposes, compatibility with the material and sufficient ventilation time is to be ensured.

5.6.2.3 Smooth surfaces are to be roughened either mechanically (rough-grinding, sand-blasting etc.) or chemically by etching. It is absolutely necessary that layers on the surface of the materials to be bonded that exert a negative effect on the bonding process (e.g. skin-forming additives in polyester resins or residues of peel ply in the case of FRP, or oxide layers in the case of aluminium) be removed.

5.6.2.4 In many cases, an increase in the strength of the bonded connection can be achieved by the use of specially matched primers. The use of primers is particularly recommended for bonded joints which later in service are relatively heavily stressed by environmental influences.

5.6.2.5 The adhesive is to be processed in accordance with the manufacturer's instructions; the proportion of fillers may not exceed the permitted limit. When mixing the adhesive, its constituents are to be mixed in such a way that they are evenly distributed, care being taken to beat in as little air as possible.

5.6.2.6 The adhesive is to be applied evenly and as bubble-free as possible to the materials to be joined. If highly thixotropic adhesives are used, it is advisable to apply a thin undercoat of the corresponding pure resin to the surfaces to be joined.

5.6.2.7 Following application of the adhesive, the materials to be joined are to be brought together without delay and fixed in place.

5.6.2.8 A loading of the adhesive joint before the adhesive has cured sufficiently is inadmissible. For all adhesive joints with thermosetting adhesives, subsequent tempering of the joint is recommended; in the case of cold-curing adhesives, tempering is necessary as a rule.

5.6.2.9 After curing, the adhesive joint is to be protected by suitable means against penetration by extraneous media (e.g. moisture).

6. Manufacturing Surveillance

6.1 General

6.1.1 For components made of FRP, manufacturing surveillance consists of the quality control of the basic materials, production surveillance and the quality inspection of the finished components.

6.1.2 In the case of manufacturing surveillance, a distinction is made between internal and third-party (external) surveillance. In the sense of these rules, third-party surveillance means periodic and random checks by **TL** of the internal surveillance as well as of the component quality.

6.1.3 **TL** reserves the right to carry out inspections in the production facilities without giving prior notice. The manufacturer is to grant inspectors access to all areas used for production, storage and testing and is to present all documentation concerning records and tests carried out.

6.1.4 The scope of third-party surveillance can be reduced in the case of production facilities that have a certified quality management system.

6.2 Incoming inspection

6.2.1 The characteristic values and properties of the materials are to be verified by the manufacturer by means of inspection documents.

The following inspection documents according to EN 10204 (ISO 10474) are required as a minimum:

EN 10204-2.2	Fibre products, gelcoat resins, paints
EN 10204-2.3	Laminating resins, prepregs, core materials, adhesives

6.2.2 During the incoming inspection, the goods are at least to be checked for any damage and for compliance of the details in the certificates with the requirements. Material values are to be checked by random sampling.

6.2.3 The goods are to be stored in accordance with the requirements of the manufacturer and these Rules.

6.3 Production surveillance

6.3.1 Details of the production process are to be laid down by specifications which also contain specimen documents for production and testing of the components. The tasks and responsibility of the production and quality control departments are to be defined clearly.

6.3.2 As the work progresses, the individual production steps are to be signed by the employees responsible for each stage on the basis of the prescribed documentation.

6.3.3 The individuals entrusted with production are to be trained in accordance with their task, and work under professionally qualified supervision. In the case of adhesive joints, the responsible supervisors are to have an appropriate qualification in adhesives, and the individuals performing the work are to have undergone suitable training.

6.3.4 The batch numbers of the materials used in the component are to be given in the production documentation, in order that they can be traced back to the manufacturer if need be. Reinforcing layers introduced into the laminate are to be checked off immediately during the production process, with indication of the fibre direction.

6.3.5 From every batch of reaction resin compound, a sample is to be taken and tested. If mixing is performed continuously, one sample per batch and production step is sufficient. These samples are to be randomly checked for their degree of curing. The results are to be recorded.

6.3.6 On request by **TL**, reference laminates of about 50 x 50 cm is to be produced in parallel. This is to result in confirmation of the material values used as a basis for the strength calculations.

6.4 Structural tests

6.4.1 During production and on completion of production, the component is to be subjected to visual inspections. In particular, attention is to be paid to voids, delamination, warping, discoloration, damage etc. In addition, the general quality, e. g. surface finish, is to be assessed.

6.4.2 By means of suitable testing procedures, the quality of the components is to be determined, if possible during production, and at the latest on completion of production. Special attention is to be paid to the bonding and to the degree of curing of the component.

