ACS (Asia Classification Society)

Rules for

Classification of Vessels

(2014)

Part 2

Materials and Welding

Rules for Classification of Vessels

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Part 2 Materials and Welding

Chapter 1 General Requirements

Section 1 Conditions for Manufacture, Survey and Certification

1 Scope

1.1 Materials, used for the construction or repair of the hull and machinery of ships which are classed or intended to be classed with ACS, are to be manufactured, tested and inspected in accordance with the requirements of this Part.

1.2 Materials complying with recognized national or international standards with specifications equivalent to the requirements of this Part may be accepted.

2 Information to be supplied to the manufacturer

2.1 The ship or machinery builder is to provide the manufacturer with such information as is necessary to ensure that inspection and testing can be carried out in accordance with these Rules.

3 Manufacture

3.1 Materials used for the construction or repair of the hull and machinery of ships which are classed or intended to be classed with ACS are to be made at works which have been approved by ACS for the type of the product being supplied.

3.2 The manufacturer should demonstrate to the satisfaction of ACS that necessary manufacturing and testing facilities are available and are supervised by qualified personnel.

3.3 Approval of manufacturers with respect to the materials and grades covered by this Part will be considered by ACS on the basis of a detailed description of the manufacturing process and inspection routines, results from testing of materials and a report made by ACS Surveyors confirming the information given by the works and results.

3.4 Where the manufacturer has more than one works, approval for individual works would be required.

4 Survey procedure

4.1 The Surveyors are to be allowed access to all the relevant parts of the works and are to be provided with necessary facilities and information to enable them to verify that manufacture is being carried out in accordance with the approved procedure. Adequate facilities are also to be provided for the selection of test materials, the witnessing of mechanical tests and the examination of materials, as required by these Rules.

4.2 Prior to the submission of material for acceptance, manufacturers are to provide the Surveyors with details of the order specification and any special conditions additional to the Rule requirements.

4.3 Before final acceptance, all materials are to be submitted to specified tests and examinations under conditions acceptable to the Surveyors. The results are to comply with Rules and all materials are to be to the satisfaction of the Surveyors.

4.4 The specified tests and examinations are to be carried out prior to the dispatch of all finished materials from the manufacturer's works. Where materials are supplied in the rough or unfinished condition, as many as possible of the specified tests are to be carried out by the manufacturer and any tests or examinations not completed are to be carried out in consultation with the Surveyors, at a subsequent stage of manufacture.

4.5 In the event of any material proving unsatisfactory, during subsequent working, machining or fabrication, it is to be rejected, not withstanding any previous certification.

5 Chemical composition

5.1 The chemical composition of the ladle samples is to be determined by the manufacturer in an adequately equipped and competently staffed laboratory. The manufacturer's analysis will be accepted, but may be subject to occasional independent checks if required by the Surveyors.

5.2 At the discretion of the Surveyors, a check chemical analysis of suitable samples from products may also be required. These samples are to be taken from the material used for mechanical tests, but where this is not practicable an alternative procedure for obtaining a representative sample is to be agreed with the manufacturer.

6 Heat treatment

6.1 Materials are to be supplied in the condition specified in, or permitted by the Rules. 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 item to be uniformly heated to the necessary temperature. In the case of very large components which require heat treatment, alternative methods will be specially considered.

7 Test material

7.1 Sufficient test material is to be provided for the preparation of the tests detailed in the specific requirements. It is, however, in the interests of manufacturers to provide additional material for any retests which may be necessary, as insufficient or unacceptable test material may be a cause for rejection.

7.2 The test material is to be representative of the item or batch and is not to be separated until all the specified heat treatment has been completed, except where provision for an alternative procedure is made in the subsequent chapters of this Part.

In case of castings where separately cast test samples are accepted, the test samples are to be cooled down under the same conditions as the castings.

7.3 All test material is to be selected by the surveyor and identified by suitable markings which are to be maintained during the preparation of the test specimen.

8 Mechanical tests

8.1 The number and direction of test specimens and their dimensions are to be in accordance with the requirements of subsequent chapters of this Part and the specific requirements for the product.

8.2 Where Charpy impact tests are required, a set of three test specimens are to be prepared and the average energy value is to comply with the requirements of subsequent Chapters of this part. One individual value may be less than the required average value provided that it is not less than 70 per cent of that value.

8.3 Where metric or imperial units are to be used for acceptance testing, the specified values are to be converted in accordance with the appropriate conversion values.

9 Definitions

9.1 The following definitions are applicable to this Part:

Item: A single forging, casting, plate, tube or other rolled product as delivered.

Piece: The rolled product from a single slab or billet or from a single ingot if this is rolled directly into plates, strips, sections or bars.

Batch: A number of similar items or pieces presented as a group for acceptance testing.

10 Retest procedures

10.1 Where the result of any test, other than an impact test, does not comply with the requirements, two additional tests of the same type may be taken. For acceptance of the material satisfactory results are to be obtained from both of these tests.

10.2 Where the results from a set of three impact test specimens do not comply with the requirements, an additional set of three impact test specimens may be tested provided that not more than two individual values are less than the required average value and, of these, not more than one is less than 70 per cent of this average value. The results obtained are to be combined with the original results to form a new average which, for acceptance, is not to be less than the required average value. Additionally, for these combined results, not more than two individual values are to be less than the required average value and, of these, not more than one is to be less than 70 per cent of this average value.

10.3 The additional tests detailed in 10.1 and 10.2 are, where possible, to be taken from material adjacent to the original tests. For castings, however, where insufficient material remains in the original test samples, the additional tests may be prepared from other test samples representative of the castings.

10.4 When unsatisfactory results are obtained from tests representative of a batch of material, the item or piece from which the tests were taken is to be rejected. The remainder of the batch may be accepted provided that two further items or pieces are selected and tested with satisfactory results. If the tests from one or both of these additional items or pieces give unsatisfactory results, the batch is to be rejected.

10.5 When a batch is rejected, the remaining items or pieces in the batch may be resubmitted individually for test, and those which give satisfactory results may be considered for acceptance by the Surveyors.

10.6 At the option of the manufacturer, rejected material may be re-submitted as another grade and may then be considered for acceptance by the Surveyors, provided that the test results comply with the appropriate requirements.

10.7 When material which is intended to be supplied in the ”as rolled" or "hot finished" condition fails test, it may be suitably heat treated and re-submitted for test, with the prior concurrence of the ship or machinery builder.

Similarly materials supplied in the heat-treated condition may be re-heat treated and resubmitted for test.

11 Visual and non-destructive examination

11.1 Prior to the final acceptance of materials, surface inspection, verification of dimensions and non-destructive examination are to be carried out in accordance with the requirements detailed in subsequent chapters of this Part.

11.2 When there is visible evidence to doubt the soundness of any material or component, such as flaws in test specimens or suspicious surface marks, the manufacturer is expected to prove the quality of the material by any acceptable method.

12 Rectification of defective material

12.1 Small surface imperfections may be removed by mechanical means provided that, after such treatment, the dimensions are acceptable, the area is proved free from defects and the rectification has been completed in accordance with applicable requirements of subsequent chapters of this Part and to the satisfaction of Surveyors.

12.2 The repair of defects by welding can be accepted only when permitted by the appropriate specific requirements and provided that the agreement of the Surveyor is obtained before the work is commenced. When a repair has been agreed, it is necessary in all cases to prove by suitable methods of non-destructive examination that the defects have been completely removed before welding is commenced. Welding procedures and inspection on completion of the repair are to be in accordance with the appropriate specific requirement and are to be to the satisfaction of the Surveyor.

13 Identification of materials

13.1 The manufacturer is to adopt a system of identification which will enable all finished material to be traced to the original cast, and the Surveyors are to be given all facilities for so tracing the material when required. When any item has been identified by the personal mark of a Surveyor, or his deputy, this is not to be removed until an acceptable new identification mark has been made. Failure to comply with this condition will render the item liable to rejection.

13.2 Before any item is finally accepted it is to be clearly marked by the manufacturer in at least one place with the particulars detailed in the appropriate specific requirements.

13.3 Hard stamping is to be used except where this may be detrimental to the material, in which case stenciling, painting or electric etching is to be used. Paints used to identify alloy steels are to be free from lead, copper, zinc or tin, i.e., the dried film is not to contain any of these elements in quantities more than 250 ppm.

13.4 Where a number of identical items are securely fastened together in bundles, the manufacturer need only brand the top of each bundle. Alternatively a durable label giving the required particulars may be attached to each bundle.

Section 2 Quality Assurance Scheme for Materials

1 General

1.1 Alternative procedures for survey and testing may be accepted by ACS at works where materials are manufactured under closely control rolled conditions by semi-continuous or continuous processes.

1.2 ACS will consider the extent to which the manufacturing and quality control procedures employed by a manufacturer ensure compliance of the materials with the requirements of the Rules.

1.3 Where it is considered that compliance with Rule requirements can be satisfactorily achieved, ACS will issue a Quality Assurance Approval Certificate to the manufacturer.

1.4 Approval by another organization will not normally be acceptable as sufficient evidence that a manufacturer's arrangements comply with ACS requirements.

1.5 The quality system procedures and practices of a manufacturer who has been granted approval will be kept under continuous review.

2 Requirements for approval

2.1 The manufacturer is required to have necessary manufacturing and testing facilities supervised by suitably qualified and trained personnel to the satisfaction of ACS.

2.2 The manufacturer is to demonstrate that the firm has experience consistent with the technology and complexity of the product type for which approval is sought and that the firm's product has been of a consistently high standard.

2.3 The manufacturer is required to establish and maintain a quality system in line with the requirements of ISO 9000 series of standards to ensure that ACS requirements for certification of materials and components are met consistently.

3 Information required for approval

3.1 Manufacturers applying for approval under this scheme are to submit the information required by 3.2 to 3.8.

3.2 A detailed specification for each product.

3.3 An outline description of all important manufacturing plant and equipments. This is to include a production flow chart indicating all stages where testing and inspection are carried out along with details of equipments used for measuring and testing.

3.4 A controlled copy of company's Quality Manual prescribing a quality system generally in compliance with the applicable requirements of ISO 9000 series of standards.

3.5 The system used for the identification and traceability of raw materials, semi-finished and finished Products.

3.6 Number and qualification of personnel engaged in quality control and quality assurance.

3.7 Information on the system of procurement and acceptance of materials e.g. ingots, billets or blooms for further processing where the manufacturer does not produce such raw materials.

3.8 Consolidated test results, physical, chemical, non-destructive tests etc. for a period of preceding three months of products, if possible, covering the full range of thickness, weight range and grades for which approval is sought. The data is to include the number of samples, minimum, maximum, average value and standard deviation. For high strength ship steels, the carbon equivalent values are also required. The data is to also include numbers of rejections during manufacture as well as after delivery and reasons thereof.

4 Assessment and approval

4.1 After receipt and appraisal of the information required by subsection 3 an assessment of the Works would be carried out by the Surveyors to ensure compliance with the Quality Manual and examine in detail Quality Control Procedures in relation to the process, products, inspections, tests and certification. Where the proposed quality control procedures are considered to be inadequate the Surveyors may, in consultation with Head Office, advise as to how these may be revised to be acceptable to ACS.

4.2 If the assessment of the Works confirms that the implementation of the Quality Management System is satisfactory, ACS will issue to the manufacturer a Quality Assurance Approval Certificate which will include details of the products for which approval has been given.

4.3 An extension of approval in respect of product type may be given at the discretion of ACS without any additional assessment.

5 Maintenance of approval

5.1 The Certificate will be valid for three years subject to surveillance assessment being carried out every six months or at more frequent intervals as deemed necessary by ACS depending on the type of product, the rate of production and standard of the Work’s quality control procedures.

5.2 When significant faults or deficiencies are found during surveillance assessments or surveillance assessments are not carried out, the Certificate of approval may be withdrawn/ suspended at the discretion of ACS.

5.3 The Surveyors are to be allowed access at all reasonable times to those parts of Works concerned with the manufacture of the products detailed in the Quality Assurance Approval Certificate.

6 Certification of products

6.1 After issue of the Quality Assurance Approval Certificate, the manufacturer would be authorized to issue certificate of products on behalf of ACS subject to the Certificates being countersigned by ACS Surveyors. Arrangements for this will be specially advised by ACS.

Chapter 2 Mechanical Testing Procedures

Section 1 General Requirements

1 General

1.1 All tests are to be carried out by competent personnel. The machines are to be maintained in satisfactory and accurate condition and are to be recalibrated at approximately annual intervals. This calibration is to be carried out by a nationally recognized Authority or other organization of standing and is to be carried out to the satisfaction of Surveyors. The accuracy of test machines is to be within ± one per cent. A record of all calibrations is to be kept available in the test house.

Testing machines are to be calibrated in accordance with the following or other equivalent recognized standards:

a) Tensile / compression testing : ISO 7500-1

b) Impact testing : ISO 148-2

2 Selection of test samples

2.1 Test samples are to be selected by the Surveyor unless otherwise agreed.

2.2 All materials in a batch presented for testing are to be of the same product form (e.g. plates, sections, bars). Normally, the materials are to be from the same cast and in the same condition of heat treatment.

3 Preparation of test specimens

3.1 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.

3.2 Test specimens are to be cut and prepared in a manner which does not affect their properties, i.e. not subjected to any significant cold straining or heating.

3.3 Where possible, test specimens from rolled materials are to retain their rolled surface on both sides.

4 Discarding of test specimens

4.1 If a test specimen fails because of faulty manufacture, visible defects, or incorrect operation of the testing machine, it may be discarded at the Surveyor’s discretion and replaced by a new test specimen prepared from material adjacent to the original test.

Section 2 Tensile Testing

1 Dimensions of tensile test specimens

1.1 Generally, proportional test specimens with a gauge length of $5.65\sqrt{S_o}$ (where S_0 is the cross-sectional area of the test length) are to be used. Where it is not possible to use such specimens, non-proportional specimens may be considered.

1.2 For the purpose of determining the different parameters related to tensile testing, three different types of test specimens may be used :

- Round test specimens;
- Flat test specimens; and
- Full cross-section test specimens.

See also Fig. 1.1.

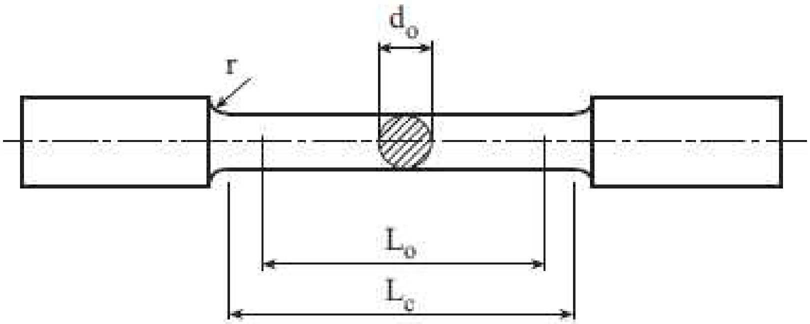


Fig.1.1 a) Round test specimen

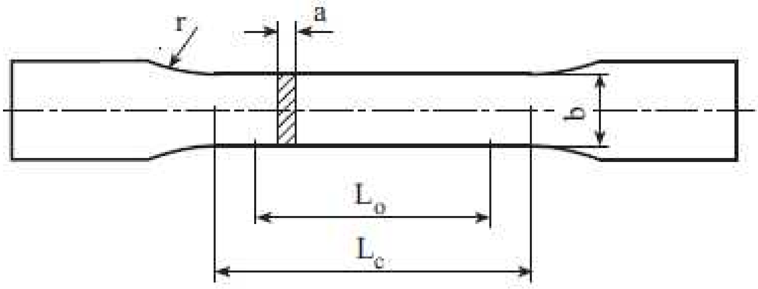


Fig. 1.1 b) Flat test specimen

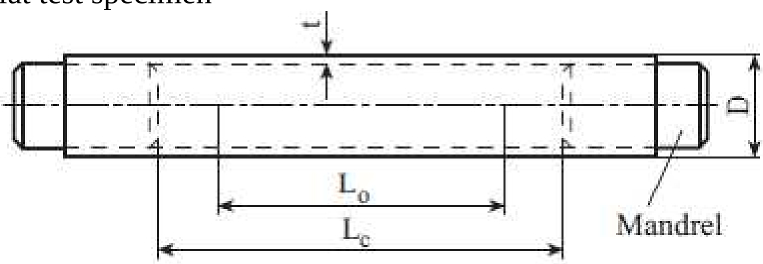


Fig. 1.1 c) Full Cross-section test specimen

1.2.1 The following symbols have been used in the figure and in subsequent paragraphs:-

d_o =diameter

a =thickness of specimen

b =width

L_o = Original gauge length

L_c = Parallel Test length

S_o = Original cross-sectional area

r = Transition radius

D =External tube diameter

t = plate thickness

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

1.2.3 For plates with thickness equal to and greater than 3 [mm], test specimen according to alternatives A or B given below are to be used.

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

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

Alternative A, Non-proportional flat test specimen

a = t

b =25 [mm]

L_o =200 [mm]

$L_c \geq 212.5$ [mm]

r =25 [mm]

Alternative B, Proportional flat test specimen

a = t

b =25 [mm]

$L_o = 5.65\sqrt{S_o}$

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

r =25 [mm]

Alternative C,

d_o =14 [mm] in general, but in no case less than 10 [mm] nor more than 20 [mm].

L_o = 5d [mm

$L_c \geq L_o + d/2$ [mm]

r =10 [mm], in general

$\geq 1.5\ d_o$ [mm], for nodular cast iron and materials with a specified elongation of less than 10%.

1.2.4 The round test specimen is to be located with its center t/4 from the plate surface or as close to this position as possible.

1.2.5 For sheets and strips with thickness less than 3 [mm]

a = t

b =12.5 [mm]

L_o =50 [mm]

$L_c \approx 75$ [mm]

r =25 [mm]

1.2.6 Wires: Full cross sectional test specimen with the following dimensions is to be used:

L_o =200 [mm]

$L_c = L_o + 50$ [mm].

1.2.7 For forgings, castings (excluding grey cast iron) and bars round test specimens with dimensions as specified in alternative C of 1.2.3 are usually to be used.

1.2.8 If for special reasons, other dimensions are to be used, they will have to conform with the following geometric relationship:

$L_o = 5d_o$;

$L_c = L_o + d_o$:

r=10 [mm], except for materials with a specified minimum elongation $A \leq 10$ per cent, where r is to be $1.5d_o$.

1.2.9 For tubes, test specimen according to alternative A or B below are to be used:

Alternative A :- Full cross-section test specimens with plugged ends -

$L_o = 5.65\ \sqrt{S_o}$

$L_c \approx L_o + D/2$

L_c is the distance between the grips or the plugs, whichever is smaller.

Alternative B :- Strip

a =wall thickness of tube

$b \geq 12$ [mm]

$L_o = 5.65\ \sqrt{S_o}$

$L_c = L_o + 2b$

The parallel test length is not to be flattened. But the enlarged ends may be flattened for gripping in the testing machine. Round test specimens may also be used provided that the wall thickness is sufficient to allow the machining of such specimens to the dimensions in alternative C in 1.2.3 above with their axes located at the mid-wall thickness.

1.2.10 The above is subject to any specific dimensions or minimum cross-sectional area requirements, with respect to test specimens, given in any subsequent Chapters of this Part.

1.2.11 Tensile test specimens for grey cast iron are to be machined to the dimensions shown in Fig. 1.2. Usually test specimens are machined from separately cast standard test coupons with 30 [mm] diameter.

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

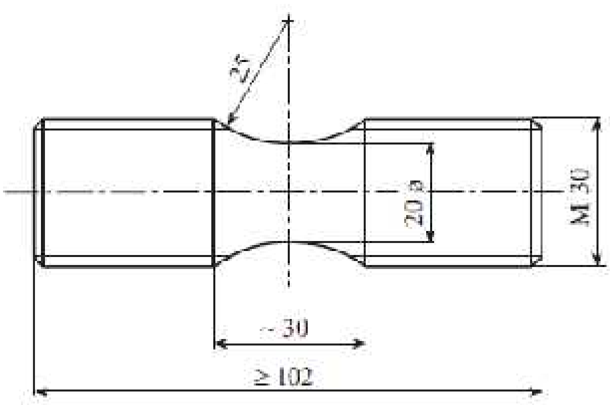


Fig. 1.2, Tensile test specimens for grey cast iron

2 Fracture elongation

2.1 Unless otherwise specified, the elongation values in this part correspond to those required for proportional test specimens over a gauge length $5.65\sqrt{S_o}$

If any part of the fracture takes place outside of the middle one-third of the original gauge length, the elongation value obtained may not be representative of the material. In such cases if the elongation measured is less than the minimum requirements, the test result may be discarded and a retest carried out.

2.2 If the material is ferritic steel of low or medium strength and not cold worked the elongation may also be measured on a non-proportional gauge length after agreement with ACS.

In that case the elongation required is to be calculated from the following formula:
where,

$$A_o = 2A_s\left(\frac{\sqrt{S_o}}{L_o}\right)^{0.4}$$

A_o = Required elongation for the nonproportional test specimen

A_s = Specified elongation on a gauge length of $5.65\sqrt{S_o}$
S_o = Cross-sectional area of test specimen
L_o = Gauge length of test specimen.

3 Definition of yield stress

3.1 The yield phenomenon is not exhibited by all the steels detailed in this Part but, for simplification the term "Yield Stress" is used throughout when requirements are specified for acceptance testing at ambient temperature.

3.2 Where reference is made to "Yield Stress" in the requirements for carbon, carbon-manganese and alloy steel products and in the requirements for the approval of welding consumables, either the upper yield stress or the 0.2 per cent proof stress under load is to be determined.

3.3 For austenitic and duplex stainless steel products and welding consumables, both the 0.2 per cent and 1.0 per cent proof stresses are to be determined.

4 Procedure for tensile testing at ambient temperature

4.1 Unless otherwise specified, the test is to be carried out at ambient temperature between 10°C and 35°C.

4.2 Yield stress (Yield point) is to be taken as the value of stress measured at the commencement of plastic deformation at yield or the value of the stress measured at the first peak obtained during yielding even when the peak is equal to or less than any subsequent peaks observed during plastic deformation at yield. The tensile test is to be carried out with an elastic stress rate within the limits indicated in Table 4.1.

Table 4.1

Modulus of elasticity (E) N/mm^2	Rate of stressing [N/mm^2] per second	
	Min.	Max.
< 150 000	2	20
≥ 150 000	6	60

4.3 After reaching the yield or proof load, the straining rate may be increased to a maximum of 0.008 per second for the determination of tensile strength.

4.4 For steel, the upper yield stress is to be calculated from :

a) the load immediately prior to a distinct drop in the testing machine lever; or

b) the load immediately prior to a fall back in the movement of the pointer or the load at a marked hesitation of this pointer; or

c) a load/extension diagram using the value of load measured either at the commencement of plastic deformation or yield or at the first peak obtained during yielding even when that peak is equal to or less than any subsequent peaks observed.

4.5 The 0.2 or 1.0 per cent proof stress (non-proportional elongation) is to be determined from an accurate load/extension diagram by drawing a line parallel to the straight elastic portion and distant from it by an amount representing 0.2 or 1.0 per cent of extensometer gauge length. The point of intersection of this line with the plastic portion of the diagram represents the proof load, from which 0.2 or 1.0 per cent proof stress can be calculated.

5 Procedure for tensile testing at elevated temperatures

5.1 The test specimens used for the determination of lower yield or 0.2 per cent proof stress at elevated temperatures are to have an extensometer gauge length of not less than 50 [mm] and a cross sectional area of not less than 65 [mm^2]. Where, however, this is precluded by the dimensions of the product or by the test equipment available, the test specimen is to be of the largest practical dimensions.

5.2 The heating apparatus is to be such that the temperature of the specimen during testing does not deviate from that specified by more than ± 5°C.

5.3 The straining rate when approaching the lower yield or proof load is to be controlled within the range 0.1 to 0.3 per cent of the extensometer gauge length per minute.

5.4 The time intervals used for estimation of strain rate from measurements of strain are not to exceed 6 seconds.

Section 3 Impact Tests

1 Dimensions of test pieces

1.1 Impact values *KV* or *KU*, [J], shall be determined on the ISO Charpy V-notch or Charpy U-notch specimens as required by the subsequent chapters. The test specimens shall be machined to the dimensions and tolerances given in Fig. 1.1 and Table 1.1.

1.2 V-notch specimens with a width of 7.5 and 5 mm shall be used only for these products from which test specimens with a width of 10 mm cannot be prepared. The impact test values obtained on such specimens shall fulfill the requirements specified in Table 1.2.

1.3 On specimens taken from plates, flats and sections, the notch shall be perpendicular to the external surface of the product, with at least one surface in rough condition.