6.4.3 Following agreement with **TL**, individual or random tests are to be carried out on finished components under static and/or dynamic loads.

B. Inspection and Testing of Fibre Composite Materials

1. Requirements

1.1 General

1.1.1 In accordance with the Rules and Guidelines of **TL**, the materials used for manufacturing components made of FRP under the supervision of **TL** is to be approved by **TL**. Approvals are granted for the following materials:

- Gelcoat and/or laminating resins,
- Reinforcing materials,
- Prepregs,
- Core materials,
- Adhesives.

1.1.2 Applications for approval by Türk Loydu Head Office **TL** is to be made by the material manufacturer or an agent. Together with the application, the following is to be submitted :

- Product description,
- Safety data sheet,
- Storage and processing instructions,
- Copy of the test certificate of a recognized testing body, i.e. an accredited testing laboratory or a notified testing body,
- A declaration in writing by the applicant that the tested materials comply with those for which the approval is requested, and that the sample is manufactured in accordance with the Rules and Guidelines of **TL,**

1.1.3 The tests are to be carried out in accordance with the standards mentioned in this rule. However, comparable standards of other countries are also acceptable after agreement with **TL** in each individual case.

1.1.4 The minimum properties required by **TL** for the tests **TL** are to be fulfilled by all specimens.

1.1.5 In the case of inadequate test results of individual specimens, attention is to be paid to the following (for a basic number of 6 tests):

- If one or two specimens yield inadequate results, the tests are to be repeated with twice as many specimens.

- If the test results are inadequate for three or more specimens, the test can be repeated on newly produced specimens, provided that **TL** agrees to this.

- If even one sample yields inadequate results while repeat-testing, then approval is not possible.

1.1.6 If the material fulfils the **TL** requirements, then a statement of material approval is issued by **TL**. This is generally valid for four years, whereby extensions are possible.

1.1.7 **TL** is to be notified immediately of all modifications or other changes to the material. Decisions regarding the further validity of the material approval is made on an individual basis.

1.1.8 A constant material quality is to be provided by the manufacturer through suitable QM measures. If this is not ensured, **TL** reserves the right to suspend, or withdraw, the approval.

1.1.9 **TL** reserves the right to demand and/or carry out spot tests of the material properties during the period required for material approval. If, in doing so, there is no adequate comparison with the required values, the material approval can be suspended or withdrawn by **TL.**

1.1.10 The approval refers only to the approved material. The applicability of this material in connection with other approved materials is to be demonstrated independently by the manufacturer, or the user, in a suitable manner. In cases of doubt, **TL** reserves the right to require a check of the properties of the material combination.

1.2 Thermosetting resins

1.2.1 General

1.2.1.1 The basic requirements listed under 1,1. apply for material approval.

1.2.1.2 A general description of the thermosetting resin, its processing conditions as well as the properties of resin in the processing state is to be submitted. The basic properties of the cured thermosetting resin are to be verified by the test certificate of a recognized testing body. These values are to fulfill specified minimum requirements.

1.2.1.3 Cold-setting unsaturated polyester (UP) resins and cold-setting epoxy (EP) resins are specifically described below. Other types of resins can also be approved after consultation with **TL**, whereby the required minimum properties are specified by **TL** on an individual basis. However, they are at least to comply with those of UP resins.

1.2.2 Description

1.2.2.1 A description of the thermosetting resin is to be submitted in order to allow an unequivocal identification:

- Resin type and state,

- Purpose,

- Manufacturer,

- Trade name.

1.2.2.2 In addition, the following is to be indicated:

- Storage conditions,
- Environmental conditions for processing,
- Type and proportion of allowed additives,
- Curing conditions, tempering.

1.2.3 Properties in the processing state and during curing

1.2.3.1 The properties are to be determined in accordance with the following standards:

- Density (DIN EN ISO 1675)
- Viscosity (DIN 53015 - DIN EN ISO 2555)
- Reactivity:

  UP resins: acid number
  (DIN EN ISO 2114)

  EP resins: epoxy equivalent
  (DIN EN ISO 3001)
- WP resins: Monomer proportion (DIN EN ISO 3251)
- Gel time (temperature increase)
  (DIN 16945, Section 6.2, 6.3 - DIN EN ISO 2535)
- Curing shrinkage (DIN 16945, Section 6.5)

1.2.4 Properties in the cured state

1.2.4.1 The following properties are to be submitted for all thermosetting resins in the cured state:

- Density,
- Water absorption,
- Strength, modulus of elasticity in tension, and tensile fracture strain,
- Strength and modulus of elasticity in bending,
- Dimensional stability under heat.