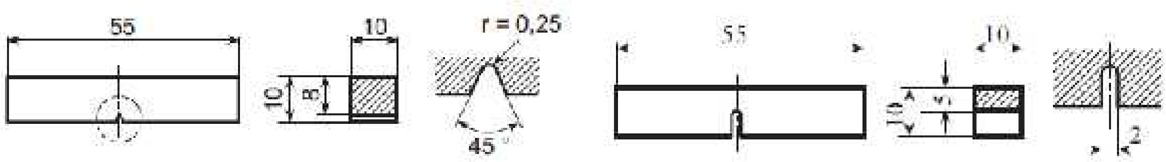


Fig. 1.1 a- Charpy V-notch Specimen b- Charpy U-notch Specimen

Table 1.1. Permitted tolerances of specimen dimensions

Dimensions	V-notch specimen		U-notch specimen	
	Normal size	Tolerance	Normal size	Tolerance
Length of specimen	55 mm	± 0,60 mm	55 mm	± 0,60 mm
Thickness of specimen	10 mm	± 0,06 mm	10 mm	± 0,11 mm
Width of specimen:				
– Normal specimen	10 mm	± 0,11 mm	10 mm	± 0,11 mm
– Sub-size specimen	7,5 mm	± 0,11 mm	—	—
– Sub-size specimen	5 mm	± 0,06 mm	—	—
Notch angle	45°	± 2°	—	—
Thickness at base of notch	8 mm	± 0,06 mm	5 mm	± 0,09 mm
Notch radius	0,25 mm	± 0,025 mm	1 mm	± 0,07 mm
Distance of notch centre from ends of specimen[1]	27,5 mm	± 0,42 mm	27,5 mm	± 0,42 mm
Angle between plane of symmetry of notch and longitudinal axis	90°	± 2°	90°	± 2°
Angle between adjacent longitudinal faces	90°	± 2°	90°	± 2°

1) For pendulum impact testing machines which have automatic specimen positioning, a tolerance of ± 0,165 is recommended rather than ± 0,42.

Table 1.2.

Dimension of Specimen [mm]	Average impact value KV [J]
10 x 10 x 55	KV
10 x 7.5 x 55	5/6 KV
10 x 5 x 55	2/3 KV

2 Testing procedure

2.1 Impact values shall be determined on three specimens. One of the obtained values may be lower than the required one, but by not more than by 30 per cent.

2.2 Impact test shall be performed on the Charpy pendulum impact testing machine with an initial striking energy of 450 or 300 but not less than 150 J. The distance between the hammer supports shall be 40 ± 5 mm. The point of impact of the hammer shall be in plane of symmetry of the specimen notch, from its opposite side, the distance between the planes of symmetry of the notch and the cutter not exceeding 0.5 mm.

2.3 Where the impact test is performed at a lower temperature, the test specimens shall be kept in the cooling medium for at least 15 minutes from the moment the temperature of the medium has become steady. At the test temperature down to -60 ^{o}C, the value of over-cooling may be reduced to -4 ^{o}C; at the moment of specimen fracture, the temperature shall not vary from the prescribed test temperature by more than ±2 ^{o}C.

2.4 Impact tests may be performed (according to the definitions adopted in standard EN ISO 3785) on longitudinal specimens (L) or transverse specimens (T). Longitudinal specimens are taken parallel with the longitudinal axis of a rolled or extruded product (along the grain flow pattern). Transverse specimens are taken perpendicular to the longitudinal and Z axes (axis Z is parallel with the direction of main force causing the material strain).

2.5 Where hull structural steel ageing resistance shall be determined (the ageing conditions – 5% strain and annealing at a temperature of 250 ^{o}C for 1 hour), the test conditions and requirements are subject to ACS acceptance in each particular case.

Section 4 Ductility Testing of Pipes and Tubes

1 Bend tests

1.1 Flat bend test specimen shall be made in accordance with Fig. 1.1. Tension side edges shall be rounded to a radius of 1 to 2 mm.

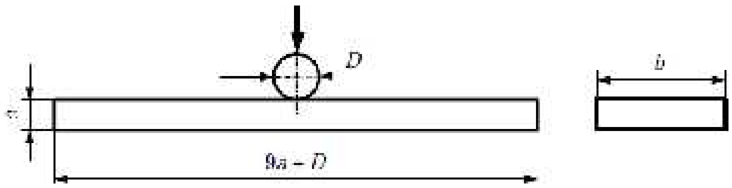


Fig. 1.1

Particulars of the testing conditions are specified in standard EN ISO 7438. Unless specified, the former diameter and the angle of bending the specimen shall be selected in accordance with the relevant standards.

1.2 Bend tests of castings, forgings and similar products shall be performed on specimens with the following cross-section dimensions: a = 20 mm; b = 25 mm.

1.3 Bend tests of plates, structural sections and strips shall be performed on specimens with the following cross-section dimensions: a = t; b = 30 mm.
If product thickness t is greater than 25 mm, it may be reduced to 25 mm by machining on one side. In that case, the former shall be placed on the machined face when testing.

1.4 Bend tests of butt welds shall be performed on specimens with the following cross-section dimensions: a = t; b = 30 mm.
For bend tests of welded joints, one part of the specimens shall be tested with the weld face in tension and the other with the weld root in tension. The weld shall be machined (or ground) flush with the surface of the plate. If product thickness t is greater than 25 mm, it may be reduced to 25 mm by machining on one side. In that case, the former shall be placed on the machined face when testing.

1.5 Side bend tests of butt welds shall be performed on specimens with the following cross-section dimensions: a = 10 mm; b = t.
Where thickness of butt welds t ≥ 40 mm, a side bend test specimen may be so split into parts of a width b ≥ 20 mm that the entire weld thickness is covered.

1.6 Test specimens, for longitudinal face and root test, shall be made in accordance with appropriate recognized standard. One part of the specimens shall be tested with the weld face in tension and the other with the weld root in tension.

2 Flattening tests

2.1 Flattening test shall be performed for metallic tubes with an outside diameter D not exceeding 406.4 mm and wall thickness t not exceeding 0.15 D.
Specimen length shall be L = 1.5 D, however the following condition shall be fulfilled: $10 \text{ mm} \le L \le 100 \text{ mm}$. Unless otherwise stated in the Rules or

relevant standards, the tube section shall be flattened until distance *H* between the testing machine pressure plates reaches the value:

$$H=\frac{(1+c)t}{(c+t/D)} \quad \text{mm}$$

where:
D – outside diameter of tube, [mm];
t – nominal tube wall thickness, [mm];
c – factor depending on the material (to be assumed in accordance with the relevant standards or subject to ACS acceptance in each particular case), its value may be taken as 0.09.

2.2 Where it is required that the flattening test be performed until the inner surfaces of the tube meet, the distance *H* between the testing machine pressure plates shall not exceed 2.25*t*.

In the case of flattening test of welded tubes, the specimen shall be so placed in the tensile testing device that the welded seam lies at 90^o to the direction of flattening, in the specimen’s centre line. The test result is considered satisfactory if the specimen is free from cracks or pulls.

Plain and smoothed ends shall be cut perpendicular to the tube axis. Reference is made to standard EN ISO 8492.

3 Drift expanding test

3.1 Drift expanding test shall be performed for tubes with the external diameter up to and including 150 mm and the wall thickness up to 9 mm. A tapered drift shall be forced into the tube until the required expansion degree is reached. Length *L* of the drift expanding test specimen shall be equal to twice the outside diameter *D* of the tube if the angle of the drift β is 30°, and *L* equal to 1.5*D* if the angle of the drift is 45° or 60°.

3.2 The test piece may be shorter provided that after testing the remaining cylindrical portion is not less than 0.5*D*. The rate of penetration of the mandrel shall not exceed 50 mm/min. The test result is considered satisfactory if the test specimen is free from cracks or pulls. Reference is made to standard EN ISO 8493.

4 Flanging tests

4.1 Flanging test specimen shall be of length L equal to approximately 1.5D. The test piece may be shorter provided that after testing the remaining cylindrical portion is not less than 0.5D. The rate of penetration of the forming tool shall not exceed 50 mm/min.

The test result is considered satisfactory if no fracture is visible with an unaided eye. Reference is made to standard EN ISO 8494.

5 Ring expanding test

5.1 Ring expanding test specimen shall have a length between 10 to 16 mm. The rate of penetration of the mandrel shall not exceed 30 mm/min. The test consists in uniform and consistent forcing a tapered drift of a taper 1:10 or 1:5 into the specimen until the expansion degree is reached. Reference is made to standard EN ISO 8495. The test result is considered satisfactory if no fracture is visible with an unaided eye.

6 Ring tensile test

6.1 Ring tensile test shall be performed for steel tubes with external diameter *D* within the range 110to 510 mm, wall thickness t not exceeding 30 mm and *t/D* ratio not greater than 0.13.

The specimen shall be a tube piece with a length of about 15 mm. The ring shall be stretched in a tensile testing machine until it breaks using two pins with a diameter equal to at least three times the wall thickness of the tube.

6.2 In the case of welded tubes, the specimen shall be so placed in the tensile testing device that the welded seam lies at 90o to the direction of the tensile load, in the specimen's centreline.

The ring shall be drawn with the rate not exceeding 5 mm/s. The ring shall have plain and smoothed ends cut perpendicular to the tube ends.

The test result is considered satisfactory if the specimen is free from surface defects and reveals no laminations or symptoms of brittleness at the point of fracture. Reference is made to standard EN ISO 8496.

7 Hardness Testing

7.1 Hardness shall be determined by Brinell *(HB*), Vickers (*HV*), Rockwell (*HRC*) method or other method subject to ACS acceptance in each particular case. Hardness tests shall be performed in accordance with the relevant standards (EN ISO 6506-1, EN ISO 6507-1, EN ISO 6508-1).

Chapter 3 Rolled Steel Plates, Strips, Sections and Bars

Section 1 General Requirements

1 Scope

1.1 This Chapter gives general requirements for hot rolled plates, strips and sections intended for use in the construction of ships, boilers, pressure vessels and machinery structures.

These requirements are also applicable to hot rolled bars, except where such materials are intended for the manufacture of bolts, shafts, etc. by machining operations only. When used for this purpose hot rolled bars are to comply with the appropriate requirements.

2 Manufacture

2.1 The steel is to be manufactured at the approved works by the open hearth, electric furnace or one of the basic oxygen processes or by other processes specially approved by ACS. The approval of the steel works is to be carried out in accordance with ACS Classification Notes.

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

2.3 It is the manufacturer's responsibility to assure that effective process and production controls in operation are adhered to in accordance with the manufacturing specifications. Where control imperfection that may lead to inferior quality of product occurs, the manufacturer is to identify the cause and establish counter measure to prevent its occurrence. Also the complete investigation report is to be submitted to the Surveyor. Each affected piece considered for further usage is to be tested to the Surveyor's satisfaction.

The frequency of testing may be increased to gain confidence for subsequent products as considered necessary.

3 Quality of materials

3.1 Defects not prejudicial to the proper application of steel are not, except by special agreement, to be grounds for rejection. Where necessary, suitable methods of non-destructive examination may be used for the detection of harmful surface and internal defects. The extent of this examination, together with appropriate acceptance standards, is to be agreed between the purchaser, manufacturer and Surveyors.

4 Thickness tolerance of plates and wide flats

4.1 The tolerance on thickness of a given product are defined as follows:

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

b) 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.

4.2 The minus tolerance for products for normal strength, higher strength and high strength quenched and tempered steels is 0.3 [mm] irrespective of nominal thickness.

4.3 The minus tolerance for products intended for machinery structures are to be in accordance with Table 4.1.

Table 4.1

Nominal thickness [mm]	Minus tolerance [mm]
≥ 5 to < 8	-0.4
≥ 8 to < 15	-0.5
≥ 15 to < 25	-0.6
≥ 25 to < 40	-0.8
≥ 40	-1.0

4.4 The tolerance for thickness below 5 [mm] may be specially agreed.

4.5 The plus tolerance on nominal thickness is to be in accordance with a recognized national or international standard or as specified.

4.6 The tolerance on sections (except for wide flats) are to be in accordance with the requirements of recognized international or national standard.

4.7 The tolerance on nominal thickness are not applicable to areas repaired by grinding which are to be in accordance with a recognized standard.

4.8 For materials intended for low temperature applications and boilers and pressure vessels, no minus tolerance is permitted in the thickness of plates and strip.

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

4.10 The responsibility for storage and maintenance of the delivered products with acceptable level of surface conditions rests with the shipyard before the products are used in fabrication.

4.11 Where zero minus tolerance is applied in accordance with class C of ISO 7452, the requirements of 4.12 to 4.14 do not apply.

4.12 Average thickness

4.12.1 The average thickness of a product or products is defined as the arithmetic mean of the measurements made in accordance with the requirements of 4.13.

4.12.2 The average thickness of a product or products for hull structural steels is not to be less than the nominal thickness.

4.13 Thickness measurements

4.13.1 The thickness is to be measured at locations of a product or products as defined in 4.14.

4.13.2 Automated method or manual method may be applied to the thickness measurements.

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

4.14 Thickness measuring locations

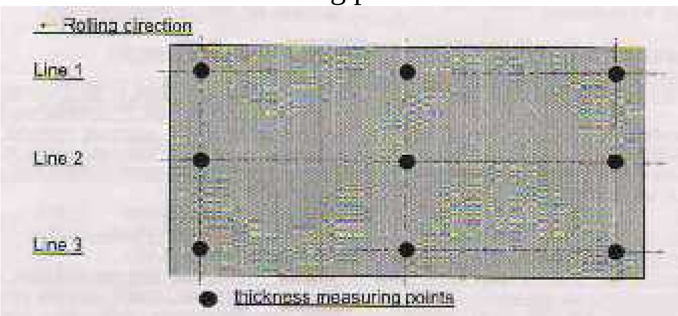
4.14.1 The requirements of 4.14.2 are to be applied to the thickness measuring locations for the thickness tolerance and the average thickness of the product.

4.14.2 At least two lines among Line 1, Line 2 or Line 3 as shown in Fig. 4.1 are to be selected for the thickness measurements and at least three points on each selected line are to be selected for thickness measurement. If more than three points are taken on each line the number of points are to be equal on each line.

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.

Fig. 4.1 : Locations of thickness measuring points



5 Heat treatment, condition of supply

5.1 All materials are to be supplied in the heat treated conditions described in the subsequent sections of this chapter unless supply in the as rolled condition is allowed.

5.2 Where the material is supplied in the as rolled condition and intended for subsequent hot forming, the manufacturer is to carry out any heat treatment which may be necessary to prevent hydrogen cracking or make the material in a safe condition for transit and Surveyors are to be advised of any such heat treatment carried out. This requirement is applicable mainly to carbon and carbon-manganese steel products over 50 [mm] thick and to alloy steel products.

5.3 Where controlled rolling or thermo-mechanical processing is permitted as an alternative to normalising, these procedures may be used subject to full details being submitted and a test program being carried out under the supervision of the Surveyors and the test results being found satisfactory by ACS. These rolling processes are defined as follows: (See Fig. 5.1).

a) 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 recrystalisation region and above the normalising temperature. The strength and toughness properties of steel produced by this process are generally less than steel heat treated after rolling or than steel produced by advanced processes.

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

c) Controlled rolling, CR - this is a procedure in which generally the final rolling temperature is controlled within the range used for normalising heat treatments so that the austenite completely recrystallises.

d) Quenching and Tempering, QT – Quenching involves a heat treatment process in which steel is heated to an appropriate temperature above the Ac3 and then suddenly 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.

e) Thermo-mechanical Rolling, TM – Thermo-mechanical controlled processing - 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 or below the Ar3 transition temperature and may involve rolling towards the lower end of the temperature range of the inter critical duplex phase region thus permitting little if any recrystallisation of the austenite. Unlike controlled rolled (normalised 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 ACS. The same applies for use of tempering after completion of the TM-rolling.

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

5.3.1 Where CR and TM with/without AcC are applied, the programmed rolling schedules are to be verified by ACS at the steel works and are to be made available when required by the attending Surveyor. On the manufacturer's responsibility, the programmed rolling schedules are to be adhered to during the rolling operation (Refer 2.3). To this effect, all the records of actual rolling are to be reviewed by the manufacturer and occasionally by the Surveyor.

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

5.3.2 The conditions of supply and the impact test requirements are detailed in subsequent sections of the Chapter.

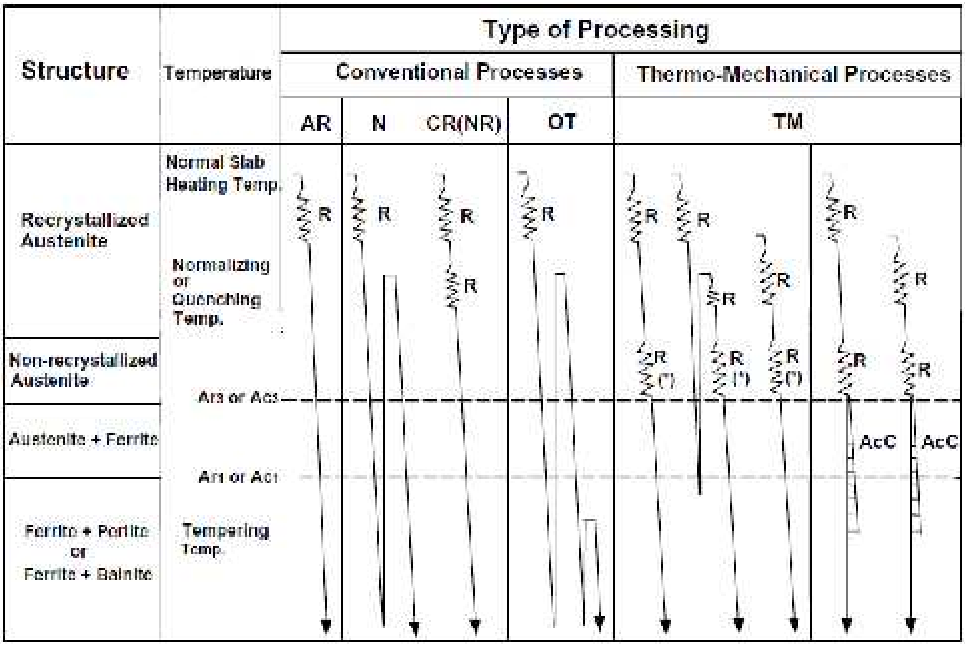


Fig. 5.3 Schematic Diagrams of thermo-mechanical and conventional processes

6 Test material

6.1 All material 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.

6.2 Test samples

a) 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.

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

6.3 Unless otherwise agreed, the test samples are to be taken from the following position :

6.3.1 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 Fig. 6.1 a). Unless otherwise agreed the tensile test specimens are to be prepared with their longitudinal axis transverse to the final direction of rolling.

6.3.2 Flats with a width < 600 [mm], bulb flats and other sections : For flats having a width of 600 [mm] or less, bulb flats and other sections the test specimens are to be taken from one end at a position approximately one third from the outer edge (See Figs. 6.1 b,c,d), or in the case of small sections as near as possible to this position. In the case of channels, beams or bulb angles the test samples may alternatively be taken from a position approximately one quarter of the width from the web centre line or axis (See Fig. 6.1 c). The tensile test specimens may be prepared with their longitudinal axis either parallel or transverse to the final direction of rolling.

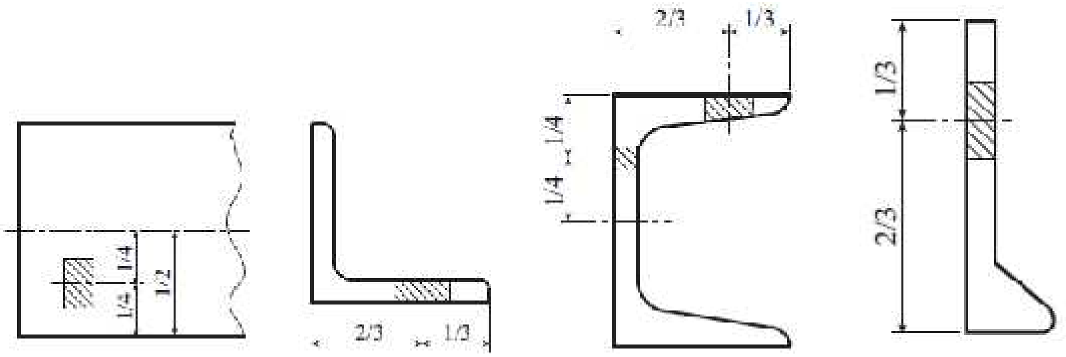
6.3.3 Bars and other similar products: The test specimens are to be taken so that the axis of the test specimen is parallel to the direction of rolling. For small sizes, the test specimen may consist of a suitable length of the full cross section of the product (the impact test specimen receiving nevertheless the necessary machining). For larger sizes, the test samples are to be taken so that the axis of the test specimen lies as near as possible to the following:

a) for non-cylindrical sections, at one third of the half diagonal from the outside.

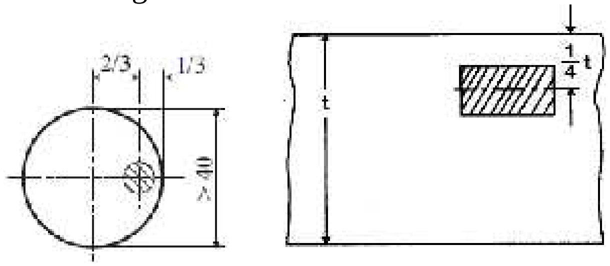
b) for cylindrical sections, at one third of the radius from outside (See Fig. 6. 1 e).

6.3.4 For plates and flats with thicknesses in excess of 40 [mm], full thickness specimens may be prepared, but when instead a machined round specimen is used then the axis is to be located at a position lying one-quarter of the product thickness from the surface as shown in Fig. 6.1.f.

Fig. 6.1



a- Plates and Flats b- Angles c- Cannels and beams d- Bulb flats



e- Rounds f- Plates and flats with thickness > 40 mm

7 Mechanical test specimens

7.1 The tensile test specimens are to be machined to the dimensions detailed in Ch. 2.

7.2 Impact test specimens: The impact test specimens are to be of the Charpy V-notch or U-notch types machined to the dimensions detailed in Ch. 2 and cut with their longitudinal axis either parallel or transverse to the final direction of rolling of the material. They are to be taken from a position close to one of the rolled surfaces, except that for plates and sections over 40 [mm] thick the axis of test specimens are to be one quarter of the thickness from one of the rolled surfaces. For bars and other similar products the axis of the test specimens are to be as specified in 6.3.3. 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 to be not nearer than 25 [mm] to a flame-cut or sheared edge.

8 Surface inspection and dimensions

8.1 Surface inspection and verification of dimensions are the responsibility of the steelmaker, and acceptance by the Surveyors of material later found to be defective shall not absolve the steel maker from this responsibility. The manufacturer is also responsible for compliance with the general requirements concerning freedom from harmful internal defects.

9 Freedom from defects

9.1 All products must have a workmanlike finish and must be free from defects and imperfections which may impair their proper workability and use. This may however, include some discontinuties of a harmless nature, minor imperfections e.g. pittings, rolling in scale, indentations, roll marks, scratches and grooves which cannot be avoided completely despite proper manufacturing and which will not be objected to provided they do not exceed the acceptable limits contained herein.

9.2 Imperfections : Notwithstanding this, the products may have imperfections exceeding the discontinuities inherent to the manufacturing process, as defined under 9.1. In such cases, limits for their acceptability are to be agreed with ACS, taking the end use of the product into consideration.

9.3 Defects : Cracks, shells, sand patches and sharp edged seams are always considered defects which would impair the end use of the product and which require rejection or repair, irrespective of their size and number. The same applies to other imperfection exceeding the acceptable limits.

10 Repairs

10.1 Surface defects in structural steel may be removed by local grinding, provided that

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

b) each single ground area does not exceed 0.25 [m2].

c) each single ground area does not exceed 2 percent 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.

d) ground area lying opposite each other on both surfaces must not decrease the product thickness by values exceeding the limits as stated above in a, b and c.

e) the ground area must have smooth transition to the surrounding surface of the product. Ground areas lying in a distance less than their average breadth to each other are to be regarded as one single area. The repairs are to be agreed with the Surveyor in each case and are to be carried out under his supervision unless otherwise agreed. Complete elimination of the defects may be verified by a magnetic particle or dye penetrant test procedure at the Surveyors' discretion.

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

10.2 Surface defects which cannot be dealt with as in 10.1 may be repaired by chipping and/ or grinding followed by welding subject to Surveyor's consent and under his supervision provided:

a) And single welded area shall not exceed 0.125 [m] and the sum of all areas shall not exceed 2 per cent of the surface side in question. The distance between two welded areas is not to be less than their average width.

b) The weld preparation must not reduce the thickness of the product below 80 per cent of the nominal thickness. For occasional defects with depths exceeding the 80 per cent limit, special consideration at the Surveyors' discretion will be necessary.

c) 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 manufacturer's requirements and protected against rehumidification before and during welding.

d) The welds 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 of which is subsequently to be ground smooth to the surface level.

e) 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.

f) 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.

g) 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.

10.3 Cracks, shells, sand patches and sharp edged seams are always considered defects which would impair the end use of the product and which require rejection or repair, irrespective of their size and number. The same applies to other imperfections exceeding the acceptable limits.

11 Special quality plate material ('z' quality)

11.1 When plate material, intended for welded construction, will be subject to significant strains in a direction perpendicular to the rolled surfaces, it is recommended that consideration be given to the use of special plate material with specified through thickness properties. These strains are usually associated with thermal contraction and restraint during welding, particularly for full penetration "T"- butt welds, but may also be associated with loads applied in service or during construction. Requirements for these materials are detailed in Sec. 8 and it is the responsibility of shipbuilder or fabricator to make provision for the use of this material.

12 Branding of materials

12.1 Every finished item is to be clearly marked by the manufacturer in at least one place with ACS brand AC and the following particulars:

a) The manufacturer's name or trade mark;

b) Identification mark for the grade of steel, (material supplied in the thermomechanically controlled process condition is to have the letter TM added after the identification mark) ;

c) Cast or identification number and/or initials which enable the full history of the item to be traced;

d) If required by the purchaser, his order number or other identification marks.

e) Steels, which have been specially approved and which differ from the requirements given in this Chapter are to have the letter "S" marked after the agreed identification mark.

12.2 Products complying with the requirements of Sec. 8 are to be marked "Z 25" or 'Z 35' as appropriate, in addition to the material grade designation e.g. 'EH36Z25' or 'EH36Z35'.

12.3 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 recognizable.

12.4 In the event of any material bearing ACS brand failing to comply with the test requirements, the brand name is to be unmistakably defaced.

13 Test certificates or shipping statements

13.1 The Surveyor is to be supplied, in duplicate, copies of the test certificates or shipping statements for all accepted materials, ACS 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:

a) Purchaser's order number and if known the ship number for which the material is intended;

b) Identification number and/or initials;

c) Identification of steel works;

d) Identification of the grade of steel;

e) Cast number and ladle analysis;

f) Condition of supply when other than as rolled e.g. normalized or controlled rolled;

g) If the material is of rimming quality, this should be stated;

h) Test results.

In the case of 'Z' quality steel, notation 'Z25' or 'Z35' as appropriate, is to be indicated with the steel grade and test results are to include through thickness reduction in area (%).

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

"We hereby certify that the material has been made by an approved process in accordance with the Rules of Asia Classification Society and has been tested satisfactorily in the presence of the surveyors of Asia Classification Society".

13.3 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 and the name of the manufacturer, the number of cast from which it was made and the ladle analysis.

The Surveyors are to have access to the works at which the steel was produced and the works must be approved by ACS.

Section 2 Normal Strength Steels for Ship Structures

1 General

1.1 Normal strength hot-rolled steel plates, wide flats, sections and bars intended for use in hull construction, is to comply with the following requirements. Steel differing in chemical composition, deoxidation practice, heat treatment or mechanical properties may be accepted, subject to special agreement by ACS.

1.2 These requirements are primarily intended to apply to steel plates not exceeding 100 [mm] in thickness and sections and bars not exceeding 50 [mm] in thickness. For greater thickness, certain variations in the requirements may be allowed or required in particular cases after consideration of the technical circumstances involved.

1.3 Additional approval tests may be required to verify the suitability for forming and welding of Grade E plate exceeding 50 [mm] in thickness.

2 Deoxidation and chemical composition

2.1 The method of deoxidation and the chemical composition of ladle samples are to comply with the requirements of Table 2.1.

2.2 When any grade of steel is supplied in the thermo-mechanically controlled processed condition, deviations in the specified chemical composition may be allowed by ACS.

3 Heat treatment, condition of supply

3.1 All materials are to be supplied in a condition complying with Table 3.1 and Table 3.2. Where alternative arrangements are permitted these are at the option of the steelmaker, unless otherwise expressly stated in the order for the material.

4 Mechanical tests

4.1 Sizes and orientation of test specimens are to be in Accordance with the requirements of Sec. 1.

4.2 For each batch presented. except where specially agreed by ACS. one tensile test is to be made from one piece unless the weight of finished material is greater than 50 tonnes in which case one extra test piece is to be made from a different piece from each 50 tonnes or fraction thereof. Additional tests are to be made for every variation of 10 [mm] in thickness of plate or diameter of products from the same cast. For sections the thickness to be considered is the thickness of the product at the point at which samples are taken for mechanical tests.

4.3 For plates of thickness exceeding 50 [mm] in Grade E steel, one tensile test is to be made on each piece.

4.4 For each batch presented, except where specially agreed by ACS at least one set of three Charpy V-notch test specimens is to be made from one piece unless the weight of finished material is greater than 50 tonnes in which case one extra set of three test specimens is to be made from a different piece from each 50 tonnes or fraction thereof. The piece selected for the preparation of test specimen is to be the thickest of each batch. Where steel plates except for Grade ’A’ steel over 50 [mm] in thickness is supplied in the controlled rolled condition, the frequency of impact test is to be made from a different piece from each 25 tonnes or fraction thereof.

4.5 When subject to the special approval of ACS, material is supplied in the as rolled condition the frequency of impact tests is to be increased to one set from each batch of 25 tonnes or fraction thereof. However, for Grade ’A’ steel over 50 [mm] thickness when supplied in the "as rolled" condition, one set of three charpy V-notch test specimens may be taken from each batch of 50 tonnes or fraction thereof.

4.6 For plates in Grade E steel, one set of three impact test specimens is to be made from each piece.

4.7 For Grade E sections, except where specially agreed, for each batch presented, one set of three impact test specimens is to be made for each 25 tonnes of normalised material and for each 15 tonnes of materials which are not normalised.

Table 2.1: Deoxidation and chemical composition

Steel grade	A	B	D	E
Deoxidation practice for thickness t (mm)	t ≤ 50 mm: any method except rimmed (1) t > 50 mm: killed	t ≤ 50 mm: any method except rimmed t > 50 mm: killed	t ≤ 25 mm: killed t > 25 mm: killed and fine grain treated	killed and fine grain treated
Chemical composition (%) (2) (3) (4)				
C max (5)	0.21 (6)	0.21	0.21	0.18
Mn min (5)	2.5 x C	0.80 (7)	0.60	0.70
Si max	0.50	0.35	0.35	0.35
P max	0.035	0.035	0.035	0.035
S max	0.035	0.035	0.035	0.035
Al (acid soluble) min			0.015 (8) (9)	0.015 (9)

(1) For sections up to a thickness of 12,5 mm, rimmed steel may be accepted subject to the special approval of the Society.

(2) When any grade of steel is supplied in the thermo-mechanically rolled condition, variations in the specified chemical composition may be allowed or required by the Society and are to be stated at the approval.

(3) The Society may limit the amount of residual elements which may have an adverse effect on the working and use of the steel, e.g. copper and tin.

(4) Where additions of any other element have been made as part of the steelmaking practice, the content is to be indicated in the ladle analysis certificate.

(5) C +1/6 Mn is not to exceed 0,40%.

(6) Max. 0,23% for sections.

(7) When Grade B steel is impact tested, the minimum manganese content may be reduced to 0,60%.

(8) Al is required for thickness greater than 25 mm.

(9) The total aluminum content may be determined instead of acid soluble content. In such cases the total aluminum content is to be not less than 0,020%. Other suitable grain refining elements may be used subject to the special approval of the Society

Table 3.1: Condition of supply for normal strength steel (1)

Grades	Thickness	Condition of supply
A	≤ 50 mm > 50 mm ≤100 mm	Any Normalized controlled rolled or thermomechanically rolled (2)
B	≤ 50 mm > 50 mm ≤100 mm	Any Normalized controlled rolled or thermomechanically rolled (2)
D	≤ 35 mm > 35 mm ≤100 mm	Any Normalized controlled rolled or thermomechanically rolled (3)
E	≤ 100 mm	Normalized or thermo-mechanically rolled (3)

Notes:

1) These conditions of supply and the impact test requirements are summarised in Table 3.2.

2) Subject to the special approval of ACS, Grades A and B steel plates may be supplied in the as rolled condition.

3) Subject to the special approval of ACS, sections in Grade D steel may be supplied in the as rolled condition provided satisfactory results are consistently obtained from Charpy impact tests.

   Similarly sections in Grade E steel may be supplied in the as rolled or controlled rolled condition.

   For the frequency of impact tests see 4.4, 4.5, 4.6 and 4.7.

4.8 Results of mechanical testing are to comply with Table 4.1. For impact tests, one individual value may be less than the required average value provided that it is not less than 70 per cent of this average value.

4.9 Minimum average energy values are specified for Charpy V-notch impact test specimens taken in either the longitudinal or transverse directions.

Generally only longitudinal test specimens need be prepared and tested except for special applications where transverse test specimens may be required. Transverse test results are to be guaranteed by the manufacturer. The tabulated values are for standard specimens 10 [mm] x 10 [mm]. For plate thicknesses lower than 10 [mm], sub-size specimens may be used with reduced requirements as follows :
Specimen 10 x 7.5 [mm] : 5/6 of tabulated energy
Specimen 10 x 5 [mm] : 2/3 of tabulated energy.

Table 3.2: Required condition of supply and number of impact tests for normal strength steels

Grade	Deoxidation Practice	Products	Condition of supply (batch for impact tests) (1)(2) Thickness [mm]				
			10 – 12.5	12.5 – 25	25 – 35	35 – 50	50 – 100
A	Rimmed	Sections	A(-)	Not applicable			
A	For t ≤ 50 mm Any method except rimmed For t > 50 mm Killed	Plates	A(-)				N(-) TM(-) CR(50), AR*(50)
A	Killed	Sections	A(-)				Not applicable
B	For t ≤ 50 mm Any method except rimmed For t > 50 mm Killed	Plates	A(-)		A(50)		N(50) TM(50) CR(25), AR*(25)
B	Killed	Sections	A(-)		A(50)		Not applicable
D	Killed	Plates Sections	A(50)		Not applicable		
D	Plates Killed and fine grain treated	Plates	A(50)			N(50) CR(50) TM(50)	N(50) TM(50) CR(25)
D		Sections	A(50)			N(50) CR(50) TM(50) AR*(25)	Not applicable
E	Killed and fine grain treated	Plates	N(Each piece) TM(Each piece)				
E		Sections	N(25) TM(25) AR*(15), CR*(15)				Not applicable

Remarks:

1. Condition of Supply

A - Any (Not Specified)

N - Normalised Condition

CR - Controlled Rolled Condition

TM - Thermo-Mechanical Rolling

AR* - As Rolled Condition subject to special approval of ACS

CR* - Controlled Rolled Condition subject to special approval of ACS.

2. Number of Impact Tests

One set of impact tests is to be taken from each batch of the specified weight in ( ) in tones or fraction thereof.

Table 4.1: Mechanical properties for normal strength steels

Steel grade	Yield stress (N/mm^2) min.	Tensile strength (N/mm^2)	El.A5(%) min (1)	Average impact energy (J) min KVL longitudinal - KVT transverse - t = thickness (mm)						
				Testtemp (°C)	t ≤ 50		50 < t ≤ 70		70 < t ≤ 100	
					KVL	KVT	KVL	KVT	KVL	KVT
A	235	400/520(2)	22	+20			34	24	41	27
B	235	400/520	22	0	27	20	34	24	41	27
C	235	400/520	22	-20	27	20	34	24	41	27
D	235	400/520	22	-40	27	20	34	24	41	27

(1) El.: elongation. For full thickness flat tensile test specimens with a width of 25 mm and a gauge length of 200mm, the elongation is to comply with the minimum values given for strength level 32 in following table.

(2) For sections in grade A of all thicknesses, the upper limit for the specified tensile stress range may be exceeded up to a maximum of 540 N/mm^2.

Strengthgrade	t ≤5	5 < t ≤10	10 <t ≤15	15< t ≤20	20 <t ≤25	25 <t ≤30	30 <t ≤40	40 <t ≤50
32	14	16	17	18	19	20	21	22
36	13	15	16	17	18	19	20	21
40	12	14	15	16	17	18	19	20

Section 3 Higher Strength Steels for Ship Structures

1 General

1.1 Higher strength steel, supplied in three strength levels, 32, 36 and 40, intended for use in hull construction, is to comply with following requirements.

Steel differing in chemical composition, deoxidation practice, heat treatment or mechanical properties may be accepted, subject to special approval by ACS. Such steel is to be given special designation.

1.2 Each strength level is subdivided into four grades, AH, DH, EH and FH differing in the required levels of notch toughness.

1.3 The requirements of this section are primarily intended to apply to plates not exceeding 100 mm in thickness in general, and sections and bars not exceeding 50 mm in thickness. For greater thickness, these requirements may be applied with certain variations, as may be agreed by ACS.

1.4 It should be noted that when fatigue loading is present, the effective fatigue strength of a welded construction of higher strength steels may not be greater than that of a construction fabricated from the normal strength steels. Precautions against corrosion fatigue may also be necessary.

Note: 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.

2 Deoxidation and chemical composition

2.1 The method of deoxidation and chemical analysis of ladle samples are to comply with the requirements of Table 2.1.

Table 2.1: Chemical composition and deoxidation practice for higher strength steels

Steel grade	AH32, DH32, EH32 AH36, DH36, EH36 AH40, DH40, EH40	FH32, FH36, FH40
Deoxidation practice	killed and fine grain treated	killed and fine grain treated
Chemical composition (%) (1) (5)		
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 (3) (4)	0.015	0.015
Nb (4)	0.02 – 0.05	0.02 – 0.05
V (4)	0.05 – 0.10	0.05 – 0.10
Ti max. (4)	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 if Al is present)

(1) Alloying elements other than those listed above or exceeding the specified limits may be accepted by the Society when proposed by the steelmaker at the time of approval and their content is to be indicated in the ladle analysis.

(2) Up to a thickness of 12,5 mm, the minimum manganese content may be reduced to 0,70.

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

(4) The steel is to contain Aluminium, niobium, vanadium or other suitable grain refining elements, either singly or in any combination. When used singly, the steel is to contain the specified minimum content of the grain refining element. When used in combination, the specified minimum content of at least one grain refining element is applicable; the sum of Nb+V+Ti is not to exceed 0.12%.

(5) When any grade of higher strength steel is supplied in the thermo-mechanically rolled condition, variations in the specified chemical composition may be allowed or required by the Society and are to be stated at the approval.

2.2 When required, the carbon equivalent value is to be calculated from the ladle analysis using the following formula.

$$\text{Carbon eq.} = C + \frac{Mn}{6} + \frac{Cr+Mo+V}{5} + \frac{Ni+Cu}{15}\%$$

Note: 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.

2.3 Slight deviations in chemical composition with respect to Grade E36 for plates exceeding 50 mm may be permitted provided that these deviations are documented and approved in advance by ACS.

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

2.5 When any grade of higher strength steel is supplied in the thermo-mechanically controlled processed condition variations in the specified chemical composition may be allowed or required by ACS.

2.5.1 For TM (TMCP) steels the following special requirements apply:

i) The carbon equivalent value is to be calculated from the ladle analysis using the following formula and to comply with the requirements of the following table:

Carbon equivalent for higher strength steels upto 100 mm in thickness produced by TM

Steel grade	Carbon equivalent CEQ max. (%) (1)	
	$t \leq 50$	$50 < t \leq 100$
AH32, DH32, EH32, FH32	0.36	0.38
AH36, DH36, EH36, FH36	0.38	0.40
AH40, DH40, EH40, FH40	0.40	0.42

t = thickness (mm)

(1) More stringent carbon equivalent limits may be agreed between the Manufacturer and the shipbuilder in individual cases.

$$\text{Carbon eq.} = C + \frac{Mn}{6} + \frac{Cr+Mo+V}{5} + \frac{Ni+Cu}{15}\%$$

ii) Other means such as cold cracking susceptibility Pcm, may be considered instead of the carbon equivalent for evaluating the weldability.

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

3 Heat treatment, condition of supply

3.1 All materials are to be supplied in a condition complying with the requirements given in Table 3.1. Where alternative conditions are permitted, these are at the option of the steelmaker, unless otherwise expressly stated in the order for material.

Table 3.1: Required condition of supply and number of impact tests for higher strength steels

Grade	Deoxi-dation Practice	Grain Refining Elements	Pro-ducts	Condition of supply (batch for impact tests) (1)(2)								
				Thickness [mm]								
				10	12.5	20	25	30	35	40	50	100
AH32 AH36	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 alone or with Ti	Plates	A(50)		AR*(25)				N(50), CR(50) TM(50)	Not applicable N(50), CR(25) TM(50)	
			Sections	A(50)						N(50) CR(50) RM(50) AR*(25)	Not applicable	
AH40	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	
DH32 DH36	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 alone or with Ti	Plates	A(50)		AR*(25)				N(50), CR(50) TM(50)	Not applicable N(50), CR(25) TM(50)	
			Sections	A(50)						N(50) CR(50) RM(50) AR*(25)	Not applicable	
DH40	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	
EH32 EH36	Killed and fine grain treated	Any	Plates	N(Each piece) TM(Each piece)								
			Sections	N(25) TM(25) AR*(15) CR*(15)							Not applicable	
EH40	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	
FH32 FH36	Killed and fine grain treated	Any	Plates	N(Each piece) TM(Each piece) QT(Each length as heat treated)							Not applicable	
			Section	N(25) TM(25) QT(25) CR*(15)							Not applicable	
FH40	Killed and fine grain treated	Any	Plates	N(Each piece) TM(Each piece) QT(Each length as heat treated)							Not applicable	
			Sections	N(25) TM(25) QT(25)							Not applicable	

Remarks
1) Condition of Supply
A - Any (Not Specified)
N - Normalised Condition
CR - Controlled Rolled Condition
TM - Thermo-Mechanical Rolling
QT - Quenched and Tempered Condition
AR* - As Rolled Condition subject to special approval of ACS
CR* - Controlled Rolled Condition subject to special approval of ACS.
2) Number of Impact Tests
One set of impact tests is to be taken from each batch of the "specified weight" in ( ) in tones or fraction thereof.
For Grades A32 and A36 steels charpy impact tests are not generally required provided that satisfactory results are obtained from occasional check tests selected by the Surveyor.

4 Mechanical tests

4.1 Sizes and orientation of test specimens are to be in accordance with the requirements of Sec. 1.

4.2 For each batch presented, except where specially agreed by ACS, one tensile test is to be made from one piece unless the weight of finished material is greater than 50 tonnes in which case one extra test piece is to be made from a different piece from each 50 tonnes or fraction thereof. Additional tests are to be made for every variation of 10 mm in thickness of plate or diameter of products from the same cast. For sections, the thickness to be considered is the thickness of the product at the point at which samples are taken for mechanical tests.

4.3 For plates of thickness exceeding 50 mm in Grade E steel, one tensile test is to be made on each piece.

4.4 For each batch of plates presented, (except for Grades EH32, EH36, EH40, FH32, FH36 and FH40) the number of Charpy V-notch impact tests is to be as follows :

i) Except where otherwise specified or specially agreed by ACS, for each batch presented, at least one set of three Charpy V-notch impact test specimens is to be made from one piece unless the weight of finished material is greater than 50 tonnes, in which case one extra set of three test specimens is to be made from a different piece from each 50 tonnes or fraction thereof.

ii) For steel plates of Grades AH40 and DH40 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.

iii) When, subject to special approval of ACS, material is supplied in the as rolled condition, the frequency of impact tests is to be increased to one set from each batch of 25 tonnes or fraction thereof.

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

4.5 For each batch of Grade EH32, EH36 and EH40 steel presented, the number of Charpy Vnotch impact tests is to be as follows :

i) For plates one set of three Charpy V-notch impact test specimens is to be taken from each piece.

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

iii) When, subject to special approval of ACS, sections are supplied in the as-rolled condition, one set of impact tests is to be taken from each batch of 15 tonnes or fraction thereof.

iv) For (ii) and (iii) above the piece selected for the preparation of test specimens is to be the thickest in each batch.

4.6 One set of Charpy V-notch impact test specimens are to be tested from each rolled length for Grades FH32, FH36 and FH40 of steel plates supplied in the normalised or thermo-mechanically controlled process condition.

4.7 For steels in the quenched and tempered condition, one tensile and one set of three Charpy V- notch impact tests are to be made on each plate as heat treated.

4.8 Generally only longitudinal (L) impact test specimens need be prepared and tested. however in all cases transverse (T) test results are to be guaranteed by the manufacturer.

4.9 The results of all tensile tests and the average energy value from each set of three impact tests are to comply with the appropriate requirements given in Table 4.1.

4.10 When standard subsidiary impact specimens are necessary.

Table 4.1 : Mechanical properties for higher strength steels

Steel grade	Yield strength (N/mm^2) min.	Tensile strength (N/mm^2)	El. A5 (%)min	Average impact energy (J) min KVL longitudinal - KVT transverse - t = thickness (mm)						
				Test temp(°C)	t ≤50		50 < t ≤ 70		70 < t ≤100	
					KVL	KVT	KVL	KVT	KVL	KVT
AH32	315	440/570	22(1)	0	31(3)	23(3)	38	26	46	31
DH32				-20	31	22	38	26	46	31
EH32				-40	31	22	38	26	46	31
FH32				-60	31	22	38	26	46	31
AH36	355	490/630	21(1)	0	34(3)	24(3)	41	27	50	34
DH36				-20	34	24	41	27	50	34
EH36				-40	34	24	41	27	50	34
FH36				-60	34	24	41	27	50	34
AH40	390	510/660	20(1)	0	39	27	46	31	55	37
DH40				-20	39	27	46	31	55	37
EH40				-40	39	27	46	31	55	37
FH40				-60	39	27	46	31	55	37

t = thickness [mm]

NOTES:

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

Strength grade	t ≤ 5	5 < t ≤10	10<t≤ 15	15< t≤20	20< t≤25	25<t≤ 30	30< t≤40	40<t≤ 50
32	14	16	17	18	19	20	21	22
36	13	15	16	17	18	19	20	21
40	12	14	15	16	17	18	19	20

2) See 4.9.

3) For Grades A32 and A36 steels a relaxation in the number of impact tests for acceptance purposes may be permitted by special agreement with ACS provided that satisfactory results are obtained from occasional check tests.

Section 4 High Strength Quenched and Tempered Steels for Welded Structures

1 General

1.1 These requirements apply to weldable high strength and tempered steel plates and wide flats up to 70 mm thickness. The application of these requirements for products with thicknesses above 70 mm and for product forms other than plates and wide flats such as sections and tubulars, are to be specially agreed.

1.2 Steel differing from the requirements in this section in respect of chemical composition, deoxidation practice, heat treatment or mechanical properties may be accepted, subject to special approval by ACS.

1.3 The steel covered by the scope of these requirements are divided into six yield strength levels of 420, 460, 500, 550, 620 and 690 N/mm^2. For each yield strength level four grades AH, DH, EH and FH are specified, based on the impact test temperature.

1.4 Special consideration may be given to the supply of those steels in thickness upto 50 mm in the TMCP condition subject to approval of ACS.

2 Approval

2.1 The steels must be approved by ACS and for this purpose the steel maker is to submit a specification containing such details as chemical composition, manufacturing process, mechanical properties, delivery condition, recommendation for welding, cold and hot forming and heat treatment. In addition, ACS may require initial approval tests to be performed. Weldability of each grade of steel is to be demonstrated by the steel maker during the initial approval procedure to the satisfaction of ACS.

3 Deoxidation and chemical composition

3.1 The steel shall be fully killed and fine grain treated.

3.2 The chemical composition is to be determined by the steel maker, in an adequately equipped competently staffed laboratory, from each cast or ladle and is to comply with the requirements of the approved specifications and limits given in Table 3.1.

3.3 The cold cracking susceptibility Pcm for evaluating weldability should 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 Pcm to be achieved is to be agreed with ACS and included in the approved specification.

4 Heat treatment

4.1 All materials are to be supplied in the quenched and tempered condition. This requirement excludes precipitation hardening steels.

Table 3.1: Chemical composition

Yield strength level (N/mm^2)	Grade	Maximum content of elements (1)					
		C	Si	Mn	P	S	N
420 to 690	AH	0.21	0.55	1.70	0.035	0.035	0.020
420 to 690	DH	0.20	0.55	1.70	0.030	0.030	0.020
420 to 690	EH	0.20	0.55	1.70	0.030	0.030	0.020
420 to 690	FH	0.18	0.55	1.60	0.025	0.025	0.020

(1) The content of other elements used for alloying and fine grain treatment is to be within the limits specified for the steel at the time of its approval and is not normally to exceed the following per cent limits:

Cu max.= 1,5 ; Cr max.= 2,0 ; Ni max.= 2,0 ; Mo max.= 1,0 ; N max.= 0,020 ; B max.= 0,06 ; Nb max.= 0,06 ; V max.= 0,10 ; Ti max.= 0,20 ; Zr max.= 0,15.

(2) The acid soluble Al content may be totally replaced by Nb, V or Ti. The total Aluminium content may be determined instead of the acid soluble content and in such cases the total Aluminium content is to be not less than 0,020%.

5 Mechanical tests

5.1 Sizes and orientation of test specimens are to be in accordance with the requirements of Sec. 1.

5.2 One tensile and one set of three Charpy V-notch impact tests are to be made on each piece as heat treated. For continuous heat treated plates special consideration may be given regarding the number and location of test specimens required.

5.3 The results of all tensile tests are to comply with the appropriate requirements given in Table 5.1 and Table 5.2. In the case of other product forms, where longitudinal tests have been agreed, the elongation values are to be 2 percent units above those given in Table 5.1 and Table 5.2.