1.2.4.2 For gelcoat and topcoat resins, the following additional information is to be submitted:

- Abrasion resistance
  (DIN 53754 - ISO 9352) 3 samples
- Resistance against seawater, fuels, hydraulic oil, weak acids and alkalis (DIN EN ISO 175)

1.2.4.3 With regard to the properties, the following is to be verified by the test certificate of a recognized testing body. For this purpose, specimens are to be used which are produced in accordance with the submitted processing guidelines. The specimens are to be cured and tempered for 16 h at 40 °C (polyester resins) or 16 h at 50 °C (epoxy resins). For gelcoat and topcoat resins, only the first four properties are to be verified:

- Density (DIN EN ISO 1183, method A), 3 specimens
- Water absorption (following DIN EN ISO 175, Specimen 50 mm x 50 mm x 4), 3 specimens
- Dimensional stability under heat
  (DIN EN ISO 75-2, method A), 3 specimens
- Tensile strength, fracture strain, modulus of elasticity in tension (DIN EN ISO 527-2, test piece 1 B), 6 specimens
- Bending strength
  (DIN EN ISO 178), 6 specimens
- Modulus of elasticity in bending (DIN EN ISO 178), 3 specimens

1.2.4.4 The mechanical properties are normally determined at standard climate 23/50 (23 °C / 50 % relative humidity). If the intended operating temperature range of the resin is not between - 20 °C and + 50 °C, further testing temperatures are to be agreed on with **TL**.

1.2.4.5 The testing speed in the case of tensile and bending tests is to be selected in such a way that a specimen or edge-fibre strain of about 1 % / min is ensured. This is to be documented in the test report. The modulus of elasticity is to be determined as a secant modulus between 0,05 % and 0,25 % strain. The water absorption is to be specifically determined at 23°C after 24 ± 1 h and 168 ± 2 h.

1.2.5 Minimum properties

1.2.5.1 For resin products consisting of UP resins, the following minimum properties are specified for use as laminating resins (values for gelcoat resins in brackets):

Tensile strength:	40 MPa	(-)
Fracture strain	%2,0	(%3,0)
Modulus of elasticity (tension)	2700 Mpa [N/mm^2]	(-)
Bending strength	80 MPa [N/mm^2]	(-)
Dimensional stability under heat:	60°C	(60°C)

The water absorption after 168 h is not to exceed 70 mg for laminating resins and 60 mg for gelcoat resins.

1.2.5.2 The following minimum properties apply to resin products consisting of EP resins :

Tensile strength:	55 MPa [N/mm^2]	(-)
Fracture strain	%2,5	(%3,5)
Modulus of elasticity	2700 MPa[N/mm^2]	(-)
Bending strength:	100 MPa [N/mm^2]	(-)
Dimensional stability under heat:	70°C	(70°C)

The water absorption after 168 h for laminating and gelcoat resins is to not exceed 50 mg.

1.2.5.3 The abrasion resistance properties and the resistance properties to extraneous media in the case of gelcoat resins may be determined by the applicant.

- The abrasion resistance determined in the test (sliding abrasion rate) shall be adequate.

- The properties stipulated in DIN ISO 175 are to be determined after 24 h and 168 h at 23 °C. Taking these properties into account and following agreement between **TL** and the applicant, the following classification is made:

  - Resistant,
  - Conditionally resistant,
  - Not resistant.

1.3 Reinforcing materials

1.3.1 General

1.3.1.1 The basic requirements listed under 1.1 apply for material approval.

1.3.1.2 A general description of the reinforcing material and of the filament is to be provided. Basic properties of laminate specimens taken from the reinforcing material are to be verified by the test certificate of a recognized testing body. These values are to fulfill specified minimum requirements.

1.3.1.3 The following applies to fibre reinforcements made of glass and carbon. Products with other reinforcing fibres, e.g. aramide, can also be approved, following agreement with **TL**, whereby the minimum properties are then specified on an individual basis.

1.3.1.4 Due to the great number of the fibre reinforcing products on the market, only the most common ones can be listed. Products not covered (e.g. complexes, hybrids), can also be approved, following agreement with **TL.**

1.3.2 Description

1.3.2.1 A description is necessary which allows an unequivocal identification of the reinforcing material:

- Fibre material,
- Reinforcement type (mat, fabric etc.),
- Manufacturer,
- Trade name.

1.3.2.2 In addition, the following is required:

- Form of supply,
- Storage conditions,
- Processing instructions.

1.3.2.3 The filament and its treatment/sizing is to be submitted:

- Filament diameter (DIN 53811 - ISO 137),
- Coupling agreed or sizing,
- Resin compatibility.

In the case of glass fibre products, the average filament diameter is to be at maximum 19 μm.

1.3.2.4 In the case of reinforcing products consisting of a combination of different fibre materials and/or filaments, all fibre types are to be indicated.

1.3.2.5 If, in the case of textile glass reinforcing products, no E-glass or R-glass is used in accordance with DIN 1259-1, then an alkali oxide content (DIN ISO 719) of less than 1 % is to be verified by means of a test certificate from a recognized testing body.

1.3.3 Properties of the reinforcing products

1.3.3.1 Rovings

- Number of the filaments in the roving
- Roving fineness (ISO 4602)

When rovings are used as gun rovings (ISO 3375), the stiffness is to be additionally verified by the certificate of a recognized testing body.

1.3.3.2 Mats (continuous and chopped-strand mats)

- Fibre length (for chopped-strand mats),
- Linear density of the fibre (ISO 1889),
- Weight per unit area (ISO 3374),
- Layer thickness (ISO 3616),
- Binder (see 1.3.3.5).

1.3.3.3 Fabric

- Linear density of the fibres, warpwise and weftwise (ISO 1889),
- Count, warpwise and weftwise (DIN EN 1049-2),
- Weight per unit area (ISO 3374),
- Fabric thickness (ISO 4603),
- Weave (DIN 61101-1).

1.3.3.4 Non-woven fabric

- Lay up,
- Weight per unit area of the individual layers and of the non-woven fabric (ISO 3374),
- Non-woven fabric thickness (ISO 4603),
- Binder (see 3.3.5).

In addition if a non-woven fabric contains mat or fabric layers, then the linear density and, where appropriate, the fibre length is to be indicated.

1.3.3.5 A difference is to be made between chemical and mechanical bond types. In the case of chemical bond types, the binder, the percentage weight (glass ISO 1887, carbon DIN 29965) and its solubility (DIN 52332) is to be indicated. In the case of mechanical bond types, the type of weave is to be indicated.

1.3.3.6 In the case of reinforcing products with different fibre materials, the percentages of materials used in the respective reinforcing directions is to be indicated.

1.3.4 Laminate properties of the reinforcing products

1.3.4.1 For laminate production, it is strongly recommended that **TL**-approved cold-setting UP resins are to be used. After curing, the specimens are to be tempered for 16 h at 40 °C. If, for special reasons, other (also warm-setting) thermosetting resins are to be used, then this is to be agreed in advance by **TL**.

1.3.4.2 For rovings, tensile test specimens are to be prepared for all fibre materials in accordance with DIN 29965, Section 4.1.3.5. The test certificate of a recognized testing body is to all be submitted to verify the tensile strength, the fracture strain and the modulus of elasticity as the mean values from six tests carried out in accordance with DIN 65382. Furthermore, the tensile strength and the modulus of elasticity is to ll be determined in accordance with DIN 65469 on flat specimens prepared for testing under tension.

1.3.4.3 For all other reinforcing products, laminate test panels are to be prepared in accordance with DIN EN 2374, Section 5.3 (Method C). In doing so, the reinforcing products are to be arranged in identical alignment. Depending on number of the reinforcing directions, the laminates are to have approximately the following thicknesses: unidirectional laminates 2 mm, bidirectional laminates 4 mm. and multi-directional laminates 5 mm.

1.3.4.4 Appropriate test panels are to be prepared by fibre resin spraying for the use of gun rovings. The length of the gun rovings in this case is to be 35 mm.

1.3.4.5 The gun prescribed number of specimens is to be cut out of the test panels for each test. In doing so, specimens are to be taken from each reinforcing direction of the laminate in order to test the mechanical properties. For products with randomly distributed reinforcing directions, specimens are to be taken from any two directions, but at right angles to each other.

1.3.4.6 The specimens are to be tested in accordance with ISO 291 after at least 16 h under standard climate conditions.

1.3.4.7 The following properties are to be verified by the test certificate of a recognized testing body:

- Fibre content (ISO 1887, carbon DIN EN 2564), 3 specimens,

- Tensile strength, fracture strain, modulus of elasticity in tension (DIN EN ISO 527-4, test piece III), 6 specimens,

- Bending strength, modulus of elasticity in bending (DIN EN ISO 14125, Method A), 6 specimens.