5.4 Unless otherwise accepted by ACS, 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 5.1 and Table 5.2. For other product forms the impact tests are to be in the longitudinal direction, the results of tests are to comply with appropriate requirements of Table 5.1 and Table 5.2. Normally subsurface test specimens will be taken, however, for material with a thickness in excess of 40 [mm], impact tests should be taken at the quarter thickness (t/4) location.

5.5 If required by ACS, through thickness tensile tests are to be performed in accordance with the requirements of Sec. 8.

Table 5.1 : Mechanical properties requirements, 70 [mm] maximum thickness

Steel grade	Yield strength (N/mm^2)min.(1)	Tensile strength(N/mm^2)	El. A5(%) min (2)	Impact Test (3) Average energy (J) min		
				Test temp(°C)	KVL	KVT
AH420	420	530/680	18	0	42	28
DH420				-20	42	28
EH420				-40	42	28
FH420				-60	42	28
AH460	460	570/720	17	0	46	31
DH460				-20	46	31
EH460				-40	46	31
FH460				-60	46	31
AH500	500	610/770	16	0	50	33
DH500				-20	50	33
EH500				-40	50	33
FH500				-60	50	33

Steel grade	Yield strength (N/mm^2) in.(1)	Tensile strength (N/mm^2)	El. A5 (%) min (2)	Impact Test (3) Average energy (J) min		
				Test temp(°C)	KVL	KVT
AH550	550	670/830	16	0	55	37
DH550				-20	55	37
EH550				-40	55	37
FH550				-60	55	37
AH620	620	720/ 890	15	0	62	41
DH620				-20	62	41
EH620				-40	62	41
FH620				-60	62	41
AH690	690	770/940	14	0	69	46
DH690				-20	69	46
EH690				-40	69	46
FH690				-60	69	46

L = Longitudinal;

T = transverse.

Note 1: Where the yield stress is not marked in the tensile test, the 0.2% proof stress is applicable.

Note 2: For full thickness flat test specimens with a width of 25 [mm] and a gauge length of 200 [mm] the elongation is to comply with the minimum values shown in Table 5.2

Note 3: For A grade steels, a reduction in the number of impact tests required for acceptance purpose may be permitted by special agreement with ACS provided that satisfactory results are obtained from occasional check tests.

Table 5.2: Elongation minimum values for a width of 25 [mm] and a 200 [mm] gauge length

Strength grade	t≤ 10	10< t≤ 15	15<t ≤ 20	20<t≤ 25	25< t≤ 40	40<t ≤ 50	50<t ≤ 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

Section 5 Steel for Low Temperature Service

1 General

1.1 This section gives specific requirements for carbon-manganese and nickel alloy steels with toughness properties at low temperatures and intended for use in the construction of cargo tanks and process pressure vessels for liquefied gases.

1.2 The requirements of this section are also applicable for other types of pressure vessels where the use of steels with guaranteed impact properties at low temperature is required.

1.3 Provision is made for plates and sections up to 40 mm thick.

1.4 Steel differing in chemical composition, condition of supply or mechanical properties may be accepted, subject to special agreement by ACS.

2 Deoxidation and chemical composition

2.1 All steels are to be in the fully killed and fine grain refined condition.

2.2 The chemical composition of carbon manganese steels are to comply with the appropriate requirements of grades AH, DH, EH and FH strength levels 32, 36 and 40 (See Table 2.1). However these grades are to be designated as LT -AH, LT -DH, LT -EH and LT -FH respectively for the uses defined in 1.1.

2.3 The chemical compositions of nickel alloy steels are to comply with the appropriate requirements of Table 2.1.

Table 2.1: Chemical composition of nickel alloy steels

Elements	1.5 Ni	3.5 Ni	5 Ni	9 Ni
C max.	0.18	0.15	0.12	0.10
Si	0.10 - 0.35	0.10 - 0.35	0.10 - 0.35	0.10 - 0.35
Mn	0.30 - 1.50	0.30 - 0.90	0.30 - 0.90	0.30 - 0.90
Ni	1.30 - 1.70	3.20 - 3.80	4.70 - 5.30	8.50 - 10.0
P max.	0.025	0.025	0.025	0.025
S max.	0.020	0.020	0.020	0.020
Al min. (acid soluble)1)	0.015	0.015	0.015	0.015
Residual elements				
Cr max.	0.25	0.25	0.25	0.25
Cu max.	0.35	0.35	0.25	0.35
Mo max.	0.08	0.08	0.08	0.08
Total of residual elements max.	0.60	0.60	0.60	0.60

1) The total Aluminum content may be determined by other methods instead of the acid soluble method. In such cases the total Aluminum content is to be not less than 0.020 percent.

3 Heat treatment

3.1 All materials are to be supplied in a condition complying with Table 3.1.

Table 3.1: Conditions of supply Grade Plates Sections and Bars

Grade	Plates	Sections and bars
LT-AH	N, TMCP	Any
LT-DH	N, TMCP	Any
LT-EH	N[2],TMCP,QT	N,TMCP
LT-EH	N[2],TMCP,QT	N,TMCP
1.5 Ni	N[2],QT,normalized and tempered	
3.5 Ni	N[2],QT,normalized and tempered	
5 Ni	N[2],QT,normalized and tempered	
9 Ni	QT, Double normalized and tempered	

1 N = Normalized

TMCP = Thermo-mechanically controlled process

QT = Quenched and tempered

2 The term "Normalized" does not include normalized rolling.

4 Mechanical tests

4.1 Test pieces for tensile testing of plates are to be cut with their principal axes transverse to the final direction of rolling.

4.2 For each batch of plate presented, one tensile test is to be made from one end of each piece unless the mass and length of the piece exceeds 5 tonnes and 15 m in which case test pieces are to be taken from both ends of each piece.

4.3 Sections and bars are to be presented for acceptance test in batches containing not more than 50 lengths, as supplied. The material in each batch is to be of the same section size, from the same cast and in the same condition of supply. One tensile test specimen is to be taken from material representative of each batch, except that additional tests are to be taken when the mass of a batch exceeds 10 tonnes.

4.4 One set of three Charpy V-notch impact test specimens are to be taken for each tensile test specimen required. For plates, these are to be cut with their principal axis perpendicular to the final direction of rolling and for sections. these are to be taken longitudinally.

4.5 The results of all tensile tests are to comply with appropriate requirements given in Table 4.1. The ratio between the yield stress and the tensile strength is not to exceed 0.9 for normalized and TMCP steels and 0.94 for Q & T steels.

4.6 The average energy value from each set of three impact tests are to comply with appropriate requirements given in Table 4.1.

4.7 When standard subsidiary impact specimens are necessary (See Sec. 2).

4.8 When steel with improved through thickness properties is required or specified in the order, the materials are to be tested as detailed in Sec. 8.

Table 4.1 : Mechanical properties for acceptance purposes

Grade of steel		Yield stress N/mm^2, min.	Tensile strength N/mm^2	Elongation on 5.65 $\sqrt{S_0}$ % min	Charpy V-notch impact test	
					Test temp ^{0}C	Impact energy min.
LT-AH	32 36 40	315 355 390	440 - 590 490 - 620 510 - 650	22 21 20	0	Plates transverse tests Average energy 27 J Sections and bars longitudinal tests Average energy 41 J
LT-DH	32 36 40	315 355 390	440 - 590 490 - 620 510 - 650	22 21 20	-20	
LT-EH	32 36 40	315 355 390	440 - 590 490 - 620 510 - 650	22 21 20	-40	
LT-FH	32 36 40	315 355 390	440 - 590 490 - 620 510 - 650	22 21 20	-60	
1.5 Ni		275	490 - 640	22	-80	
3.5 Ni		285	450 - 610	21	-95	
5 Ni		390	540 - 740	21	-110	
9 Ni		490	640 - 790	18	-196	

Notes:

1 These requirements are applicable to products not exceeding 40 mm in thickness. The requirements for thicker products are subject to agreement.

2 The minimum design temperatures at which plates of different thicknesses in the above grades may be used are given in relevant sections of the rule. Consideration will be given to the use of thicknesses greater than those in the table or to the use of temperatures below – 165°C

Section 6 Steels for Boilers and Pressure Vessels

1 General

1.1 The following requirements are for carbon, carbon-manganese and alloy steels intended for use in the construction of boilers and pressure vessels. In addition to specifying mechanical properties at ambient temperature for the purpose of acceptance testing, these requirements also give details of appropriate mechanical properties at elevated temperatures which may be used for design purposes.

1.2 Where it is proposed to use a carbon or carbon-manganese steel with a specified minimum tensile strength intermediate to the following specified properties, corresponding minimum values for yield and elongation and mechanical properties at elevated temperatures may be obtained by interpolation.

1.3 Carbon and carbon-manganese steels with a specified minimum tensile strength of greater than 490 N/mm^2 but not exceeding 520 [N/mm^2] may be accepted provided that details of proposed specifications are submitted for approval.

1.4 Where it is proposed to use alloy steels other than those specified herein, details of the specifications are to be submitted for approval. In such cases the specified minimum tensile strength is not to exceed 600 [N/mm^2].

1.5 Materials intended for use in the construction of the cargo tanks and process pressure vessels, storage tanks for liquefied gases and for other low temperature applications are to comply with the rules requirements.

2 Deoxidation and chemical composition

2.1 The method of deoxidation and the chemical analysis of ladle samples is to comply with the requirements of Table 2.1.

Table 2.1: Deoxidation and chemical composition

Grade of steel	Deoxidation	Chemical composition per cent						
C and C-Mn steel		C max.	Si	Mn	P max.	S max.	Al	Residual elements
360 AR 410 AR 460 AR	Any method except rimmed steel	0.18 0.21 0.23	0.50 max. 0.50 max. 0.50max.	0.40-1.30 0.40-1.30 0.80-1.50	0.040 0.040 0.040	0.040 0.040 0.040	- - -	Cr 0.25 max. Cu 0.30 max. Mo 0.10 max. Ni 0.30 max. Total 0.70 max.
360 410 460 490	Any method except rimmed steel Killed	0.17 0.20 0.20[1] 0.20[1]	0.35 max. 0.35 max. 0.40 max. 0.10-0.50	0.40-1.20 0.50-1.30 0.80-1.40 0.90-1.60	0.035 0.035 0.035 0.035	0.035 0.035 0.035 0.035	- - -	
360 FG 410 FG 460 FG 490 FG	Killed fine grained	0.17 0.20 0.20[1] 0.20[1]	0.35 max. 0.35 max. 0.40 max. 0.10-0.50	0.40-1.20 0.50-1.30 0.80-1.50 0.90-1.60	0.035 0.035 0.035 0.035	0.035 0.035 0.035 0.035	See note 2 See note 2 See note 2 See note 2	

Alloy steels	Deoxi-dation	C	Si	Mn	P max.	S max.	Al	Cr	Mo	Residual elements
1 Cr 1/2 Mo 470	Killed	0.10-0.18	0.15-0.35	0.4-0.8	0.035	0.035	See note3	0.70-1.30	0.40-0.60	Cu 0.30 max. Ni 0.30 max.
2 1/4 Cr 1 Mo 480		0.10-0.18	0.15-0.50	0.4-0.8	0.035	0.035	See note3	2.00-2.50	0.90-1.10	

Notes:

1 For thickness greater than 30 mm, carbon 0.22 percent max.

2 Aluminium (acid soluble) 0.015 per cent min, or Aluminium (total) 0.018 percent min. Niobium, Vanadium or other suitable grain refining elements may be used either in place of or in addition to Aluminum.

3 Aluminum (acid soluble or total) 0.020 percent max.

3 Heat treatment, condition of supply

3.1 All materials are to be supplied in a condition complying with the requirements of Table 3.1.

However, when agreed, material intended for hot forming may be supplied in the as rolled condition.

Table 3.1 : Heat treatment

Grade of steel	Condition of supply
Carbon and carbon-manganese 360 AR to 460 AR	As rolled maximum thickness or diameter is 40 [mm]
Carbon and carbon-manganese 360 to 490	Normalized or controlled rolled
Carbon and carbon-manganese 360 FG to 490 FG	Normalized or controlled rolled
1 Cr 1/2 Mo 470	Normalized and tempered
2 1/4 Cr Mo 480	Normalized and tempered

4 Mechanical tests

4.1 For plates a tensile test specimen is to be taken from one end of each piece when the weight does not exceed 5 tonnes and the length does not exceed 15 [m]. When either of these limits is exceeded, tensile test specimens are to be taken from both ends of each piece. A piece is to be regarded as the rolled product from a single slab or a single ingot, if this is rolled directly into plates.

4.2 For strips, tensile test specimens are to be taken from both ends of each coil.

4.3 Sections and bars are to be presented for acceptance tests in batches containing not more than 50 lengths, as supplied. The material in each batch is to be of the same section size, from the same cast and in the same condition of supply. One tensile test specimen is to be taken from material representative of each batch, except that additional tests are to be taken when the weight of a batch exceeds 10 tonnes.

4.4 Where plates are required for hot forming and it has been agreed that the heat treatment will be carried out by the fabricator, the tests at the steel works are to be made on material which has been cut from the plates and given a normalizing or normalizing and tempering heat treatment in a manner simulating the treatment which will be applied to the plates.

4.5 If required by the Surveyors or by the fabricator test material may be given a simulated stress relieving heat treatment prior to the preparation of the test specimens. This has to be stated on the order together with agreed details of the simulated heat treatment and the mechanical properties which can be accepted.

4.6 The results of the tensile tests are to comply with the appropriate requirements given in Table 4.1, Table 4.2 and Table 4.3.

Table 4.1: Mechanical properties for acceptance purposes : carbon and carbon-manganese steels - as rolled

Grade of steel	Thickness [mm]	Yield stress [N/mm^2] min.	Tensile strength [N/mm^2]	Elongation on $5.65 \sqrt{S_0}$ % min
360 AR	≤ 40	190	360 – 480	24
410 AR	≤ 40	215	410 – 530	22
460 AR	≤ 40	240	460 - 580	21

Table 4.2: Mechanical properties for acceptance purposes : carbon and carbon-manganese steels-normalized or controlled rolled

Grade of steel	Thickness [mm] (see Note)	Yield stress [N/mm^2] min.	Tensile strength [N/mm^2]	Elongation on 5.65 $\sqrt{S_0}$ % min
360	> 3 ≤ 16 > 16 ≤ 40 > 40 ≤ 63	205 195 185	360 - 480	26 26 25
410	> 3 ≤ 16 > 16 ≤ 40 > 40 ≤ 63	235 225 215	410 - 530	24 24 23
460	> 3 ≤ 16 > 16 ≤ 40 > 40 ≤ 63	285 255 245	460 - 580	22 22 21
490	> 3 ≤ 16 > 16 ≤ 40 > 40 ≤ 63	305 275 265	490 - 610	21 21 20
360 FG	> 3 ≤ 16 > 16 ≤ 40 > 40 ≤ 63	235 215 195	360-480	26 26 25
410 FG	> 3 ≤ 16 > 16 ≤ 40 > 40 ≤ 63	265 245 235	410 - 530	24 24 23
460 FG	> 3 ≤ 16 > 16 ≤ 40 > 40 ≤ 63	295 285 275	460 - 580	22 22 21
490 FG	> 3 ≤ 16 > 16 ≤ 40 > 40 ≤ 63	315 315 305	490 - 610	21 21 21

Note:

For thicknesses greater than 63 [mm], the minimum values for yield stress may be reduced by 1 percent for each 5 [mm] increment in thickness over 63 [mm]. The minimum elongation values may also be reduced one unit, e.g. 20 percent reduced to 19 percent for all thicknesses over 63 [mm]. For thicknesses over 100 [mm], the above values are to be agreed.

Table 4.3: Mechanical properties for acceptance purposes : alloy steels-normalized and tempered

Grade of steel	Thickness [mm] (see Note)	Yield stress [N/mm^2] min.	Tensile strength [N/mm^2]	Elongation on 5.65 $\sqrt{S_0}$ % min
1 Cr 1/2 Mo 470	> 3 ≤ 16 > 16 ≤ 40 > 40 ≤ 63	305 305 305	470 - 620	20 20 19
2 1/4 Cr Mo 480	> 3 ≤ 16 > 16 ≤ 40 > 40 ≤ 63	275 265 265	480 - 630	18 18 17

Note:

For thicknesses greater than 63 [mm], the minimum values for yield stress may be reduced by 1 percent for each 5 [mm] increment in thickness over 63 [mm]. The minimum elongation values may also be reduced one unit, e.g. 20 percent reduced to 19 percent for all thicknesses over 63 [mm]. For thicknesses over 100 [mm], the above values are to be agreed.

5 Mechanical properties for design purposes at elevated temperatures

5.1 Nominal values for the minimum lower yield or 0.2 per cent proof stress at temperatures of 50°C and higher are given in the following tables :

Table 5.1 Carbon and carbon manganese steels - As rolled (applicable only when the design temperature does not exceed 350°C).

Table 5.2 Carbon and carbon-manganese steels normalized or controlled rolled.

Table 5.3 Alloy steels. Normalized and tempered.

5.2 These values are intended for design purposes only and verification is not required except for materials complying with National or proprietary specifications where the elevated temperature properties used for design purposes are higher than those given in Table 5.1 to Table 5.3. The extent of testing in such cases would have to be specially agreed by ACS.

5.3 Values for the estimated average stress to rupture in 100,000 hours are given in Table 5.4 and may be used for design purposes.

Table 5.1: Mechanical properties for design purposes - Carbon and carbon - manganese steels - as rolled

Grade of steel	Thickness [mm]	Design temperature ^{0}C (see note)						
		50	100	150	200	250	300	350
		Nominal minimum lower yield or 0.2 percent proof stress[N/mm^2]						
360 AR 410 AR 460 AR	≤ 40	154 186 218	153 183 213	152 181 210	145 174 203	128 155 182	108 134 161	102 127 153

Note : Maximum permissible design temperature is 350°C

Table 5.2: Mechanical properties for design purposes - carbon and carbon – manganese steels - normalized or controlled rolled

Grade of steel	Thickness [mm] (see Note)	Design temperature °C								
		50	100	150	200	250	300	350	400	450
		Nominal minimum lower yield or 0.2 percent proof stress [N/mm^2]								
360	> 3 ≤ 16 > 16 ≤ 40 > 40 ≤ 63	183 173 166	175 171 162	172 169 158	168 162 152	150 144 141	128 124 124	117 117 117	115 115 115	113 113 113
410	> 3 ≤ 16 > 16 ≤ 40 > 40 ≤ 63	220 204 196	211 201 192	208 198 188	201 191 181	180 171 168	150 150 150	142 142 142	138 138 138	136 136 136
460	> 3 ≤ 16 > 16 ≤ 40 > 40 ≤ 63	260 235 227	248 230 222	243 227 218	235 220 210	210 198 194	176 176 176	168 168 168	162 162 162	158 158 158
490	> 3 ≤ 16 > 16 ≤ 40 > 40 ≤ 63	280 255 245	270 248 240	264 245 236	255 237 227	228 214 210	192 192 192	183 183 183	177 177 177	172 172 172
360 FG	> 3 ≤ 16 > 16 ≤ 40 > 40 ≤ 63	214 200 183	204 196 179	185 183 172	165 164 159	145 145 145	127 127 127	116 116 116	110 110 110	106 106 106
410 FG	> 3 ≤ 16 > 16 ≤ 40 > 40 ≤ 63	248 235 222	235 228 215	216 213 204	194 192 188	171 171 171	152 152 152	141 141 141	134 134 134	130 130 130
460 FG	> 3 ≤ 16 > 16 ≤ 40 > 40 ≤ 63	276 217 262	262 260 251	247 242 236	223 220 217	198 198 198	177 177 177	167 167 167	158 158 158	153 153 153
490 FG	> 3 ≤ 16 > 16 ≤ 40 > 40 ≤ 63	297 293 283	284 279 272	265 260 256	240 237 234	213 213 213	192 192 192	182 182 182	173 173 173	168 168 168

Note : For thicknesses greater than 63 [mm], the values for lower yield or 0.2 percent stress are to be reduced by 1 percent for each 5 [mm] increment in thickness upto 100 [mm]. For thicknesses over 100 [mm], the values are to be agreed and verified by test.

Table 5.3: Mechanical properties for design purposes : alloy steels-normalized tempered

Grade of Steel	Thickness [mm] (see Note)	Design temperature ^{0}C									
		50	100	200	300	350	400	450	500	550	600
		Nominal minimum lower yield or 0.2 percent proof stress [N/mm^2]									
1 Cr 1/2 Mo 470	>3 ≤ 63	284	270	248	216	203	199	194	188	181	174
2 1/4 Cr Mo 480	>3 ≤ 63	255	249	233	219	212	207	194	180	160	137

Note : For thicknesses greater than 63 [mm], the values for lower yield or 0.2 percent stress are to be reduced by 1 percent for each 5 [mm] increment in thickness upto 100 [mm]. For thicknesses over 100 [mm], the values are to be agreed and verified by test.

Table 5.4: Mechanical properties for design purposes : estimated average values for stress to rupture in 100,000 hours [N/mm2]

Temp. ^{0}C	Grades of steel				
	Carbon and carbon-managanese			Alloy Steels	
	360 FG 410 FG 460 FG	360 410 460	490 490 FG 510 FG	1 CR 1/2 Mo 470	2 1/4 Cr 1 Mo 480
380	171	219	227	-	-
390	155	196	203	-	-
400	141	173	179	-	-
410	127	151	157	-	-
420	114	129	136	-	-
430	102	109	117	-	-
440	90	92	100	-	-
450	78	78	85	-	221
460	67	67	73	-	204
470	57	57	63	-	186
480	47	48	55	210	170
490	36	-	47	177	153
500	-	-	-	146	137
510	-	-	-	121	122
520	-	-	-	99	107
530	-	-	-	81	93
540	-	-	-	67	79
500	-	-	-	54	69
560	-	-	-	43	59
570	-	-	-	35	51
580	-	-	-	-	44

Section 7 Steels for Machinery Structures

1 General

1.1 Steel plates, strips, sections or bars intended for use in the construction of welded machinery structures are to comply with one of the following alternatives:

a) Any grade of normal strength structural steel or high strength structural steel as detailed in Sec. 2 and 3.

b) Any grade of carbon or carbon-manganese steel as detailed in Sec. 6 except that for this application batch testing is acceptable and the same is to be carried out in accordance with the requirements of Sec. 2.

Section 8 Plates with Specified minimum through Thickness Properties ('Z' quality)

1 General

1.1 Following requirements are for special quality plate material with improved ductility in the through thickness or "Z direction.

1.2 The use of this material known as 'Z' quality steel, is recommended when plate material, intended for welded construction, will be subject to significant strain in a direction perpendicular to the rolled surfaces. These strains are usually associated with thermal contraction and restraint during welding, particularly for full penetration "T"- butt welds but may also be associated with loads applied in service or during construction. Where these strains are of sufficient magnitude, lamellar tearing may occur. Two 'Z' quality steels are specified; Z25 for normal ship applications and 'Z35' for more severe applications.

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

1.3 This special quality material is to comply with the requirements of Sec. 2, 3, 4, 5, 6 and 7 as appropriate and the following additional requirements.

2 Manufacture

2.1 All plates are to be manufactured at works which have been approved by ACS for this quality of material.

2.2 The sulphur content is not to exceed 0.008 percent, as determined by ladle analysis. It is recommended that the steel should be efficiently vacuum de-gassed.

3 Test material

3.1 Unless otherwise agreed, through thickness tensile tests are only required for plate materials where the thickness exceeds 15 [mm].

A test sample large enough to provide six test specimens are to be cut from the centre of one end of each rolled piece representing the batch. (See Fig. 3.1). Where appropriate the end selected should be representative of the top end of an ingot or the start of a concast strand. Generally three through thickness tensile test specimens are to be prepared while the rest of the sample remains for possible retests.

3.2 The batch size is to be determined depending on the product and sulphur content as given in Table 3.2.

Fig. 3.1: Plate and wide flat sampling position

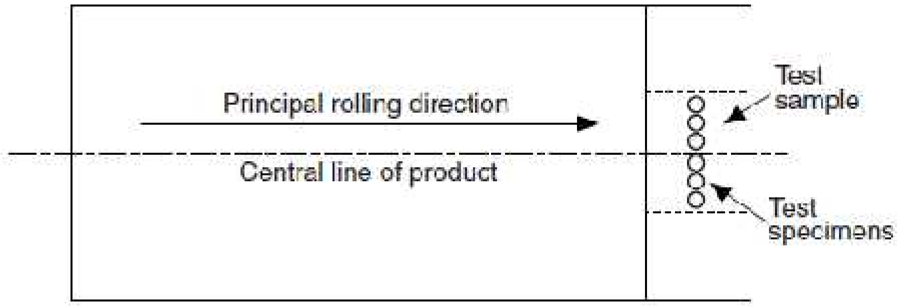


Table 3.2: Batch size dependent on product and sulphur content

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	Maximum 50 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	Maximum 50 t of products of the same cast, thickness and heat treatment

4 Dimensions of through thickness tensile test specimens

4.1 At the option of the steel maker test specimens (Fig. 4.1a) or test specimens with welded extensions (Fig. 4.1b) may be used. For both types of test specimens, the diameter of the parallel portion is not to be less than 6 [mm] when plate thickness is less than or equal to 25 [mm] and 10 [mm] when the plate thickness is greater than 25 [mm]. Alternatively, round test specimens, including those with welded extensions, may be prepared in accordance with a recognized standard.