Deviating from the standard the modulus of elasticity in tension is to be determined as a secant modulus between 10 % and 50 % of the fracture strain.

In addition, for carbon fibres, the compressive strength and the modulus of elasticity in compression is to be demonstrated.

1.3.4.8 The testing speeds are to be selected in such a way to ensure a strain rate of 1 % / min in the test piece or the edge fibre. The testing speed is to be indicated.

1.3.4.9 Testing is to be carried out in a standard climate 23/50 (23 °C / 50 % relative humidity). If the operating temperatures of the fibres are not between -20 °C and +50 °C, then additional testing temperatures is to be agreed on with **TL**.

1.3.5 Minimum properties

1.3.5.1 For approval, fibre reinforced products are to fulfill specified minimum values for the mechanical properties. The influence of the fibre volume content on the properties has been taken into account when specifying the values. The values refer to the 0° direction in the case of a uniform lay up. If necessary, a correction to the actual lay up is to be done.

1.3.5.2 The minimum values of all mechanical properties to be verified are determined by means of the following equation together with the values given in Table.13.1:

$$X_{min} = \alpha \left[X_{ref} \left(\frac{\varphi}{0,4} \right) \right]$$

X_{min} = Minimum required value,

X_{ref} = Reference value for fibre volume content φ=0,4,

α = Factor for lay-up,

φ = Fibre volume content $0,2 \le \varphi \le 0,6$.

Deviations from the above specification are allowed for laminates with glass mats or gun rovings; in these cases, the minimum values for a percentage fibre weight content of $0,25 \le \psi \le 0,35$: are:

- Tensile strength:

  $R_Z = 1278\ \psi^2 - 510\psi + 123$ [MPa],

- Young's modulus (tension),

  $E = (37\ \psi - 4,75)10^3$ [MPa],

- Bending strength,

  $R_B = 502\ \psi^2 + 106,8$ [MPa],

1.3.5.3 In the case of multidirectional lay up of the reinforcing products, the values are to be proved at least for one direction (preferably 0°).

1.3.5.4 For reinforcing products with different fibre materials in one direction, the values of the material with the lower minimum properties are to be fulfilled.

1.3.5.5 The minimum values for fabric are 95 % of the specified values for 0° / 90° lay up.

1.3.5.6 The stiffness of the gun rovings to be verified in accordance with DIN 52316 is to not be below 130 mm.

1.3.5.7 The linear relationship between the property and fibre volume content assumed when specifying minimum values does not apply for all properties, and are therefore not to be used to extrapolate measured values.

1.4 Prepregs

1.4.1 General

1.4.1.1 The basic requirements listed under 1.1 are to apply for material approval.

1.4.1.2 Since prepregs are based on resin systems which cure under heat, consultation with **TL** concerning the curing process of the resins is required.

1.4.1.3 The testing of cured prepreg laminates is identical with the laminate testing of fibre reinforced products. Taking into account the resin system, the minimum characteristic values are to be agreed on with **TL**.

1.4.1.4 Unidirectional non-woven prepregs and woven prepregs are considered within the framework of these Rules. Other prepregs can also be approved, following agreement with **TL**.

1.4.2 Prepreg properties

1.4.2.1 A description is necessary which allows an unequivocal identification of the prepreg:

- Fibre material,
- Resin system,
- Reinforcement type,
- Trade name,
- Manufacturer,
- Storage conditions, processing guidelines.

Table 13.1 Coefficients for the determination of the minimum properties

Fibre	Properties	X_{ref} [MPa]	α			
			0°	**0°/90°**	**0°/±45°**	**0°/90°/±45°**
Glass	Tensile strength	500	1,00	0,55	0,50	0,45
	Young's Modulus of elasticity	26.000	1,00	0,67	0,57	0,55
	Bending strength	650	1,00	0,55	0,45	0,40
Carbon	Tensile strength	900	1,00	0,55	0,50	0,45
	Modulus of elasticity	80.000	1,00	0,55	0,45	0,42
	Bending strength	725	1,00	0,55	0,45	0,40
	Compressive strength	600	1,00	0,55	0,50	0,45
	Modulus of elasticity compression	70.000	1,00	0,55	0,50	0,45

1.4.2.2 The following properties are to be submitted for the non-cured prepreg material:

- Mass per unit area (DIN EN 12127)
- Resin percentage by weight (DIN 29971, Section 5.1.1.4)
- Layer thickness (DIN 53885)
- Resin flux percentage by weight (DIN 65090, Section 5.1.1)

1.4.2.3 The following are necessary for the reinforcing material:

- Filament diameter (DIN 53811 - ISO 137),
- Count (DIN EN 1049-2),
- Bond type (only woven prepregs).