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

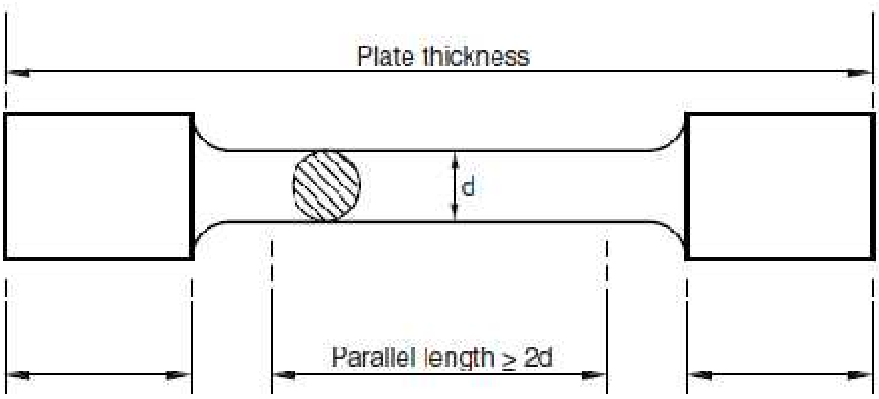


Fig. 4.1 a: Plain test specimen

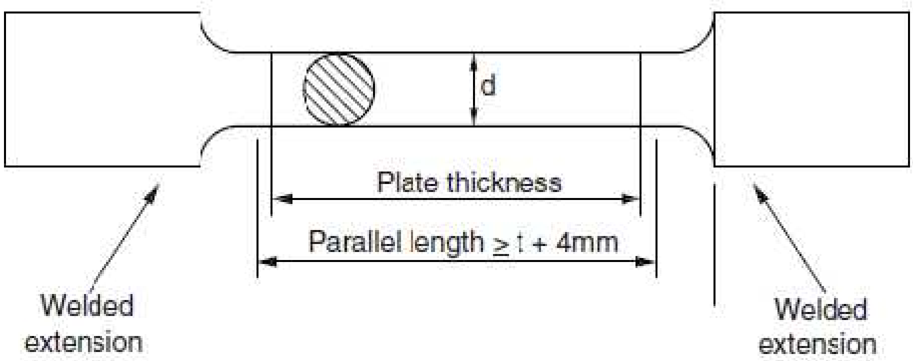


Fig. 4.1 b: Test specimen with welded extension

5 Mechanical tests

5.1 The acceptable minimum average value for the reduction of area of the three tensile test specimens taken in the through thickness direction are given in Table 5.1. Only one individual value may be below the minimum average, but not less than the minimum individual value for the appropriate grade.

Table 5.1 : Reduction of area acceptance

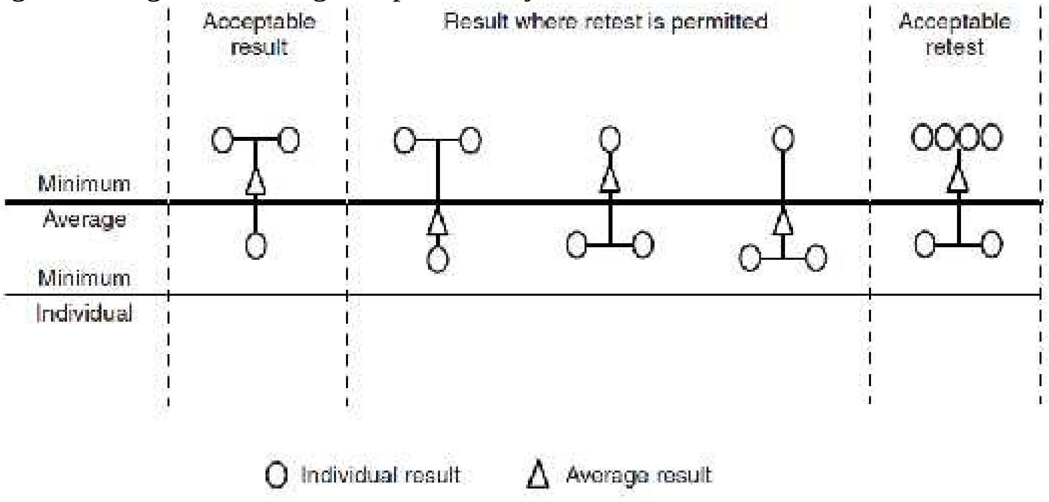
Grade	Z25	Z35
Minimum average	25%	35%
Minimum individual	15%	25%

5.2 A value less than minimum individual value will require rejection of the piece. However, in case of batch testing each remaining piece in the batch may be individually tested.

5.3 Depending on the test results, retest may be permitted in the cases shown in Fig. 5.3. 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 not more than two results below the minimum average.

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

Fig. 5.3: Diagram showing acceptance / rejection and retest criteria



6 Non-destructive examination

6.1 All special 'Z' quality plates are to be ultrasonically tested in the final supply condition, with a probe of frequency 4 MHz. The ultrasonic testing is to be carried out in accordance with either EN 10160-1989 Level S2/E3 or ASTM A578 Level C.

Section 9 Austenitic and Duplex Stainless Steels

1 Scope

1.1 This section gives the requirements for rolled products in austenitic and duplex (austenite plus ferrite) stainless steels intended for use in the construction of cargo tanks, storage tanks and process pressure vessels for chemicals and liquefied gases.

1.2 Austenitic stainless steels are suitable for applications where the lowest design temperature is not lower than –165°C.

1.3 Austenitic stainless steels are also suitable for service at elevated temperatures and for such applications the proposed specification should contain, in addition to the requirements of 1.6, minimum values for 0.2 and 1.0 per cent proof stresses at the design temperature.

1.4 Duplex stainless steels are suitable for applications where the lowest design temperature is above 0°C. Any requirement to use duplex stainless steels below 0°C will be subject to special consideration.

1.5 Duplex stainless steels are also suitable for service at temperatures upto 300°C and for such applications the proposed specification should include, in addition to the requirements of 1.6, a minimum value for 0.2 per cent proof stress at the design temperature.

1.6 A specification giving details of the chemical composition, heat treatment and mechanical properties, including for the austenitic grades, both the 0.2 and 1.0 percent proof stresses, is to be submitted for consideration and approval.

2 Chemical composition

2.1 The chemical composition of ladle samples is to comply with the requirements given in Table 2.1.

3 Heat treatment

3.1 All materials are to be supplied in the solution treated condition.

Table 2.1: Chemical composition

Type and grade of steel	Chemical composition % (see Note)									
	C max	Si max	Mn max	P max	S max	Cr	Ni	Mo	N	other
Austenitic										
304L	0.03	}	}	}	}	17.0-20.0	8.3-13.0	-	0.10	-
304LN	“	}	}	}	}	17.0-20.0	3.0-12.0	-	0.10-0.22	-
316L	“	}	}	}	}	16.0-18.5	10.0-15.0	2.0-3.0	0.10	-
316LN	“	1.0	2.0	0.045	0.03	16.0-18.5	10.0-14.5	2.0-3.0	0.10-0.22	-
317L	“	}	}	}	}	18.0-20.0	11.0-15.0	3.0-4.0	0.10	-
317LN	“	}	}	}	}	18.0-20.0	12.5-15.0	3.0-4.0	0.10-0.22	-
321	0.06	}	}	}	}	17.0-19.0	9.0-12.0	-	0.10	5×C≤Ti≤0.7
347	0.06	}	}	}	}	17.0-19.0	9.0-13.0	-	0.10	10×C≤Nb≤1.0
Duplex										
UNS S31803	0.03	1.0	2.0	0.03	0.02	21.0-23.0	4.5-6.5	2.5-3.5	0.08-0.20	-
UNS S32750	0.03	0.80	1.2	0.035	0.02	24.0-26.0	6.0-8.0	3.0-5.0	0.24-0.32	Cu 0.50 max.

4 Mechanical tests

4.1 Tensile test specimens are to be taken in accordance with the appropriate requirements of sec. 5.4 and sec. 6.4.1.

4.2 For the duplex grades, one set of three Charpy V-notch impact test specimens machined in the longitudinal direction from each tensile test piece is to be tested at –20°C. The average energy value of the three specimens is to be not less than 41 Joules.

For austenitic grades of steel, impact tests are only required for design temp. below –105°C. In such cases, impact tests carried out at a temperature of –196°C on a set of three charpy V-notch specimens are to comply with the following:

a) Plates : Transverse test pieces; minimum average energy value 27 Joules.

b) Strips, sections and bars : Longitudinal test pieces, minimum average energy value 41 Joules.

4.3 Where standard subsidiary Charpy Vnotch test specimens are necessary, see Chapter 2, Sec.3.

4.4 The results of all tensile tests are to comply with the requirements of Table 4.1 or the approved specification.

5 Through thickness tests

5.1 Where material will be strained in a through thickness direction during welding or in service, through thickness tests are required on plates over 10 [mm] thick in all the grades of steels listed in Table 2.1, apart from Grades 304L, 304LN, 321 and 347.

5.2 Testing is to conform with the requirements of Section 8, with the exception given in 5.3.

5.3 When the reduction in area is less than 35 per cent, metallographic or other evidence is required to show that no significant amount of any detrimental phase, such as sigma, is present.

Table 4.1 : Mechanical properties for acceptance purposes

Type and grade of steel	0.2% Proof stress [N/mm^2] minimum	1% Proof stress [N/mm^2] minimum	Tensile strength [N/mm^2] minimum	Elongation on 5.65 $\sqrt{S_0}$ % minimum
Austenitic				
304L	170	210	485	40
304LN	205	245	515	40
316L	170	210	485	40
316LN	205	245	515	40
317L	205	245	515	40
317LN	240	280	550	40
321	205	245	515	40
347	205	245	515	40
Duplex				
UNS S 31803	450	-	620	25
UNS S 32750	550	-	795	15

6 Intergranular corrosion tests

6.1 For certain specific applications such as storage tanks for chemicals, it may be necessary to demonstrate that the material used is not susceptible to intergranular corrosion resulting from grain boundary precipitation of chromium-rich carbides.

6.2 When required, one test of this type is to be carried out for each tensile test. The testing is to be carried out in accordance with ASTM A262, practice E, copper-copper sulphatesulphuric acid or another recognized standard. The bent specimen is to be free from cracks indicating the presence of intergranular attack. The material for the test is to be taken adjacent to that for the tensile test.

7 Dimensional tolerances

7.1 The minimum tolerance on thickness is to be as given in sec. 1; Table 4.1.

8 Clad plates

8.1 Carbon or carbon-manganese steel plates, clad on one or both surfaces with a suitable grade of austenitic or duplex stainless steel, may be used for the construction of cargo or storage tanks for chemicals.

8.2 The carbon or carbon-manganese steel base plates are to comply with the requirements of Section 6 and the austenitic or duplex cladding material generally with the requirements of this section.

8.3 The process of manufacture is to be specially approved and may be either by roll cladding or by explosive bonding.

8.4 Where the use of clad materials is proposed, the material specification is to be submitted for consideration, together with details of the extent and the acceptance standards for non-destructive examination.

9 Identification of materials

9.1 The particulars detailed in sec. 1.12 are to be marked on all materials which have been accepted.

10 Certification of materials

10.1 Each test certified or shipping statement is to give the information detailed in sec. 1.13, together with general details of heat treatment and where applicable, the results obtained from intercrystalline corrosion tests. The chemical composition is to include the content of all the elements detailed in Table 2.1.

Chapter 4 Steel Castings

Section 1 General Requirements

1 Scope

1.1 All important steel castings, as defined in the relevant construction rules are to be manufactured and tested in accordance with the requirements of this Chapter.

1.2 Where required by the relevant Rules dealing with design and construction, castings are to be manufactured and tested in accordance with Ch.1 and Ch.2, together with the general requirements given in this Section and the appropriate specific requirements given in Sec.2 to 5.

1.3 As an alternative to 1.3, castings which comply with national or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this chapter or alternatively are approved for a specific application.

Generally, survey and certification are to be carried out in accordance with the requirements of Ch.1.

2 Manufacture

2.1 Castings are to be made by manufacturer approved by ACS.

2.2 The steel is to be manufactured by a process approved by ACS.

2.3 All flame cutting, scarfing or arc-air gouging to remove surplus metal is to be undertaken in accordance with recognized good practice and is to be carried out before the final heat-treatment. Preheating is to be employed when necessitated by the chemical composition and/or thickness of the castings. If necessary, the affected areas are to be either machined or ground smooth.

2.4 For certain components including steel castings subjected to surface hardening process, the proposed method of manufacture may require special approval by ACS.

2.5 When two or more castings are joined by welding to form a composite the proposed welding procedure is to be submitted for approval. Welding procedure qualification tests may be required.

3 Quality of castings

3.1 All castings are to be free from surface or internal defects which would be prejudicial to their proper application in service. The surface finish is to be in accordance with good practice and any specific requirements of the approved plan.

3.2 The surfaces are not to be treated in any way which may obscure defects.

4 Chemical composition

4.1 All castings are to be made from killed steel and the chemical composition is to be appropriate for the type of steel and the mechanical properties specified for the castings. The chemical composition of each heat is to be determined by the manufacturer on a sample taken preferably during the pouring to the heat. When multiple heats are tapped into a common ladle, the ladle analysis shall apply.

5 Inspection

5.1 All castings are to be cleaned and adequately prepared for examination; suitable methods include pickling, caustic cleaning, wire brushing, local grinding, shot or sand blasting. The surfaces are not to be hammered, peened or treated in any way which may obscure defects.

5.2 Before acceptance all castings are to be presented to the Surveyors for visual examination. Where applicable, this is to include the examination of internal surfaces. Unless otherwise agreed, the verification of dimensions is the responsibility of the manufacturer.

5.3 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 castings to be examined, extent of testing and acceptance criteria are detailed in ACS Classification Notes on "Guidelines for Non- Destructive Examination of Steel Castings for Marine Application.

5.4 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 Surveyors and are to be to their satisfaction.

5.5 In the event of any casting proving defective during subsequent machining or testing, it is to be rejected notwithstanding any previous certification.

6 Hydraulic pressure testing

6.1 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 Surveyors and are to be to their satisfaction.

7 Rectification of defective castings

7.1 General

i) Steel casting defects are to be removed with or without weld repair before considering suitable for use subject to approval of ACS.

ii) Procedure of removal of defect and weld repair is to be in accordance with ACS or other internationally accepted notes and Guidelines for Non- Destructive Examination of Steel Castings for Marine Application.

iii) Where the defective area is to be repaired by welding, the excavations are to be suitably shaped to allow good access for welding. The resulting grooves are to be subsequently ground smooth and complete elimination of the defective material is to be verified by MT or PT.

iv) 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 groves 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.

v) 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.

7.2 Weld repairs

When it has been agreed that a casting can be repaired by welding the following requirements apply:

i) 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:

ii) 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 preheated depending on their chemical composition and the dimensions and position of the weld repairs.

iii) Welding s to be done under cover in positions free from draughts and adverse weather conditions by qualified welders with adequate supervision. As far as possible, all welding is to be carried out in the downhand (flat) position.

iv) The welding consumables used are to be of an appropriate composition, giving a weld deposit with mechanical properties similar and in no way inferior to those of the parent castings. Welding procedure tests are to be carried out by the manufacturer to demonstrate that satisfactory mechanical properties can be obtained after heat treatment as detailed in Sec.2.

v) After welding has been completed the castings are to be given either a suitable heat treatment in accordance with the requirements of Sec.2 or a stress relieving heat treatment at a temperature of not less than 550°C. The type of heat treatment employed will be dependent on the chemical composition of the casting and the dimensions, positions and nature of the repairs.

vi) Subject to the prior agreement of ACS special consideration may be given to the omission of postweld heat treatment or to the acceptance of local stress relieving heat treatment where the repaired area is small and machining of the casting has reached an advanced stage.

vii) 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 repaired depending on the dimensions and nature of the original defect. Satisfactory results are to be obtained from all forms of nondestructive testing used.

8 Identification of castings

8.1 The manufacturer is to adopt a system of identification which will enable all finished castings to be traced to the original cast and Surveyors are to be given full facilities for so tracing the castings when required.

8.2 Before acceptance, all castings which have been tested and inspected with satisfactory results are to be clearly marked by the manufacturer with the following particulars:

i) Steel quality.

ii) Identification number, cast number or other marking which will enable the full history of the casting to be traced.

iii) Manufacturer's name or trade mark.

iv) The ACS brand name 'AC'.

v) Abbreviated name of the ACS local office.

vi) Personal stamp of Surveyors responsible for inspection.

vii) Where applicable, test pressure.

8.3 When small castings are manufactured in large numbers, modified arrangements for identification may be specially agreed with ACS.

9 Certification

9.1 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:-

a) Purchaser's name and order number;

b) Description of castings and steel quality;

c) Identification number;

d) Steel making process, cast number and chemical analysis of ladle samples;

e) Results of mechanical testing;

f) General details of heat treatment;

g) Where applicable, test pressure.

Section 2 Hull and Machinery Steel Castings for General Applications

1 Scope

1.1 The requirements given in this section 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 requirements are applicable only to steel castings where the design and acceptance tests are related to mechanical properties at ambient temperature. For other applications, additional requirements may be necessary, especially when the castings are intended for service at low or elevated temperatures.

1.3 Where the use of alloy steel castings is proposed full details of the chemical composition, heat treatment, mechanical properties, testing inspection and rectification are to be submitted for approval of ACS.

2 Chemical composition

2.1 For carbon and carbon-manganese steel castings the chemical composition is to comply with the overall limits given in Table 2.1 or where applicable, the requirements of the approved specification.

2.2 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 2.1: Chemical composition limits for hull and machinery steel castings (%)

Steel type	Applications	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	0.60	0.50-1.60	0.040	0.040	0.30	0.030	0.40	0.15	0.80
	Castings for welded construction	0.23	0.60	1.60 max	0.040	0.040	0.30	0.30	0.40	0.15	0.80

3 Heat treatment

3.1 Castings are to be supplied in one of the following conditions:

Fully annealed

Normalized

Normalized and tempered

Quenched and tempered

The tempering temperature is not less than 550^{o}C.

3.2 Castings or component such as crankshafts and engine bedplates, where dimensional stability and freedom from internal stresses are important are to be given a stress relief heat treatment. This is to be carried out at a temperature of not less than 550°C followed by furnace cooling to 300°C or lower.

3.3 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 ACS. Sufficient thermocouples are to be connected to the furnace charge to measure and record that its temperature is adequately uniform unless the temperature uniformity of the furnace is verified at regular intervals.

3.4 If a casting is locally reheated or any straightening operation is performed after the final heat treatment, a subsequent stress relieving heat treatment may be required in order to avoid the possibility of harmful residual stresses.

3.5 The manufacturer's works 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.

4 Mechanical tests

4.1 Test material, sufficient for the required tests and for possible retest purposes is to be provided for each casting or batch of castings.

4.2 At least one test sample is to be provided for each casting. Unless otherwise agreed these test samples are to be either integrally cast or gated to the castings and are to have a thickness of not less than 30 [mm].

4.3 Where the casting is of complex design or where the finished mass exceeds 10 tonnes, two test samples are to be provided. Where large castings are made from two or more casts, which are not mixed in a ladle prior to pouring, two or more test samples are to be provided corresponding, the number of the casts involved. These are to be integrally cast at locations as widely separated as possible.

4.4 For castings where the method of manufacture has been specially approved by ACS in accordance with sec.1.2.4, the number and position of test samples is to be agreed with ACS having regard to the method of manufacture employed.

4.5 As an alternative to 4.2, where a number of small castings of about the same size, each of which is under 1000 Kg in mass are made from one cast and heat treated in the same furnace charge, a batch testing procedure may be adopted using separately cast test samples of suitable dimensions. At least one test sample is to be provided for each batch of castings.

4.6 The test samples are not to be detached from the casting until the specified heat treatment has been completed and they have been properly identified.

4.7 One tensile test specimen is to be taken from each test sample.

4.8 The preparation of test specimens and the procedures used for mechanical testing are to comply with the relevant requirements of Ch.2. Unless otherwise agreed all tests are to be carried out in the presence of the Surveyors.

5 Mechanical properties

5.1 Table 5.1 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.

5.2 Castings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Table 5.1 but subject to any additional requirements of the relevant construction rules.

5.3 The mechanical properties are to comply with the requirements of Table 5.1, appropriate to the specified minimum tensile strength or, where applicable, the requirements of the approved specification.

5.4 Where the result of a tensile test does not comply with the requirements, two additional tests may be taken. If satisfactory results are obtained from both of these additional tests the casting or batch of castings is acceptable. If one or both retests fail the castings or batch of castings is to be rejected.

5.5 The additional tests detailed in 5.4 are to be taken, preferably from the same, but alternatively from another, test sample representative of the casting or batch of castings.

5.6 At the option of the manufacturer, when a casting or batch of castings has failed to meet the test requirements, it may be reheat treated and re-submitted for acceptance tests.

Table 5.1: Mechanical properties for hull and machinery steel castings

Specified minimum Tensile strength(1) [N/mm^2]	Yield stress [N/mm^2] min.	Elongation on 5.65 $\sqrt{S_0}$ % min.	Reduction of area % min
400	200	25	40
440	220	22	30
480	240	20	27
520	260	18	25
560	300	15	20
600	320	13	20

Note:

(1) A tensile strength range of 150 [N/mm^2] may additionally be specified.

Section 3 Ferritic Steel Castings for Low Temperature Services

1 General

1.1 This Section gives the requirements for castings in carbon-manganese and nickel alloy steels intended for use in liquefied gas piping systems where the design temperature is lower than 0°C and for other applications where guaranteed impact properties at low temperatures is required.

1.2 Other steel types may also be accepted upon consideration in each case.

2 Chemical composition

2.1 The chemical composition of ladle samples is to comply with the overall limits given in Table 2.1. The carbon-manganese steel is to be fine grain treated.

Table 2.1: Chemical composition of ferritic steel castings for low temperature service

Type of steel	Chemical composition %						
	C max	Si max	Mn	S max.	P max.	Ni	Residual elements max.
Carbon - manganese	0.25	0.60	0.70-1.60	0.030	0.030	0.80 max.	
2 1/4 Ni	0.25	0.60	0.50-0.80	0.025	0.030	2.00-3.00	Cr 0.25, Cu 0.30 Mo 0.15, V 0.03 Total 0.60
3 1/2 Ni	0.15	0.60	0.50-0.80	0.025	0.025	3.00-4.00	

3 Heat treatment

3.1 Castings are to be supplied in one of the following conditions:

a) normalized.

b) normalized and tempered.

c) quenched and tempered.

4 Mechanical tests

4.1 The mechanical properties of steel castings are to comply with requirements given in Table 4.1.

4.2 The tensile test is to be carried out at ambient temperature and the impact tests are to be carried out at the temperature specified in the table.

4.3 The average energy value from a set of three charpy V-notch impact test specimens is not to be lower than the required average value given in Table 4.1. One individual value may be less than the required average value provided that it is not less than 70 per cent of this average value.

5 Non-destructive testing

5.1 The non-destructive examination of castings is to be carried out in accordance with the appropriate requirements of sec. 1.7 and additionally agreed between the manufacturer, purchaser and Surveyor.

Table 4.1: Mechanical properties for acceptance purposes: ferritic steel castings for low temperature service

Type of steel	Grade	Yield stress [N/mm^2] min.	Tensile strength [N/mm^2]	Elongation on 5.65 $\sqrt{S_0}$ % min.	Reduction of area % min	Charpy V-notch impact tests	
						Test temp ^0C	Average energy J min.
Carbon-managanese	400 430 450	200 215 230	400-550 430-580 460-610	25 23 22	40 35 30	-60 (see Note)	27
2 1/4 Ni	490	275	490-640	20	35	-70	34
3 1/2 Ni	490	275	490-640	20	35	-95	34

Note: The temperature for carbon-manganese steels may be 5^{o}C below the design temperature if the latter is above -55^{o}C, with a maximum test temperature of -20^{o}C.

Section 4 Steel Castings for Propellers

1 Scope

1.1 These requirements are applicable to the manufacture of cast 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 requirements may also be used for the repair of propellers damaged in service, subject to prior approval of ACS.

2 Manufacture

2.1 All propellers, blades and bosses are to be manufactured by foundries approved in accordance with Pt.2, Ch.1. The scope of the procedure tests involved in the approval is to be agreed.

2.2 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.

2.3 Chemical composition

Typical cast steel propeller alloys are grouped into four types depending on their chemical composition as given in Table 2.1.

2.4 Heat treatment

Martensitic castings are to be austenitized and tempered. Austenitic castings should be solution treated.

2.5 Mechanical tests

2.5.1 The mechanical properties are to meet the requirements in Table 2.2. These values refer to the test specimens machined from integrally cast test bars attached to the hub or on the blade.

2.5.2 Where possible, the test bars attached on blades are to be located in an area between 0.5 to 0.6R, where R is the radius of the propeller.

2.5.3 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 nonthermal procedures.

2.5.4 Separately cast test bars may be used subject to prior approval of ACS. The test bars are to be cast from the same heat as the castings represented and heat treated with the castings represented.

Table 2.1: Typical chemical composition for steel propeller castings

Alloy type	**C max. (%)**	**Mn max. (%)**	**Cr (%)**	**Mo (1) max. (%)**	**Ni (%)**
Martensitic (20 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
Martensitic (19 Cr 11 Ni)	0.12	1.6	16.0 - 21.0	4.0	8.0 - 13.0

Note 1) Minimum values are to be in accordance with recognised national or international standards

Table 2.2: 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[1)] energy min. (J)**
(20 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	-

Notes:

1) Not required for general service and the lowest ice class notations. For other ice class notations, tests are to be made -10^{o}C.

2) $R_{p1.0}$ value is 205 [N/mm^2].

2.5.5 At least one set of mechanical tests is to be made on material representing each casting in accordance with Part 2, Chapter 2.

2.5.6 As an alternative to 2.5.5, 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 castings in the batch.

3 Visual examination

3.1 All castings must be supplied in a clean fettled condition.

3.2 All finished castings are to be 100% visually inspected by the Surveyor. The Surveyor may require areas to be etched for the purpose of investigating weld repairs.

3.3 Castings are to be free from cracks, hot tears or other imperfections which, due to their nature, degree or extent, will interfere with the use of the castings.

4 Dimensions, dimensional and geometrical tolerances

4.1 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.

4.2 Static balancing is to be carried out on all propellers in accordance with the approved drawing. Dynamic balancing may be necessary for propellers running above 500 rpm.

5 Non-destructive examination

5.1 All finished castings are subject to nondestructive testing in accordance with the requirements given in 5.2 to 5.9.

5.2 In order to relate the degree of nondestructive 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 properties.

5.3 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.

5.4 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.

5.5 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;

Nonlinear 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 dimension greater than 1.5 [mm] shall be considered relevant.

5.6 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 shall be taken in the most unfavorable location relative to the indication being evaluated.

5.7 The indications detected may, with respect to their size and number, not exceed the values given in the Table 5.1.

5.8 Where serious doubt exists that the castings are not free from internal defects, further non-destructive inspections are to be carried out upon request of the Surveyor, e.g. radiographic and/or ultrasonic tests. The acceptance criteria are then to be agreed between the manufacturer and ACS in accordance with the recognised standard.

5.9 The foundry is to maintain records of inspections traceable to each casting. These records are to be reviewed by the Surveyor. The foundry is also to provide the Surveyor with a statement confirming that non-destructive tests have been carried out with satisfactory results.

Table 5.1: 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

Notes:

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.

6 Repair

6.1 Defective castings are to be repaired in accordance with the requirements given in 6.2 to 6.7 and, where applicable, the requirements of 7.

6.2 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.

6.3 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.

6.4 The excavations are to be suitably shaped to allow good access for welding. The resulting grooves are to be subsequently ground smooth and complete elimination of the defective material is to be verified by liquid penetrant testing. Welds having an area less than 5 [cm^2] are to be avoided.

6.5 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.

6.6 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 ACS.

6.7 Repair welding is generally permitted in severity Zone C.

7 Weld repair procedure

7.1 The scope of the procedure tests involved in the qualification is given in 10. 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.

7.2 All weld repairs are to be made by qualified welders using qualified procedures.

7.3 Welding is to be done under controlled conditions free from draughts and adverse weather.

7.4 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.

7.5 Slag, undercuts and other imperfections are to be removed before depositing the next run.

7.6 The martenistic steels are to be furnace re-tempered after weld repair. Subject to prior approval, however, local stress relieving may be considered for minor repairs.

7.7 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.

7.8 The manufacturer is to be maintain records of welding, subsequent heat treatment and inspections traceable to each casting repaired. These records are to be reviewed by the Surveyor.

8 Identification

8.1 Castings are to be clearly marked by the manufacturer in accordance with the requirements of Ch.1. The following details are to be marked on all castings which have been accepted:

a) Heat number or other marking which will enable the full history of the casting to be traced;

b) The ACS certificate number and abbreviated name of local ACS office;

c) Ice class symbol, where applicable;

d) Skew angle for high skew propellers;

e) Date of final inspection.

8.2 The AC stamp is to be put on when the casting has been accepted.

9 Certification

9.1 The manufacturer is to provide the Surveyor with an inspection certificate giving the following particulars for each casting which has been accepted:

a) Purchaser's name and order number;

b) Vessel identification, where known;

c) Description of the casting with drawing number;

d) Diameter, number of blades, pitch, direction of turning;

e) Skew angle for high skew propellers;

f) Final mass;

g) Alloy type, heat number and chemical composition;

h) Casting identification number;

i) Details of time and temperature of heat treatment;

j) Results of the mechanical tests.

9.2 The manufacturer is to provide a statement regarding non-destructive tests as required by 5.9 and where applicable, records of weld repairs as required by 7.8.

10 Welding procedure qualification test

10.1 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 Fig. 10.1.

10.2 Non-destructive testing

Prior to sectioning, the test assembly is to be visually inspected and liquid penetrant tested. Imperfections shall be assessed in accordance with 5.

10.3 Macro-examination

Two macro-sections shall be prepared and etched on one side to clearly reveal the weld metal, the fusion line and the heat affected zone. The sections are to be examined by eye (aided by low power hand lens if desired) for any imperfections present in the weld metal and HAZ. Cracks or crack-like imperfections, slag inclusions and pores greater than 3 [mm] are not permitted.

10.4 Tensile testing

Two flat transverse tensile test specimens shall be prepared. The tensile strength shall meet the specified minimum value of the base material. The location of fracture is to be reported, i.e. weld metal, HAZ or base material.

10.5 Charpy V-notch testing

Impact test is not required, except where the base material is impact tested. Charpy V-notch test specimens shall be in accordance with rules requirements. Two sets shall 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 shall comply with the requirement specified for the base material.

10.6 Hardness testing

One of the macro-sections shall be used for HV5 hardness testing. Indentations shall traverse 2 [mm] below the surface. At least three individual indentations are to be made in the weld metal, the HAZ (both sides) and in the base material (both sides). The values are to be reported for information.

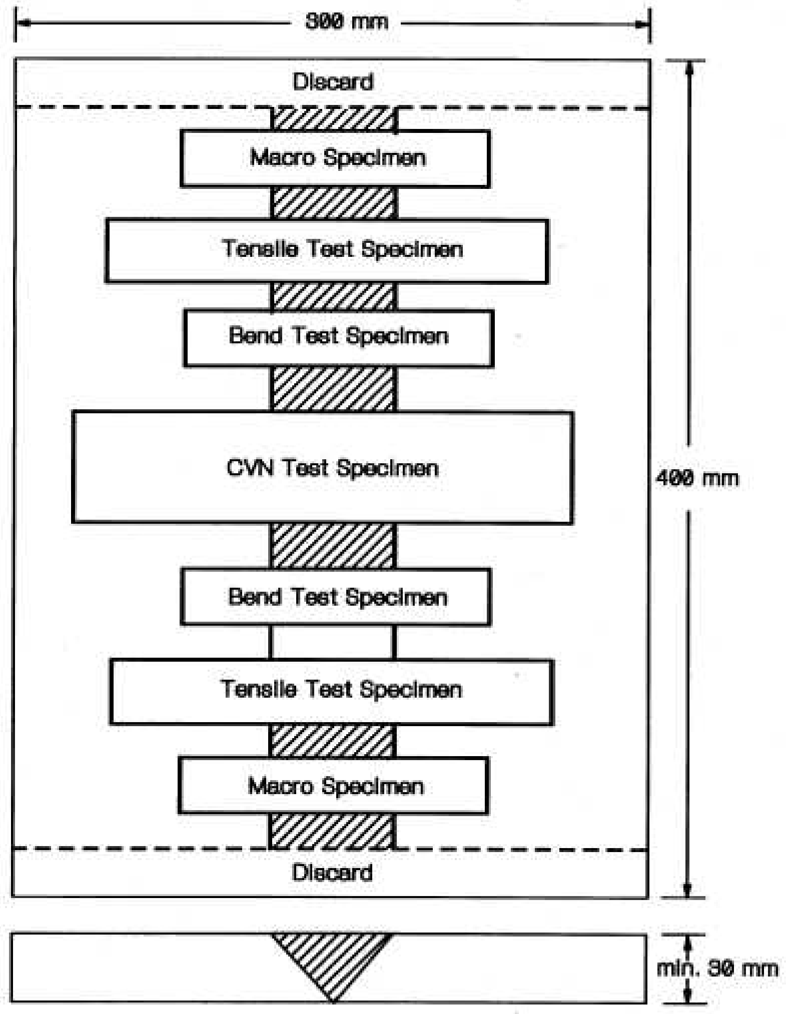


Fig. 10.1 Weld test assembly

Section 5 Austenitic Stainless Steel Castings

1 Scope

1.1 This section gives the requirements for castings in austenitic stainless steels for piping systems in ships for liquefied gases where the design temperature is not lower than –165oC and in bulk chemical carriers.

1.2 Where it is proposed to use alternative steels, particulars of the specified chemical composition, mechanical properties and heat treatment are to be submitted for approval.

2 Chemical composition

2.1 The chemical composition of ladle samples is to comply with the requirements given in Table 2.1.

Table 2.1: Chemical composition of austenitic stainless steel castings

Type of steel	Chemical composition %								
	C max	Si	Mn	S	P	Cr	Mo	Ni	Others
304L	0.03	0.20-1.5	0.50-2.0	0.40 max.		17.0-21.0	-	8.0-12.0	-
304	0.08						-	8.0-12.0	-
316L	0.03						2.0-3.0	9.0-13.0	-
316	0.08						2.0-3.0	9.0-13.0	-
317	0.08						3.0-4.0	9.0-12.0	-
347(see Note)	0.06						-	9.0-12.0	Nb ≥8×C≤0.90

Note: When guaranteed impact values at low temperature are not required, the maximum carbon content may be 0.08% and the maximum niobium may be 1.00%.

3 Heat treatment

3.1 All castings are to be solution treated at a temperature of not less than 1000°C and cooled rapidly in air, oil or water.

4 Mechanical tests

4.1 One tensile test specimen is to be prepared from material representing each casting or batch of castings. In addition, where the castings are intended for liquefied gas applications, where the design temperature is lower than –55°C, one set of three Charpy V-notch impact test specimens is to be prepared.

4.2 The tensile test is to be carried out at ambient temperature and the results are to comply with the requirements given in Table 4.2.

4.3 The average value for impact test specimens is to comply with the appropriate requirements given in Table 4.2. One individual value may be less than the required average value provided that it is not less than 70 percent of this average value.

Table 4.2: Mechanical properties for acceptance purposes : austenitic stainless steel castings

<table>
<tr><th rowspan="2">Type of steel</th><th rowspan="2">Tensile strength [N/mm^2] minimum</th><th rowspan="2">1.0% proof stress [N/mm^2] minimum</th><th rowspan="2">Elongation on 5.65 $\sqrt{S_0}$ % minimum</th><th rowspan="2">Reduction of area % minimum</th><th colspan="2">Charpy V-notch impact tests</th></tr>
<tr><th>Test temp ^{0}C</th><th>Average energy J minimum</th></tr>
<tr><td>304L</td><td>430</td><td>215</td><td rowspan="2">26</td><td rowspan="2">40</td><td rowspan="2">-196</td><td rowspan="2">41</td></tr>
<tr><td>304</td><td>480</td><td>220</td></tr>
<tr><td>316L</td><td>430</td><td>215</td><td rowspan="2">26</td><td rowspan="2">40</td><td rowspan="2">-196</td><td rowspan="2">41</td></tr>
<tr><td>317</td><td>480</td><td>240</td></tr>
<tr><td>347</td><td>480</td><td>215</td><td>22</td><td>35</td><td>-196</td><td>41</td></tr>
</table>

5 Intergranular corrosion tests

5.1 Where corrosive conditions are anticipated in service, intergranular corrosion tests are required on castings in grades 304, 316 and 317. Such tests may not be required for grades 304L, 316L and 347.

5.2 Where an intergranular corrosion test is specified, it is to be carried out in accordance with the appropriate standard.

6 Non-destructive examination

6.1 The non-destructive examination of castings is to be carried out in accordance with the appropriate requirements of Classification Notes “Guidelines for non-destructive examination of steel castings for marine application” and additionally agreed between the manufacturer, purchaser and Surveyor.

Section 6 Castings for other Applications

1 General

1.1 Details of chemical composition, heat treatment, mechanical properties of steel castings for crankshafts and those intended for elevated temperature service are to be submitted for approval of ACS.

Chapter 5 Steel Forgings

Section 1 General Requirements

1 Scope

1.1 All important steel forgings, as defined in the relevant construction Rules, are to be manufactured and tested in accordance with the requirements of this Chapter.

1.2 Where required by the relevant Rules dealing with design and construction, forgings are to be manufactured and tested in accordance with Ch.1 and 2, together with the general requirements given in this Chapter.

1.3 Alternatively, forgings which comply with National or proprietary specifications may be accepted provided such specifications give reasonable equivalence to these requirements or are otherwise specially approved for a specific application by ACS.

2 Manufacture

2.1 Forgings are to be made at the works approved by ACS.

2.2 The steel used in the manufacture of forgings is to be made by a process approved by ACS.

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. The reduction ratio is to be in accordance with the following Table:

Method of manufacture	Total reduction ratio (see notes 1, 2, 3 &4)
Made directly from ingots or forged blooms or billets	3 :1 where L> D 1.5:1 where L ≤ D
Made from rolled products	4:1 where L > D 2:1 where L ≤ D

Notes:

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

2 the reduction ratio is to be calculated with reference to the average cross-sectional area of the ingot. Where an ingot is initially upset, this reference area may be taken as the average cross-sectional area after this operation.

3 For rolled bars used as a substitute for forgings (see 1.1) the reduction ratio is not to be less than 6 : 1

4 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 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 required special approval by ACS. In such cases, tests may be required to demonstrate that a satisfactory structure and grain flow are obtained.

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.

2.7 For certain components, subsequent machining of all flame cut surfaces may be required.

2.8 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 qualification tests may be required.

3 Quality of forgings

3.1 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 is applicable.

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. Heat treatment is to be carried out in properly constructed furnaces which are efficiently maintained and have adequate means for control and recording of temperature. The furnace dimensions are to be such as to allow the whole furnace charge to be uniformly heated to the necessary temperature.
In the case of very large forgings alternative methods of heat treatment will be specially considered by ACS.

5.2 Except as provided in 5.7 and 5.8 forgings are to be supplied in one of the following conditions:

a) Carbon and carbon-manganese steels
   - Fully annealed
   - Normalized
   - Normalized and tempered
   - Quenched and tempered

b) Alloy steels
   - Quenched and tempered

For all types of steel the tempering temperature is not less than 550°C. Where forgings for gearing are not intended for surface hardening tempering at lower 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 ACS. 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 for any reasons a forging is subsequently heated for further hot working the forging is to be re-heat treated.

5.5 If any straightening operation is performed after the final heat treatment, a subsequent stress relieving heat treatment to avoid harmful residual stresses is to be carried out, unless otherwise agreed.

5.6 Where it is intended to surface harden forgings, full details of the proposed procedure and specification are to be submitted for the approval of ACS. 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 does not impair the soundness and properties of the steel.

5.7 Where induction hardening or nitriding is to be carried out after machining, 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 after machining, forgings are to be heat treated at an appropriate stage (generally either by full annealing or by normalising 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 manufacturer is to maintain records of heat treatment identifying the furnace used, furnace charge, date, temperature and time at the beginning and end of heat treatment cycle. The records are to be presented to the Surveyor on request.

6 Mechanical tests

6.1 The requirements of Mechanical tests and mechanical properties are given in Section 2 and 3.

7 Inspection

7.1 Before acceptance, all forgings are to be presented to the Surveyors for visual examination. Where applicable, this is to include the examination of internal surfaces and bores. Unless otherwise agreed, the verification of the dimensions is the responsibility of the manufacturer.

7.2 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.

7.3 When required by the conditions of approval for surface hardened forgings, (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.

7.4 In the event of any forging proving defective during subsequent machining or testing, it is to be rejected notwithstanding any previous certification.

8 Rectification of defective forgings

8.1 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.

8.2 Repair welding of crankshaft forgings is not permitted. In the case of other forgings repair welding may be allowed subject to prior approval of ACS. 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.

8.3 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.

a) Purchaser's name and order number;

b) Description of forgings and steel quality identification number;

c) Steel making process, cast number and chemical analysis of ladle sample;

d) Results of mechanical tests;

e) General details of heat treatment;

f) Identification number.

9 Identification of forgings

9.1 Before acceptance, all forgings, which have been tested and inspected with satisfactory results, are to be clearly marked in at least one place with the ACS brand AC and the following particulars:

a) The manufacturer's name or trade mark;

b) Identification mark for the grade of steel;

c) Identification number and/or initials which enable the full history of the forging to be traced;

d) Personal stamp of Surveyor responsible for inspection;

e) Test pressure, where applicable;

f) Date of final inspection;

g) The 'ACS' name;

h) Abbreviated name of ACS local office.

9.2 Where small forgings are manufactured in large numbers, modified arrangements for identification may be specially agreed with ACS.

10 Certification

10.1 The manufacturer is to provide the Surveyor, in duplicate, with a test certificate or shipping statement giving the following particulars for each forging or batch of forgings which has been accepted:

a) Purchaser’s name and order number;

b) Description of forgings and steel quality identification number;

c) Steel making process, cast number and chemical analysis of ladle sample;

d) Results of mechanical tests;

e) General details of heat treatment;

f) Identification number.

Section 2 Hull and Machinery Steel Forgings for General Applications

1 Scope

1.1 The requirements given in this section are applicable to steel forgings intended for hull and machinery applications such as rudder stocks, pintles, propeller shafts, crankshafts, connecting rods, piston rods, gearing etc. Where relevant, these requirements are also applicable to material for forging stock and to rolled bars intended to be machined into components of simple shape.

1.2 These requirements are applicable only to steel forgings where the design and acceptance tests relate to mechanical properties at ambient temperature. For other applications, additional requirements may be necessary especially when the forgings are intended for service at low or elevated temperatures.

2 Chemical Composition

2.1 The chemical composition is to comply with the overall limits given in Tables 2.1 and 2.2 or, where applicable, the requirements of the approved specification.

2.2 At the option of the manufacturer, suitable grain refining elements such as Aluminum, niobium or vanadium may be added. The content of such elements is to be reported.

2.3 Elements designated as residual elements in the individual specifications are not to be intentionally added to the steel. The content of such elements is to be reported.

Table 2.1: Chemical composition limits1) for hull steel forgings6)

Steel type	C	Si	Mn	P	S	Cr	Mo	Ni	Cu 4)	Total residuals
C, C-Mn	0.23 2), 3)	0.45	0.20-1.50	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 (Ceq) is not more than 0.41%, calculated using the following formula:

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

3) The carbon content of C and C-Mn steel forgings not intended for welded construction may be 0.65 maximum.

4) Elements are considered as residual elements.

5) Specification is to be submitted for approval.

6) Rudder stocks and pintles should be of weldable quality.

Table 2.2: Chemical composition limits 1) for machinery steel forgings

Steel type	C	Si	Mn	P	S	Cr	Mo	Ni	Cu	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 (Ceq) is not more than 0.41%.

3) Elements are considered as residual elements unless shown as a minimum.

4) Where alloy steel forgings are intended for welded constructions, the proposed chemical composition is subject to approval by ACS.

5) One or more of the elements is to comply with the minimum content.

3 Mechanical tests

3.1 Adequate number of test coupons are to be provided for carrying out tests including for retest purposes, with a cross-sectional area of not less than that part of the forging which it represents. This test material is to be integral with each forging except as provided in 3.7 and 3.10. Where batch testing is permitted according to 3.10 the test material may alternatively be a production part or separately forged. Separately forged test material is to have a reduction ratio similar to that used for the forgings represented.

3.2 For the purpose of these requirements a set of tests is to consist of one tensile test specimen and when required in other sections of Rules three Charpy V-notch impact test specimens.

3.3 Test specimens are normally to be cut with their axes either parallel (longitudinal test) or tangential (tangential test) to the principal axial direction of each product.

3.4 Unless otherwise agreed, the longitudinal axis of test specimens is to be positioned as follows:

a) for thickness or diameter upto maximum 50 [mm], the axis is to be at the mid-thickness or the center of the cross section.

b) for thickness or diameter greater than 50 [mm], the axis is to be at one quarter thickness (mid-radius) or 8- [mm], whichever is less, below any heat treated surface.

3.5 Except as provided in 3.10 the number and direction of tests is to be as follows:

a) 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.3.5a, Fig.3.5b and Fig.3.5c may be used. Where a forging exceeds both 4

tonnes in mass and 3 [m] in length one set of tests is to be taken from each end. These limits refer to the 'as forged' mass and length but excluding the test material.

b) Pinions - Where the finished machined diameter of the toothed portion exceeds 200 [mm] one set of tests is to be taken from each forging in a tangential direction adjacent to the toothed portion (test position B in Fig.3.5d).
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.3.5d). If however, the journal diameter is 200 [mm] or less the tests are to be taken in a longitudinal direction (test position A in Fig.3.5d). Where the finished length of the toothed portion exceed 1.25 [m], one set of tests is to be taken from each end.

c) Small pinions - Where the finished diameter of the toothed portion is 200 [mm] or less one set of tests is to be taken in a longitudinal direction (test position A in Fig.3.5d).

d) Gear wheels - One set of tests is to be taken from each forging in tangential direction (test position A or B in Fig.3.5e).

e) Gear wheel rims (made by expanding) One set of tests is to be taken from each forging in a tangential direction (test position A or B in Fig.3.5.f). Where the finished diameter exceeds 2.5 [m] or the mass (as heat treated excluding test material) exceeds 3 tonnes, two sets of tests are to be taken from diametrically opposite positions (test positions A and B in Fig. 3.5f). The mechanical properties for longitudinal test are also to be applied.

f) Pinion sleeves - One set of tests is to be taken from each forging in tangential direction (test position A or B in Fig.3.5g). Where the finished length exceeds 1.25 [m] one set of tests is to be taken from each end.

g) Crank webs One set of tests is to be taken from each forging in a tangential direction.

h) Solid open die forged crankshafts
One set of tests is to be taken in a longitudinal direction from the driving shaft end of each forging (test position A in Fig.3.5h). 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.3.5h). Where, however, the crankthrows are formed by machining or flame cutting, the second set of tests is to be taken in a tangential direction from material removed from the crankthrow at the end opposite the driving shaft end (test position C in Fig.3.5h).

3.6 For closed die crankshaft forgings and crankshaft forgings where the method of manufacture has been specially approved in accordance with sec. 1.2.5, the number and position of test specimens is to be agreed with ACS having regard to the method of manufacture employed.