1.5 Core materials

1.5.1 General

1.5.1.1 The basic requirements listed under 1.1 are to apply for material approval.

1.5.1.2 A general description of the core material is to be submitted. The basic properties are to be verified by the test certificate of a recognized testing body.

1.5.1.3 Rigid foam materials and cross-grained balsa are considered specifically as a core material within the framework of these Rules. Cores made of other materials can also be approved, following agreement with **TL**.

1.5.2 Rigid foams

1.5.2.1 The following information is necessary for a general description:

- Basic material and additives,
- Trade name,
- Manufacturer,
- Resin systems suitable for bonding/coating,
- Storage conditions.

1.5.2.2 The manufacturer is to provide details of the maximum permissible processing temperatures and the operating temperature limits. The long-term operating temperature is to at least cover the range -20 °C to +50 °C.

1.5.2.3 The test certificate of a recognized testing body verifying the following properties is to be submitted:

- Apparent density (ISO 845);
  sample thickness ≥ 25 mm, 3 specimens
- Water absorption (ISO 2896), 3 specimens
- Compressive strength (ISO 844), 6 specimens, vertical to the plane of the test panel
- Modulus of elasticity (compression) (ISO 844), 3 specimens, test piece III, vertical to the plate plane of the panel
- Shear strength (DIN 53294), 6 specimens
- Shear modulus (DIN 53294), 6 specimens

1.5.2.4 The specimens are to be tested without foam skin. The testing shall take place in a standard climate 23/50 (23°C/50 % relative humidity). Testing procedures are given mainly for rigid foams, whereas in the case of tough foams **TL** is to be consulted if there is any doubt.

1.5.2.5 The following minimum properties are specified for an apparent density of 60 kg/m^3 and 200 kg/m^3.

	60 kg/m^3	**200 kg/m^3**
Compressive strength [MPa]	0,6	3,5
Modulus of elasticity (compression) [MPa]	40	200
Shear strength [MPa]	0,5	2,6
Shear modulus [MPa]	15	65
Water absorption (vol.%) (after 28 days)	2	2

1.5.2.6 In the case of other apparent densities, linear interpolation of the densities are to be used to determine strengths and moduli.

1.5.3 Cross-grained balsa wood

1.5.3.1 The requirements for cross-grained balsa wood are specified in Section 12.

1.5.3.2 Adhesion of balsa wood is not to be impaired by impregnation.

1.6 Adhesives

1.6.1 General

1.6.1.1 The basic requirements listed under 1.1 are to apply for material approval.

1.6.1.2 A general description of the adhesive is to be provided. Basic properties of the cured adhesive are to be verified by the test certificate of a recognized testing body.

1.6.1.3 The following specifically considers cold-setting and hot-setting thermosetting adhesives as well as hot-melt adhesives. Other adhesives, provided that they can be used for processing of FRP (e.g. expansion adhesives) can also be used, following agreement with **TL**.

1.6.2 Description

1.6.2.1 A description of the adhesive is to be submitted in order to allow an unequivocal identification of the adhesive:

- Type of adhesive,
- Manufacturer,
- Trade name,
- Storage conditions,
- Processing and curing guidelines,
- Volume shrinkage after exceeding the gel point,
- Glass transition temperature (ISO 11357-2).

1.6.2.2 In the case of adhesive films with backing, the backing material is to be specified.

1.6.3 Properties of the adhesive

1.6.3.1 In the processing state, the following information is to be provided:

- Density (DIN EN ISO 1675)

- Viscosity (DIN 53019)

1.6.3.2 In the case of two-component thermosetting resins which cure at room temperatures, the pot life (DIN 16945, Section 6.3) is to also be indicated.

1.6.4 Properties in the cured state

1.6.4.1 The following mechanical properties are to be verified by the certificate of a recognized testing body (on 6 specimens respectively):

- Tensile lap-shear strength (DIN EN 1465),

- Peeling resistance (ISO 11339)

- Dimensional stability under heat (DIN EN ISO 75-2, Method A)

In addition, a long-duration shear tension test (based on DIN EN 1465) is to be carried out. In doing so, the sample is subject to loads in a standard climate 23 °C / 50 % relative humidity at 60 % of the mean tensile lap-shear strength for 192 ± 2 h.