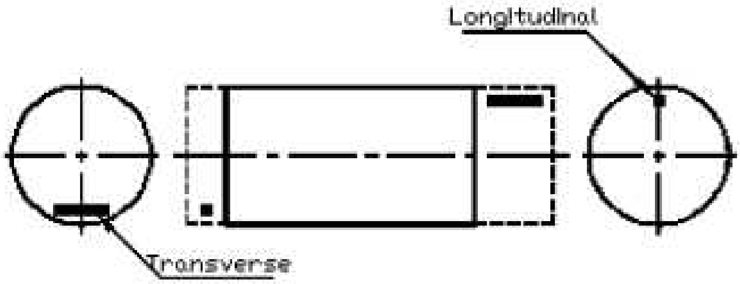


Fig. 3.5 a: Plain shaft

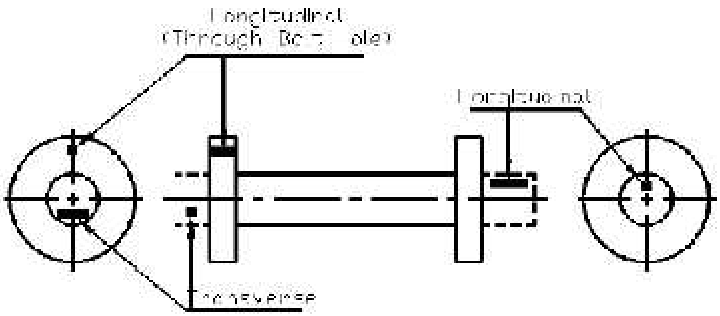


Fig. 3.5 b: Flanged shaft

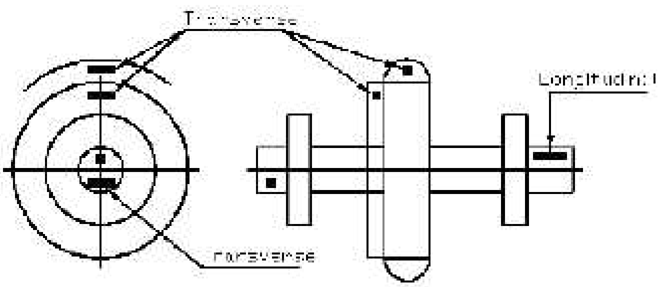
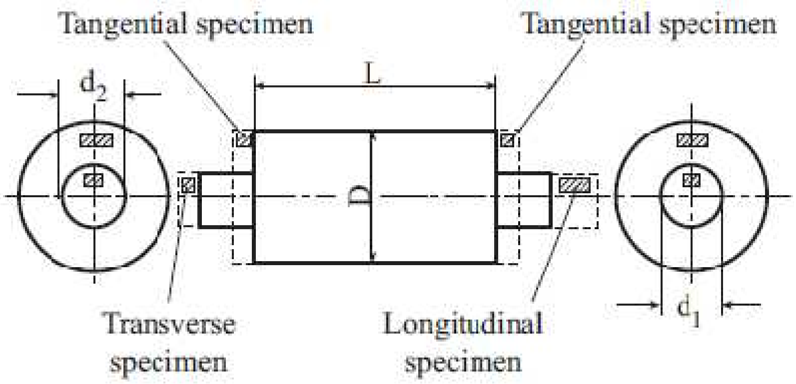


Fig.3.5. c: Flanged shaft with collar



L = Length of tooth system
D = Diameter of tooth system
d_1, d_2 = Diameter of bearing journal

Fig. 3.5 d: Pinion

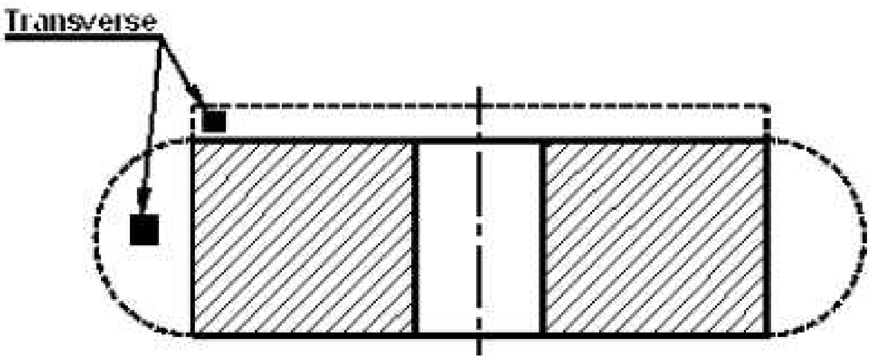


Fig. 3.5 e: Gear wheel

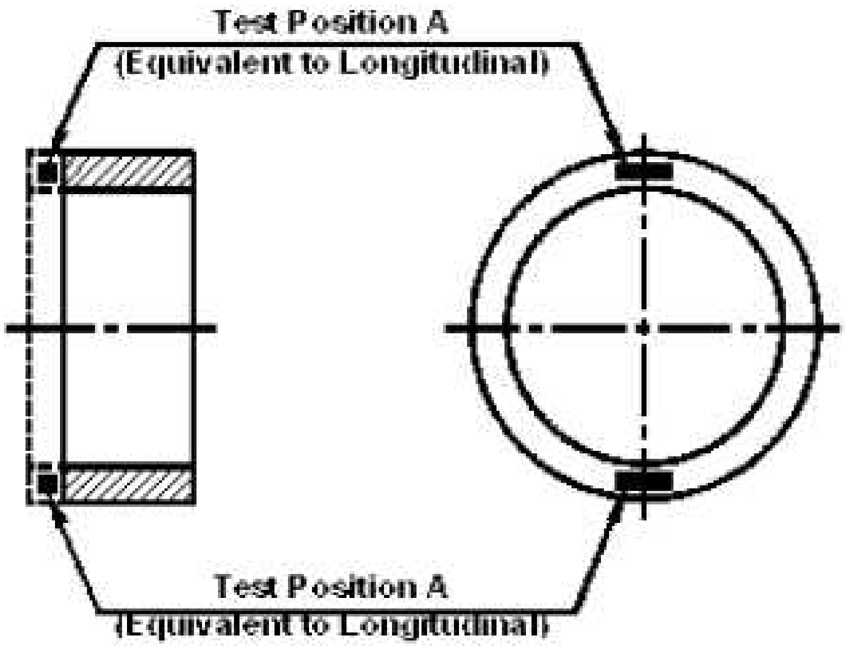


Fig. 3.5 f: Gear rim (made by expanding)

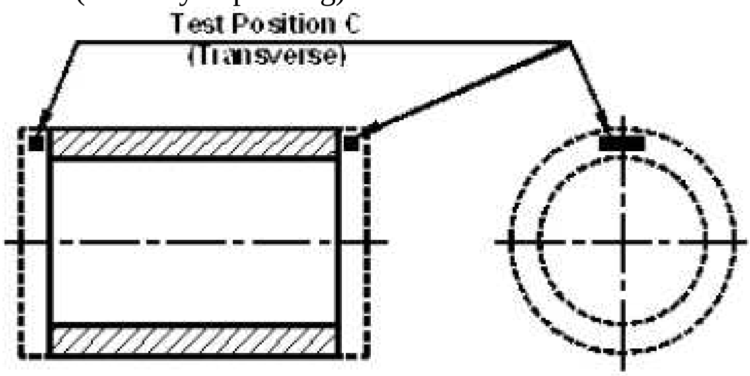


Fig. 3.5 g: Pinion Sleeve

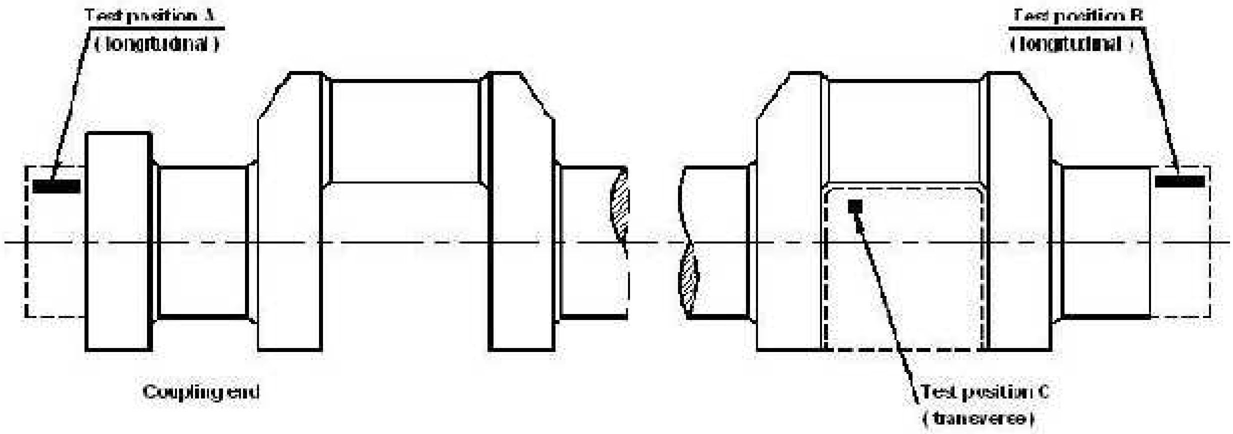


Fig. 3.5 h: Solid forged crankshaft

3.7 When a forging is subsequently divided into a number of components, all of which are heat treated together in the same furnace charge, for test purposes this may be regarded as one forging and the number of tests required is to be related to the total length and mass of the original multiple forging.

3.8 Except for components which are to be carburized or for hollow forgings where the ends are to be subsequently closed, test material is not to be cut from a forging until all heat treatment has been completed.

3.9 When forgings are to be carburized sufficient test material is to be provided for both preliminary tests in the as forged condition and for final tests after completion of carburizing.

For this purpose duplicate sets of test material are to be taken from positions as detailed in 3.5, except that irrespective of the dimensions or mass of the forging, tests are required from one position only and in the case of forgings with integral journals, are to be cut in a longitudinal direction. This test material is to be machined to a diameter of D/4 or 60 [mm], whichever is less, where D is the finished diameter of the toothed portion.

For preliminary tests, one set of test material should be given a blank carburizing and it should undergo same heat treated cycle which the forged material will be subjected to.

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 forge master or gear manufacturer 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 ACS.

3.10 Normalized forgings with mass upto 1000 Kg each and quenched and tempered forgings with mass upto 500 Kg each may be batch tested. A batch is to consist of forgings of similar shape and dimensions, made from the same heat of steel, heat treated in the same furnace charge and with a total mass not exceeding 6 tonnes for normalized forgings and 3 tonnes for quenched and tempered forgings respectively.

3.11 A batch testing procedure may also be used for hot rolled bars. A batch is to consist of either:

i) 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

ii) bars of the same diameter and heat, heat treated in the same furnace charge and with a total mass not exceeding 2.5 tonnes.

3.12 The preparation of test specimens and the procedures used for mechanical testing are to comply with the relevant requirements of Pt.2, Ch.2. Unless otherwise agreed all tests are to be carried out in the presence of the Surveyor.

4 Mechanical properties

4.1 Table 4.1 and Table 4.2 gives the minimum requirements for yield stress, elongation, reduction of area and impact test energy values corresponding to different strength levels but it is not tended 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.

4.2 Forgings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Table 4.1 and Table 4.2 but subject to any additional requirements of the relevant construction rules.

4.3 The mechanical properties are to comply with the requirements of Table 4.1 and Table 4.2 appropriate to the specified minimum tensile strength or, where applicable the requirements of the approved specification.

4.4 At the discretion of ACS hardness tests may be required in the following cases:

i) 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.

ii) 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, for information purposes, typical Brinell hardness values are given in Table 4.2.

4.5 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 including depth of hardening are to comply with the approved specifications.

4.6 Where the result of a tensile test does not comply with the requirements, two additional tests may be taken. If satisfactory results are obtained from both of these additional tests the forging or batch of forgings is acceptable. If one or both retests fail the forging or batch of forgings is to be rejected.

4.7 Where the results from a set of three impact test specimens do not comply with the requirements an additional set of three impact test specimens may be taken provided that not more than two individual values are less than the required average value and of these not more than one is less than 70% of this average value. The results obtained are to be combined with the original results to form a new average which, for acceptance of the forgings or batch forgings, is to be not less than the required average value.

Additionally, for these combined results not more than two individual values are to be less than the required average value and of these not more than one is to be less than 70% of this average value.

4.8 The additional tests detailed in 4.6 and 4.7 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 hatch of forgings.

4.9 At the option of the manufacturer, when a forging or a batch of forgings has failed to meet the test requirements, it may be re- heat treated and re-submitted for acceptance tests.

Table 4.1: 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 As min. %		Reduction of area Z min. %	
			Long.	Tang.	Long.	Tang.
C and C-Mn	400	200	26	19	50	35
	440	220	24	18	50	35
	480	240	22	16	45	30
	520	260	21	15	45	30
	560	280	20	14	40	27
	600	300	18	13	40	27
Alloy	550	350	20	14	50	35
	600	400	18	13	50	35
	650	450	17	12	50	35

1) The following ranges for tensile strength may be additionally specified:
specified minimum tensile strength : < 600 [N/ mm^2] ≥ 600 [N/mm^2]
tensile strength range : 120 [N/ mm^2] 150 [N/ mm^2]

Table 4.2: Mechanical properties for machinery steel forgings 2)

Steel type	Tensile strength[1)] Rm min. [N/mm^2]	Yield stress Re min. [N/mm^2]	Elongation As min %		Reduction of area Z min. %		Hardness[3)] (Brinell)
			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	175-215
	700	420	16	12	45	30	205-245
	800	480	14	10	40	27	235-275
	900	630	13	9	40	27	260-320
	100	700	12	8	35	24	290-365
	1100	770	11	7	35	24	320-385

1) The following ranges for tensile strength may be additionally specified:
specified minimum tensile strength : < 600 [N/mm^2] ≥ 600 [N/mm^2]
tensile strength range : 120 [N/mm^2] 150 [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 27J (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.

Section 3 Ferritic Steel Forgings for Low Temperature Service

1 Scope

1.1 The requirements for carbon-manganese and nickel steels suitable for low temperature service are detailed in this section. They are applicable to all forgings with material thickness up to and including 50 [mm] used for the construction of cargo tanks, storage tanks and process pressure vessels for liquefied gases and where the design temperature is less than 0°C, to forgings for the piping systems.

1.2 The requirements are also applicable to forgings for other pressure vessels and pressure piping systems where the use of steels with guaranteed impact properties at low temperatures is required.

2 Chemical composition

2.1 The chemical composition of ladle samples is, in general, to comply with the requirements given in Table 2.1 of Ch.3, Sec. 3.

3 Heat treatment

3.1 Forgings are to be normalized, normalized and tempered or quenched and tempered in accordance with the approved specification.

4 Mechanical tests

4.1 At least one tensile and three V-notch impact test specimens are to be taken from each forging or each batch of forgings. Where the dimensions and shape allow, the test specimens are to be cut in a longitudinal direction.

4.2 The impact tests are to be carried out at a temperature appropriate to the type of steel and for the proposed application. Where forgings are intended for ships for liquefied gases the test temperature is to be in accordance with the requirements given in Table 4.1 of Ch.3, Sec.5.

4.3 The results of all tensile tests are to comply with the approved specification.

4.4 The average energy values for impact tests are also to comply with the approved specification and generally with the requirements of Ch.3, Sec.5.

4.5 For material thickness above 50 [mm], the material properties are to be agreed.

5 Pressure tests

5.1 When applicable, pressure tests are to be carried out in accordance with the requirements of the relevant construction Rules.

Section 4 Austenitic Stainless Steel Forgings

1 General

1.1 Forgings in austenitic stainless steels are acceptable for use in the construction of cargo tanks, storage tanks and piping systems for chemicals and liquefied gases. They may also be accepted for elevated temperature service in boilers.

1.2 Where it is proposed to use forgings in these types of steels, details of the chemical composition, heat treatment and mechanical properties are to be submitted for approval.

These are to comply in general, with the requirements of Chapter 3, Section 9 for austenitic steel plates.

1.3 Unless otherwise specified, impact tests are not required for acceptance purposes. Where they are required tests are to be made on longitudinal specimens at minus 196°C and the minimum average energy requirements is to be 41J.

2 Mechanical properties for design purposes

2.1 Where austenitic stainless steel forgings are intended for service at elevated temperatures, the nominal values for the minimum one per cent proof stress at temperatures of 100°C and higher given in Table 2.1 may be used for design purposes.

Verification of these values is not required except for material complying with a National or proprietary specification in which the elevated temperature properties proposed for design purposes are higher than those given in Table 2.1.

3 Non-destructive examination

3.1 Non-destructive examination is to be carried out in accordance with the requirements of Classification Notes or as otherwise agreed between the manufacturer, purchaser and Surveyor.

4 Intergranular corrosion tests

4.1 Where corrosive conditions are anticipated in service, intergranular corrosion tests are required on forgings in Grades 304, 316 and 317. Such tests may not be required for Grades 304L, 316L, 321 and 347.

4.2 When an intergranular corrosion test is specified, it is to be carried out in accordance with ASTM A262.

Table 2.1: Mechanical properties for design purposes : austenitic stainless steels

Grade	Nominal 1% proof stress [N/mm^2] at a temperature												
	100^{0}C	150^{0}C	200^{0}C	250^{0}C	300^{0}C	350^{0}C	400^{0}C	450^{0}C	500^{0}C	550^{0}C	600^{0}C	650^{0}C	700^{0}C
304L	168	150	137	128	122	116	110	108	106	102	100	96	93
316L	177	161	149	139	133	127	123	119	115	112	110	107	105
316LN	238	208	192	180	172	166	161	157	152	149	144	142	138
321	192	180	172	164	158	152	148	144	140	138	135	130	124
347	204	192	182	172	166	162	159	157	155	153	151	-	-

Chapter 6 Steel Pipes and Tubes

Section 1 General Requirements

1 Application

1.1 The requirements of this Section apply to seamless and welded steel pipes, tubes and fittings intended for boilers, pressure vessels and systems operating at ambient, high or low temperature.

Provision is also made for pipes intended for structural applications, at ambient temperature. Section 1, specifies the requirements common to all the above-mentioned steel pipes, while the appropriate specific requirements are indicated in Section 2 to 7. The general term pipes will be used in the following text to mean pipes and tubes.

1.2 Special requirements may be specified in cases of applications intended for dangerous substances or particularly severe service conditions.

In cases of applications involving the storage and transport of liquefied gases, the appropriate requirements of the Society's Rules for the Classification of Steel Ships also apply.

2 Manufacturing process

2.1 The steel used is to be manufactured as detailed in Ch.1.

Unless a specific method is agreed for individual supplies, or specific requirements are given in the relevant Sections, the pipes may be manufactured by one of the following methods:

a) seamless, hot or cold finished

b) welded, by automatic processes

c) welded, as above hot and/or cold finished.

In the case of welded pipes, the following processes are to be used depending on the grade of steel:

a) electrical resistance (ERW), induction (IW), submerged arc (SAW) welding for carbon and carbon manganese steels

b) electric tungsten arc process (GTAW), plasma (PAW), submerged (SAW) arc welding for austenitic or austenitic-

ferritic steels.

The welding process is to be approved according to the applicable requirements. Unless specially approved by the Society, pipes in carbon and carbon-manganese steel for offshore structural applications are to be seamless or longitudinally welded. Nickel steel pipes are to be manufactured seamless. Unless otherwise specified, the manufacturing process is left to the discretion of the Manufacturer.

3 Approval

3.1. Welded pipes and fittings and, unless otherwise specified by the Society, seamless pipes and fittings in low alloyed or alloyed steels, intended for high temperature are to be manufactured by approved Manufacturers.

In other cases the Manufacturers are in any event to be recognized by the Society.

4 Quality of materials

4.1 All pipes are to have a workmanlike finish consistent with the method of manufacture and to be free from defects and surface or internal imperfections which may impair their use in subsequent fabrication or service.

4.2 All pipes are to be reasonably straight and their ends are to be cut perpendicular to the axis without leaving chips or burrs.

5 Visual, dimensional and non-destructive examinations

5.1 Each pipe is to be submitted by the Manufacturer to visual examination and verification of dimensions.

All pipes intended for severe conditions, such as super heater tubes, pressure cylinders, pressure systems with working pressure higher than 4.0 N/mm^2, pipes conveying liquefied gases and dangerous media, are to be presented to the Surveyor for visual examination and verification of dimensions.

5.2 The dimensional tolerances on the thickness and diameter are to be in accordance with recognized standards.

In welded pipes, the weld reinforcement is to be well faired and within allowable limits.

5.3 Welded pipes are to be submitted by the Manufacturer to an appropriate, automatic non-destructive test of welded joints as specified at the approval.

6 Rectification of surface defects

6.1 Rectification of surface defects by grinding

Small surface defects and imperfections may be removed by grinding, provided that the pipe thickness after repair is within the permissible tolerance and the ground zone is well faired into the adjacent zone.

6.2 Rectification of surface defects by welding

Repairs by welding may be accepted at the Surveyor's discretion. The repair procedure is to be submitted for consideration. The repaired areas are subsequently to be examined by magnetic particle or liquid penetrant methods and/or by other appropriate non-destructive tests.

7 Condition of supply

7.1 Pipes are to be supplied in the required heat treated or equivalent condition. Where alternative supply conditions are accepted, the choice of the supply condition, unless otherwise required, is left to the Manufacturer; the condition of supply is always to be mentioned in the testing documentation.

7.2 Pipes which are to be expanded after supply are to be annealed at least at their ends.

8 Hydrostatic test

8.1 With the exception of pipes intended for structural application, each pipe is to be subjected to hydrostatic test at the Manufacturer's works. The test pressure P, in N/mm^2, is given by the following formula but the maximum pressure may not be higher than 14 N/mm^2:

$P=2tf/D$

where:

D : Nominal outside diameter of the pipe, in mm

t : Nominal wall thickness of the pipe, in mm

f : Equal to:

- 0,80 R_{eH} for ferritic steels
- 0,70 $R_{p0.2}$ for austenitic or austenitic-ferritic steels.

The test pressure is to be maintained for a sufficient time to verify the tightness and at least for 5 seconds.

The test pressure is to be measured by means of a suitable, calibrated pressure gauge.

8.2 Unless otherwise agreed, the Manufacturer's certificate of the hydrostatic test is accepted. The hydrostatic test of pipes intended for boilers, super heaters or pressure systems with working pressure higher than 4.0 N/mm^2, or conveying liquefied gases and dangerous media, may be required to be witnessed by the Surveyor.

8.3 Subject to the prior approval of the procedure, a nondestructive test by ultrasonic or eddy current may be accepted as an alternative to the hydrostatic test.

9 Sampling and testing

9.1 Batch composition

Pipes are to be presented for mechanical and technological tests in the final supply condition and, unless otherwise indicated in the relevant Sections, in batches.

For pipes which are not heat treated, the batch is to consist of pipes of the same size, manufactured by the same procedure, from the same type of steel.

For pipes which are supplied in the heat treated condition, the batches are to consist of pipes of the same size, manufactured from the same type of steel and subjected to the same heat treatment in a continuous furnace or heat treated in the same furnace charge. For pipes welded by the electric submerged arc welding process, the batch is also to consist of pipes welded with the same welding materials.

For pipes intended for low temperature service, the batch is also to consist of material originating from the same cast.

The size of the batch is to be in accordance with Table 9.1.

Table 9.1: Number of pipe as made lengths per batch

Outside diameter range (mm)	Maximum number of tubes per batch (1)
D ≤ 114,3	200
114.3 < D ≤ 323.9	100
323.9 < D	50

(1) Residual quantities of up to 10 lengths may be allocated to the other batches presented for testing.

9.2 Sampling

The test samples are to be cut from a length selected at random from each batch, for the tests specified in the various Sections. The specimens for all or part of the following tests, as detailed in the various Sections, are to be obtained from the individual samples.

a) mechanical tests

- tensile test, longitudinal direction
- tensile test transverse to the weld for pipes with D ≥ 300 mm
- 3 Charpy V-notch impact tests, longitudinal direction.

For pipes having thickness less than 6 mm, reduced specimens having the maximum thickness are to be used.

b) technological tests

- flattening test

For welded pipes, two tests are to be carried out; in one test the specimen is to be positioned with the welded joint at 0°, in the other at 90°, to the direction of the force.

The distance between plates to be reached during the test is determined by the following formula:

$$Z=\frac{(1+C)t}{(C+t/D)}$$

where the value of C is indicated in the tables relevant to the mechanical properties of the various pipes

- a bend test is to be performed in lieu of the flattening test for pipes having D > 400 mm or thickness greater than 15% of D

For welded pipes, one test is carried out with the outside surface of the pipe in tension and the other with the inside surface of the pipe in tension. The mandrel diameter is indicated in the various Sections and the bend angle is to be equal to 180°

- flanging or drift expanding test for pipes having D ≤150 mm or thickness ≤9 mm.

9.3 Preparation of test specimens

For the preparation of test specimens and for the testing procedures, reference is to be made to the applicable requirements of the rules.

9.4 Tensile and technological tests

The results of the test are to comply with the values specified in the appropriate tables.

If during the tensile test there is no marked yield stress ReH, the 0,2% proof stress Rp0,2 is taken as an alternative.

9.5 Impact test

The average value is to comply with the minimum average value required; only one individual value may be less than the average value required, provided that it is not less than 70% of it. The values required for the various products are relevant to standard specimens 10x10 mm2. For subsize specimens reference is to be made to Ch 2, Sec 3.

For reduced specimens obtained from pipes having thickness less than 6 mm, the energy required is proportional to the area of the specimen, referring to the specimen 10 x 5 mm2 and to the energy required for this specimen.

9.6 Re-test procedures

For re-test procedure, reference is made to Ch 1, Sec 1.10.

10 Identification and marking

10.1 The Manufacturer is to adopt a system of identification which enables the material to be traced to its original cast, as appropriate.

10.2 All pipes and tubes are to be identified and marked with the following indications:

a) Society's brand
b) Manufacturer's name or trade mark
c) Identification mark for the type of steel
d) Cast number or identification number and/or letters, which will enable the history of the fabrication of the piece or bundle to be traced.

Marking is to be applied by punching. In the case of small wall thickness which may be damaged by punching, alternative methods such as paint, electrical engraving or rubber stamps may be used. Marking on labels is accepted for small pipes.

11 Documentation and certification

11.1 The testing documentation is to be issued and is to include all the required information, as appropriate.

The ladle analysis is to include the content of refining and alloying elements as applicable. If rimming steel is supplied, this condition is to be stated on the certificate.

11.2 When pipes are made from steel produced in a mill other than that where the pipes are manufactured, the Surveyor is to be supplied with a steelmaker's certificate stating the manufacturing process, the grade of steel, the cast number and the relevant ladle analysis.

Section 2 Pipes for Pressure Systems Operating at Ambient Temperature

1 Application

1.1 The requirements of this section apply to seamless and welded carbon and carbon manganese steel pipes, intended for piping systems or pressure vessels operating at ambient temperature or when impact properties at a temperature not lower than -20°C are specified.