1.6.4.2 The testing is to be carried out for two different conditioning states of the specimens:

- 24 ± 1 h after curing at 23 °C and storage at 50 % relative humidity

- 1000 ± 12 h storage in distilled water at 23 °C

1.6.4.3 For each test and conditioning state, specimens with adhesive layer thicknesses of 0,5 mm and 3 mm are to be used.

1.6.4.4 All tests are all to be carried out in a standard climate 23 °C / 50 % relative humidity. In addition, the tensile lap-shear strength is to be verified at 50 °C.

1.6.5 Minimum properties

1.6.5.1 The following properties are to be achieved for directly tested specimens as well as specimens tested after wet storage:

- Tensile lap-shear strength: 12 MPa

- Peeling resistance: 2 N/mm

- Dimensional stability under heat: 65 °C

1.6.5.2 Strain in creep is to be below 0.18 mm. in the long-duration shear tension test for an adhesive layer thickness of 0,5 mm. and below 1 mm. for an adhesive layer thickness of 3 mm.

C. Repair of Components

1. General

1.1 Requirements for operation and personnel

1.1.1 Repairs are only to be performed by workshops which are approved by **TL** for the repair of components made from fibre-reinforced thermosetting resins.

1.1.2 The shop approval for manufacturing components made of fibre-reinforced plastics using the hand lay-up method includes approval for repairing the parts within that production facility. For repairs outside of the production facility (i.e. in the field), an extension of the shop approval is required.

1.1.3 The repairs are only to be carried out by persons with proven professional knowledge. This professional knowledge is in general to be verified by certificates of the corresponding training courses. If such certificates are not available, the minimum requirement is to consist of training completed for a technical profession, in conjunction with internal training and several months of experience.

1.1.4 The head of the repair team is responsible for proper execution of the repair and is to be named explicitly in the shop approval. His professional knowledge is to be verified by certificates of the corresponding training courses and professional experience of several years. In addition, a procedure test - to be carried out at the shop under supervision of **TL** - is required.

1.1.5 The shop approval is granted by **TL** Head Office on the basis of the information to be submitted with related form and the report submitted by the **TL** surveyor. The related form deals with the following points:

- General information on the shop,
- Personnel,
- Internal quality management,
- Incoming inspection,
- Storage of the materials for repair in the shop and during field work,
- Mechanical processing capabilities,
- Production equipment.

1.2 Prerequisites

1.2.1 In the case of repairs which affect the structural integrity of the component, a repair plan is to be established and approved by **TL** before starting to any repair work. If the same repair is to be carried out several times, a general repair plan can be established and submitted to **TL** for approval.

1.2.2 Repairs to the gelcoat resin and (minor) repairs which do not fall under 1.2.1 are to be standardized and approved by **TL** according to the standardized procedure.

1.2.3 For the approval of a repair according to 1.2.1, all design and repair drawings needed to assess the repair of the component are to be submitted to **TL**. The repair plan will be examined by **TL** and approved if found suitable.

1.2.4 A report is required for each repair and has to be signed by the head of the repair team.

1.2.5 Materials approved by **TL** are only to be used for the repair.

1.2.6 The thermosetting resins used for repair is to be at least equivalent to the original thermosetting resin used for production. To ensure low residual stresses in the area to be repaired, the use of fast-setting highly reactive thermosetting resins is to be avoided. Unless the original thermosetting resin is used, the elongation at break of the thermosetting resins used for the repair is to be at least 2,5 %.

1.2.7 If the materials and laminates used for the repair are not identical to those employed when the component was manufactured, compatibility and equivalence of that particular combination of materials to the original ones are to be verified with respect to their properties.

2. Procedure

2.1 Preparation

2.1.1 Damaged material, or material which no longer exhibits complete bonding, is to be removed from the area to be repaired.

2.1.2 The region adjacent to the damaged area is to be chamfered. The chamfer ratio (chamfer length l_s to chamfer thickness t_s) depends on the tensile strength of the repair material, (σ_{Mat}) in the chamfer direction, and the permissible shear stress (τ)**.** The minimum chamfer ratio is to be calculated by means of the following formula:

$$\frac{\sigma_{Mat}}{\tau} = \frac{l_s}{t_s} \cdot x$$

x = 1 for hand laminate,

x = 1,05 in case of tempering,

x = 1,15 for curing under vacuum and tempering.

The permissible shear stress is to be 9 N/mm^2 for repairs in the shop and 7 N/mm^2 for repairs in the field.

2.1.3 The minimum overlap length for each layer is not to be less than 10 mm on all sides.

2.1.4 Due to the required draping ability (for curved surfaces and in the chamfered joint area; see Fig. 13.1), the weight per unit area of the reinforcing materials used for repair work is as far as possible, not to exceed 600 g/m^2 per layer (more layers with less weight per unit area are better than only a few layers with a high weight per unit area).

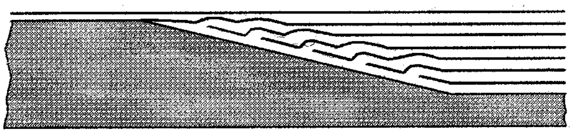


Figure 13.1 Chamfered joint area for a repair (schematic)

2.1.5 In order that the stress magnification associated with a chamfered joint is as low as possible, at least three reinforcing layers should be used for each area to be repaired.

2.1.6 The area to be repaired is to be cleaned and grinded thoroughly, e.g. by using sandpaper with a grain of 80 or 120.

2.1.7 If the laminate has been in direct contact with water for a lengthy period, the laminate is to be dried properly before repair work is started.

2.1.8 As far as possible, the area to be repaired is to be relieved of the stress caused by its own weight. In the case of repairs performed in the field, special arrangements are to be taken if necessary to prevent the occurrence of external loads (e.g. caused by vibration).

2.1.9 For repairs in the field, the workplace is to be arranged in such a way that good accessibility to the area to be repaired and sufficient illumination are both ensured.

2.1.10 For repairs in the field, measures are to be taken against moisture as well as direct UV radiation.

2.1.11 The component temperature, at least within the repair area, is to be kept within the range permitted in 2.2.1.

2.1.12 The mixing ratio of resin to hardener is to be maintained as precisely as possible (in the case of epoxy resins, the relative deviation from the mixing ratio shall not exceed 3 %). The actual mixing ratio and the quantities used is to be recorded in a dosing report.

2.2 Execution

2.2.1 During the repair work and the curing period, a surrounding air and a component temperature between 16 and 25 °C as well as a maximum relative humidity of 70 % is to be maintained. If the resin or adhesive manufacturer has not specified other permissible values, these values are to apply.

2.2.2 Calibrated thermometers and hygrometers are to be used for monitoring in the vicinity of the repair or at a position agreed upon with **TL**.

2.2.3 It is to be ensured that no changes in elongation occur in the laminate during the repair.

2.2.4 The lay-up at the prepared area to be repaired is to be performed by means of the hand lay-up method, as far as possible in the same sequence that was applied for the original laminate. The fibre orientation is to be identical.

2.2.5 Attention is to be paid for providing good impregnation of the reinforcing material. Voids are to be avoided.

2.2.6 A mat or fabric with a weight per unit area of approx. 225 g/m^2 maximum 450 g/m^2 for boats) and a low percentage fibre weight content (approx. 30 %) is to be used as the final layer.

2.2.7 The laminate is to be given sufficient surface protection by means of a coating resin. If the repair areas are subjected to increased moisture levels, a high resistance to hydrolysis is required of the coating resin.

2.2.8 If unsaturated polyester or vinyl resins are used for the topcoat, inhibition problems are to be avoided by excluding atmospheric oxygen (e.g. by adding paraffin or using foil coverings).

2.3 Curing

2.3.1 During the curing process, it is to be ensured that no changes in elongation take place in the laminate.

2.3.2 Repaired components are only to be subjected to loads or put into further operation after the thermosetting resin has cured sufficiently.

2.3.3 If no explicit values are quoted for the curing process by the manufacturer of the thermosetting resin system, the following time periods is to apply for cold-setting resin systems:

- For a constant temperature of 16 °C: at least 72 h,
- For a constant temperature of 25 °C: at least 38 h.

2.3.4 If the repaired component was tempered during manufacture, the area to be repaired is also to be tempered after setting, if no proof is provided to show that this is not necessary.

3. Documentation

3.1 Repair report

3.1.1 The repair report is at least to contain the following points:

- Designation of the component and, if applicable, its identification number,
- Date and location of the repair (address of the shop or location in the field),
- Start time of repair,
- Position and type of damage,
- Repair plan and approval No.,
- Climatic conditions during repair and the curing period (and the wind speed, in case the work was not performed within a closed room),
- Materials used (with batch number),
- Mixing ratios for thermosetting resin systems; dosing report,
- Lay up (number of layers and orientation),
- Any deviations from the repair plan,
- Duration of the repair,
- Curing time,
- Signature of the head of the repair team.

Note:

To assist in describing and explaining the repair, sketches or pictures may be added to the repair report.