2 Steel grades

2.1 The requirements apply to carbon and carbon manganese steels, which are classed into five groups indicated by the minimum ultimate tensile strength Rm , in N/mm2: 320, 360, 410, 460 and 510.

Each group is further subdivided into grades HA, HB and HD, based on quality level and impact properties, as applicable. The letters HA, HB and HD mean impact properties at +20°C, 0°C and -20°C, respectively.

3 Condition of supply

3.1 Seamless cold finished pipes are to be normalised, while hot finished pipes may be normalised or normalized formed. Welded pipes are to be supplied in the condition specified at the approval.

At the Manufacturer’s discretion, normalising and tempering may be carried out in lieu of normalizing.

4 Chemical composition

4.1 The method of deoxidation and chemical composition on ladle analysis are to comply with the requirements specified in Table 4.1.

Table 4.1: Chemical composition

Steel grade	deoxidation	Chemical composition (%) (1)					
		C max	Mn	Si max	P max	S max	Al tot. min. (1)
320 HA	Semi-killed or killed (2)	0.16	0.40-0.70	0.35	0.040	0.040	
360HA 360 HB	Semi-killed or killed	0.17	0.40-1.00	0.35	0.040	0.040	
410HB	Killed	0.21	0.40-1.20	0.35	0.040	0.040	
410HD	Killed and fine grained						0.020
460HB	Killed	0.22	0.80-1.40	0.35	0.040	0.040	
460HD	Killed and fine grained						0.020
510HB	Killed	0.220	0.60-1.80	0.35	0.035	0.035	
510HD	Killed and fine grained						0.020

(1) Nb, V or Ti may be used for grain refining as a complete or partial substitute for Al. The grain refining elements are to be specified at the time of approval; in general Nb and V are not to exceed 0,05 and 0,10%, respectively.

Additional alloying elements are to be submitted for consideration and approval. Residual elements not intentionally added are not to exceed the following limits (%): Ni ≤0.30 ; Cu ≤0.25 ; Cr ≤0.25 ; Mo ≤0.10. Total: Ni + Cu + Cr + Mo ≤0.70

(2) For welded pipes, rimmed steel may also be used, as specified at the approval.

5 Mechanical properties

5.1 The mechanical properties are specified in Table 5.1.

Table 5.1: Mechanical properties

Steel grade	Yield stress R_{eH} (N/mm^2) min. for thickness t (mm)			Tensile strength R_m (N/mm^2)	Elong. A_s (%) min.	Average impact energy (J) min.		Technological tests		
	t≤16	16<t≤40	40<t≤60			Test temp (0C)	KVL	flattening test constant C for √D		Bend test diameter mandrel
								√D≤0.15	√D>0.15	
320HA	195			320 – 440	25	+20	27	0.09	0.08	4 t
360HA	235	225	215	360 – 500	24	+20				
360HB						0				
410HB	255	245	235	410 – 550	22	0		0.07	0.06	
410HD						-20				
460HB	285	275	265	460 – 580	21	0				
460HD						-20				
510HB	355	345	(1)	510 - 630	19	0	34			
510HD						-20				

(1) To be agreed between Manufacturer and purchaser.

6 Mechanical and technological tests

6.1 For pipes intended for pressure cylinders, the tests are to be carried out on each as made length. Pipes intended for other applications are to be presented in batches, as specified in Sec. 1; Table 9.1.

One pipe is to be selected from each batch for the required tests as follows:

a) seamless pipes:

- one tensile test, longitudinal direction
- one flattening test or one bend test

- 3 Charpy V-notch impact tests, longitudinal direction, for pipes having thickness ≥11 mm and, when impact properties are required at -20°C, for thickness ≥6 mm

b) welded pipes:

- one tensile test on base metal, longitudinal direction
- one tensile test transverse to the weld for pipes with D ≥300 mm
- two flattening tests or two bend tests
- 3 Charpy V-notch impact tests, longitudinal direction, for pipes having thickness ≥11 mm and, when impact properties are required at -20°C, for thickness ≥6 mm.

Section 3 Pipes for Structural Applications

1 Application

1.1 Steel pipes for structural application at ambient temperature are to comply with the requirements specified in section 2, with the exception of the hydrostatic test which is not required.

2 Steel grades

2.1 Unless otherwise agreed with the Society, steel grades are to correspond to the types specified in section 2 with designation 410 HA-HB, 460 HB-HD and 510 HB-HD. Steels for offshore structural applications are to be killed and fine grain treated. The symbol ST is to be added to the steel designation to clearly indicate that pipes are intended for structural application.

3 Mechanical and technological tests

3.1 Pipes are to be tested as specified in 2.6 except pipes for offshore structural applications which are to be tested as specified in the following.
One pipe is to be selected from each batch for the required tests as follows:

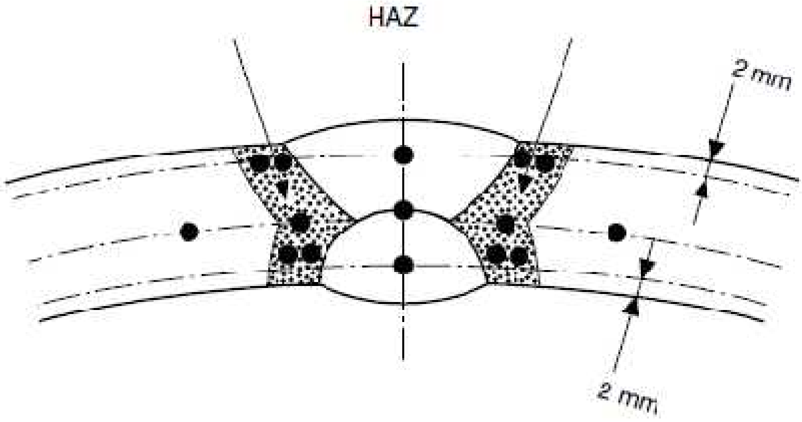
a) seamless pipes:

- one tensile test, longitudinal direction
- one flattening test or one bend test
- Charpy V-notch impact tests on a set of specimens, longitudinal direction

b) welded pipes:

- one tensile test on base metal, longitudinal direction
- one tensile test transverse to the weld for pipes with D ≥ 300 mm
- face and root bend tests
- Series of 3 Charpy V-notch tests on sets of 3 specimens taken transverse to the weld and located with the notch in the weld axis, the fusion line and 2mm away from the fusion line in the HAZ
- Hardness tests on the weld macro-section. The Vickers method HV10 is normally used. Three rows of indentations are to be made; one row at 2 mm below outer surface, one row at 2 mm below inner surface and one row crossing the weld root as shown in Fig 3.1. The values are not to exceed the maximum value allowed for the qualification of welding procedure.

Figure 3.1: Hardness test HV10



4 Non-destructive examination

4.1 Pipes are to be examined as specified in section 1.5.

In addition, pipes for offshore structural applications are to be examined as shown in Table 4.1.

Table 4.1: NDE of pipes for offshore structural applications

Type of tests	Wall thickness (mm)			
	T ≤ 10 mm	10 mm < t ≤ 20 mm	20 < t ≤ 49 mm	T > 49 mm
UT of weld	-	100% length	100% length	100% length
UT of tube (1)	-	Grid (3)	Grid (3)	10% surface (2)
Radiographic inspection of weld	Ends	Ends	Ends	Ends
MPi of weld	10% length (2)	10% length (2)	100% length	100% length
MPi of tube (1) (4)	Grid (3)	Grid (3)	Grid (3)	10% surface
Repairs	100% MPi + Radiographic	100% MPi + UT	100% MPi + UT	100% MPi + UT

Note 1: UT = Ultrasonic testing; MPi = Magnetic particle inspection.

(1) Except if plates were US tested at the steel mill.

(2) When non-destructive tests are carried out only at random (10%), UT and MPi are to be performed in different locations.

(3) Dimensions of the grid to be agreed with the Society.

(4) Seamless tubes and hot formed welded tubes only.

Section 4 Pipes for High Temperature Service

1 Application

1.1 The requirements of this Section apply to seamless and welded pipes intended for boilers, superheaters and heat exchangers, or pressure parts operating at elevated temperatures.

2 Steel grades

2.1 The requirements apply to carbon, carbon-manganese steels and low alloy steels (Mo, Cr-Mo and Cr-Mo-V).

2.2 Carbon and carbon manganese steels are classed into five groups which are indicated by the minimum ultimate tensile strength Rm (N/mm^2): 320, 360, 410, 460 and 510.

2.3 Low alloy steels are designated according to the chemical composition into the grades 0.3Mo – 0.5Mo0.5Cr, 1Cr0.5Mo – 2.25Cr1Mo – 0.5Cr0.5Mo0.25V.
The figures mean the nominal percentage content of the main alloying elements.

3 Condition of supply

3.1 The products are to be supplied in the conditions indicated in Table 3.1.

Table 3.1: Mechanical properties - Conditions of supply

Steel grade	Heat treatment (1)	Yield stress R_{eH}(N/mm^2) min. for t (mm)		Tensile strength R_m (N/mm^2)	Elong. A_s (%) min.	Technological tests			
						C (3)	Di/D (4)		
		T ≤ 40	40<t≤60				≤ 0.6	0.6<Di/D≤0.8	>0.8
320	N or NR	195		320 – 440	25	0.09	12	15	19
360	N or NR	225	215	360 – 500	25	0.09	12	15	19
410	N or NR	245	235	410 – 550	22	0.06	10	12	17
460	N or NR	270	260	460 – 580	21	0.06	8	10	15
510	N or NR	345	(2)	510 – 640	21	0.06	8	10	15
0,3Mo	N	270	260	450 – 600	22	0,07	8	10	15
0.5Cr 0.5Mo	N+T	270	260	440 – 570	22	0.07	8	10	15
1Cr 0,5Mo	N or N+T	290	280	440 – 590	22	0.07	8	10	15
2.25Cr 1Mo	N+T	280	270	450 – 600	20	0.06	8	10	15
	A	205	205	410 – 560	22	0.06	8	10	15
0.5Cr 0.5Mo 0.25V	N+T	300	290	460 - 610	20	0.06	8	10	15

(1) N: normalising - NR : normalising forming - T: tempering - A : annealing.

(2) To be agreed between Manufacturer and purchaser.

(3) Constant C for flattening test.

(4) Expanding or flanging test; increase of outside diameter D, in %, as a function of Di/D.

4 Chemical composition

4.1 The chemical composition on ladle analysis is to comply with the requirements specified in Table 4.1.
Steels are to be killed with the exception of grades 320 and 360 which may be semi-killed.

Table 4.1: Chemical composition

Steel grade	Chemical composition (%) (1)								
	C max	Mn	Si	P max	S max	Cr	Mo	V	Al tot
320	0.16	0.40-0.70	≤ 0.35	0.030	0.030				
360	0.17	0.40-1.00	≤ 0.35	0.030	0.030				
410	0.21	0.40-1.20	≤ 0.35	0.030	0.030				
460	0.22	0.80-1.40	≤ 0.35	0.030	0.030				
510	0.22	0.60-1.80	≤ 0.35	0.035	0.035				
0.3Mo	0.12-0.20	0.40-0.80	0.10-0.35	0.035	0.035		0.25-0.35		≤0.020
0.5Cr 0.5Mo	0.10-0.18	0.50-0.90	0.10-0.35	0.035	0.035	0.40-0.65	0.45-0.60		≤0.020
1Cr 0.5Mo	0.10-0.18	0.40-0.70	0.10-0.35	0.035	0.035	0.70-1.10	0.45-0.65		≤0.020
2.25Cr 1Mo	0.08-0.15	0.40-0.70	0.10-0.35	0.035	0.035	2.00-2.50	0.90-1.20		≤0.020
0.5Cr 0.5Mo 0.25V	0.10-0.18	0.40-0.70	0.15-0.50	0.035	0.035	0.70-1.10	0.45-0.65	0.22-0.28	≤0.020

(1) With the exception of refining elements, additional alloying elements are to be submitted for consideration and approval.

Residual elements are permitted provided they do not impair the properties, subsequent processing or behaviour in service.

For C and C-Mn steels, the following limits (%) apply: Ni ≤0.30; Cu ≤0.25; C ≤0.25; Mo ≤0.10;

Total: Ni+Cu+Cr+Mo ≤ 0.70. For Mo and Cr-Mo alloy steels, the limits are the following (%): Ni ≤0.30; Cu ≤0.25.

5 Mechanical properties

5.1 The mechanical properties and conditions of supply are specified in Table 3.1.

6 Mechanical properties at elevated temperatures

6.1 The values of the yield stress ReH or 0,2% proof stress Rp0,2 at temperatures of 100°C and higher are given in Table 6.1.

The values are for design purposes only. Their verification is in general not required during the testing, unless figures

Higher than those shown in Table 6.1 and in accordance with recognised standards are proposed by the steel Manufacturer.

In such cases, the verification is required and the procedures detailed in 6.2 and 6.3 are to be followed.

Table 6.1: Minimum proof stress (Rp0.2) values at elevated temperatures

Steel grade	$R_{p0,2}$ (N/mm^2) at a temperature (^{0}C) of (1)									
	100	150	200	250	300	350	400	450	500	550
320 HA	170	16	150	125	100	95	90	85		
360 HA	190	175	165	145	120	115	110	105		
410 HA	210	200	190	170	150	140	130	125		
460 HA	235	220	215	195	180	165	160	155		
510 HA	250	240	230	215	195	180	175	170		
0.3 Mo	240	235	225	205	175	160	155	150	145	
0.5Cr 0.5Mo (2)										
1Cr 0.5Mo	265	250	245	235	190	180	175	165	155	150
2.25Cr 1Mo (3) 2.25Cr 1Mo (4)	260 110	250 100	245 90	235 85	230 80	215 75	205 70	195 65	180 65	165 70
0.5Cr 05Mo 0.25V	260	250	235	215	190	185	175	165	155	145

(1) The values for temperatures <200°C are given for information.

(2) Values to be determined during preliminary approval .

(3) Normalized and tempered condition.

(4) Annealed condition.

6.2 When the Rp0,2 is required to be verified, at least one tensile test for each cast is to be carried out at the agreed temperature.
In cases of pipes of different thickness, the sample is to be taken from a pipe selected among those of greatest thickness. The dimensions of the specimens and the testing procedure are to be in accordance with the requirements of Ch 2, Sec 2. The results of tests are to comply with the values specified in Table 6.1.

6.3 As an alternative to the systematic verification of the required Rp0.2 as in 6.2, it may be agreed with the individual steelmakers to carry out an adequate program of tests on the normal production of each steel, in accordance with an ad hoc procedure. Subsequent to the satisfactory results of the approval tests, tensile tests at elevated temperatures are not generally required during the routine testing of the material supplied but as a random check for the confirmation.

6.4 For design purposes only, the estimated values of the stress to rupture in 100000 hours are given in Table 6.2 for groups of steels.

Table 6.2: Average values for stress to rupture in 100000 hours (N/mm^2)

Temperature (^0C)	Carbon and carbon manganese steels		Alloy steels				
	360/410	460/510	0,3Mo	1Cr 0,5Mo	2,25Cr 1Mo		0.5Cr 0.5Mo 0.25V
					N +T (1) (3)	A (2)	
380	170	225					
490	155	200					
400	140	175					
410	125	155					
420	110	135					
430	100	115					
440	90	100					
450	75	85	240	280	220	195	
460	65	70	205	250	205	180	
470	55	60	175	220	185	165	
480	45	55	140	200	170	155	215
490	35	45	115	170	150	140	190
500		40	95	140	135	125	170
510			75	120	120	115	150
520			60	97	105	100	130
530			45	80	90	90	115
540			35	65	76	76	100
550			30	54	68	68	85
560				43	58	58	70
570				35	50	50	55
580					44	44	45

Note 1: The values shown are estimated average values; the lower limit of the range is approximately 20% less than the average value.

(1) N + T = normalizing + tempering.

(2) A = annealing.

(3) When the tempering temperature exceeds 750°C, the values relevant to the annealing heat treatment are to be used.

7 Mechanical and technological tests

7.1 For pipes intended for boiler headers, the tests are to be carried out on each as made length. Other pipes are to be presented in batches and the number is defined in Table 1.9.1.

Two pipes are to be selected from each batch for the required tests, as follows:

a) seamless pipes and tubes:

- one tensile test, longitudinal direction
- one flattening test or one bend test on a mandrel of diameter 4 t
- one expanding or flanging test, when required

b) welded pipes:

- one tensile test on base metal, longitudinal direction
- one tensile test transverse to the weld
- two flattening or two bend tests transverse to the weld for pipes with $D \geq 300$ mm on a mandrel of diameter 4 t
- one expanding or flanging test, when required.
- When required in section 4.6.1, a tensile test at elevated temperature is to be performed on one sample per cast.

Section5 Ferritic Steel Pipes for Pressure Service at Low Temperature

1 Application

1.1 The requirements of this Section apply to seamless and welded steel pipes intended for construction of piping systems, pressure vessels and plants, when impact properties at temperatures lower than -20°C are specified.

Provision is made for pipes with wall thickness up to 40 mm.

2 Steel grades

2.1 The requirements apply to carbon and carbon-manganese steels and nickel alloy steels.

2.2 The carbon and carbon-manganese steels are classed into four groups which are indicated by the minimum ultimate tensile strength Rm (N/mm^2): 360, 410, 460 and 510.

Each group is further subdivided into two grades LE and LF,based on the quality level and impact properties.

The letters LE and LF mean impact properties at - 40°C and - 60°C, respectively.

2.3 The Ni alloy steels are designated according to the chemical composition into the grades 3.5Ni, 9.0Ni.

The figures mean the Ni nominal percentage content.

3 Condition of supply

3.1 The pipes are to be supplied in the conditions indicated in Table 3.1.

Table 3.1: Mechanical properties and condition of supply

Steel grade	Heat treatment (1)	Yield stress R_{eH} (N/mm^2) min. for t(mm)		tensile Strength R_m(N/mm^2)	Elong. A_s (%) min	Average impact energy (J) min.		Technological tests		
		≤ 25	25 < t ≤ 40			Test temp(^{0}C)	KVL	Flattening contest C for t/D		Bend test diameter mandrel
								t/D ≤ 0.15	t/D ≥ 0.15	
360 LE	N	225	215	360-500	22	-40	27	0.09	0.08	4 t
360 LE						-60				
410 LE	N	255	245	410-550	20	-40	27	0.07	0.06	
410 LE						-60				
460 LE	N	275	265	460-580	20	-40	27			
460 LE						-60				
510 LE	N	345	335	510-630	19	-40	34			
510 LE						-60				
3.5 Ni	N orN+T or Q+T	255	245	450-640	19	-100	34			
9.0 Ni	N+N+T	470	460	640-840	16	-195	41			
9.0 Ni	Q+T	570	560	690-840						

(1) N: Normalizing; N+T: Normalizing and tempering; N+N+T: Double normalising and tempering; Q+T: Quenching and tempering.

4 Chemical composition

4.1 The steel is to be killed and fine grained and the chemical composition on ladle analysis is to comply with the requirements specified in Table 4.1.

Table 4.1: Chemical composition

Steel grade	Chemical composition (%) (1)							
	C max	Mn	Si	P max	S max	Ni	Al tot	Others (3)
360 LE-LF	0.17	0.40-1.00	≤ 0.35	0.030	0.025	≤0.30 (2)	≥0.020	Cr ≤ 0.25 Cu ≤ 0.30 Mo ≤ 0.10
410 LE-LF	0.18	0.60-1.30	≤ 0.35	0.030	0.025	≤0.30 (2)	≥0.020	
460 LE-LF	0.18	0.60-1.30	≤ 0.35	0.030	0.025	≤0.30 (2)	≥0.020	
510 LE-LF	0.20	1.00-1.60	≤ 0.35	0.030	0.025	≤0.30 (2)	≥0.020	
3.5 Ni	0.15	0.30-0.90	0.15-0.35	0.025	0.020	3.25-3.75	-	
9.0 Ni	0.12	0.30-0.90	0.15-0.35	0.025	0.020	8.50-9.50	-	

1) With the exception of refining elements, additional alloying elements are to be submitted for consideration and approval; residual elements are permitted provided they do not impair the properties, subsequent processing or behaviour in service.

(2) Higher Ni content up to 0.80 % may be agreed for LF grades.

(3) When the pipes are subjected to hot forming: Cu < 0.25.

5 Mechanical properties

5.1 The mechanical properties and conditions of supply are specified in Table 3.1.

6 Mechanical and technological tests

6.1 The pipes are to be presented in batches and the number of pipes per batch is defined in Table 1.9.1. Two pipes are to be selected from each batch for the required tests, as follows:

a) seamless pipes and tubes:

- one tensile test, longitudinal direction
- one flattening test or one bend test
- 3 Charpy V-notch impact tests, longitudinal direction, for thickness ≥3 mm

b) welded pipes:

- one tensile test on base metal, longitudinal direction
- one tensile test transverse to the weld
- two flattening tests or two bend tests transverse to the weld for pipes with D ≥300 mm
- 3 Charpy V-notch impact tests, longitudinal direction, for thickness ≥3 mm.

Section 6 Austenitic and Austenitic-Ferritic Stainless Steel Pipes

1 Application

1.1 The requirements of this Section apply to seamless and welded austenitic and austenitic-ferritic stainless steel pipes intended for use in the construction of piping systems for chemicals, liquefied gases and bulk chemical tankers.

1.2 Austenitic stainless steels are suitable for use at both elevated and low temperatures. When austenitic stainless steels are proposed for use at elevated temperatures, details of chemical composition, heat treatment and mechanical properties are to be submitted for consideration and approval.

Ferritic-austenitic (duplex) steels are suitable for use for service temperatures between -20°C and +275°C.

2 Steel grades

2.1 The requirements apply to Cr-Ni stainless steels. Steels are designated according to AISI grades; the corresponding ISO grades are also indicated in Table 2.1.

Table 2.1: Chemical composition

ISO grade designation	AISI grade designation	Chemical composition (%) (1)								
		C max	Mn max	Si max	P max	S max	Cr	Ni	Mo	Others
X2CrNi1810	304L	0,03	2,00	1,00	0,045	0,035	17,0-19,0	9,0-13,0	-	
X5CrNi1810	304	0,07	2,00	1,00	0,045	0,035	17,0-19,0	9,0-13,0	-	
X2CrNi1713	316L	0,03	2,00	1,00	0,045	0,035	16,0-18,5	11,0-14,0	2,0-2,5	
X5CrNi1713	316	0,07	2,00	1,00	0,045	0,035	16,0-18,5	11,0-14,0	2,0-2,5	
X6CrNiTi1810	321	0,08	2,00	1,00	0,045	0,035	17,0-19,0	9,0-13,0	-	5C≤Ti≤0,08
X6CrNiNb1810	347	0,08	2,00	1,00	0,045	0,035	17,0-19,0	9,0-13,0	-	10C≤Nb≤1,0
X2CrNiMoN2253	UnS31803	0,03	2,00	1,00	0,030	0,020	21,0-23,0	4,50-6,50	2,5-3,5	0,08≤N≤0,2

(1) With the exception of refining elements, additional alloying elements are to be submitted for consideration and approval.

Residual elements are permitted provided they do not impair the properties, subsequent processing or behaviour in service of the material.

3 Condition of supply

3.1 The pipes are to be supplied in the solution treated condition.

4 Chemical composition

4.1 The chemical composition on ladle analysis is to comply with the requirements specified in Table 2.1.

5 Mechanical properties

5.1 The mechanical properties are specified in Table 5.1.

Table 5.1: Mechanical properties

<table>
<tr><th rowspan="3">Steel Grade</th><th colspan="2" rowspan="2">Yield strength (N/mm^2) min. (1)</th><th rowspan="3">Tensile strength R_m(N/mm^2)</th><th rowspan="3">Elong. A_s (%) min</th><th colspan="2" rowspan="2">Average impact energy KVL (J) at</th><th colspan="4">Technological tests</th></tr>
<tr><th rowspan="2">C (2)</th><th colspan="3">Di/D (3)</th></tr>
<tr><th>$R_{p0.2}$</th><th>R_{p1}</th><th>-196^{0}C</th><th>-20^{0}C</th><th>≤0.6</th><th>0.6<Di/D≤0.8</th><th>>0.8</th></tr>
<tr><td>304L</td><td>175</td><td>205</td><td>490-690</td><td>30</td><td>41</td><td></td><td></td><td rowspan="6">9</td><td rowspan="6">15</td><td rowspan="6">17</td></tr>
<tr><td>304</td><td>195</td><td>235</td><td>490-690</td><td>30</td><td>41</td><td></td><td></td></tr>
<tr><td>316L</td><td>185</td><td>215</td><td>490-690</td><td>30</td><td>41</td><td></td><td></td></tr>
<tr><td>316</td><td>205</td><td>245</td><td>490-690</td><td>30</td><td>41</td><td></td><td>0.09</td></tr>
<tr><td>321</td><td>195</td><td>235</td><td>510-710</td><td>30</td><td>41</td><td></td><td></td></tr>
<tr><td>347</td><td>205</td><td>245</td><td>510-710</td><td></td><td>41</td><td></td><td></td></tr>
<tr><td>UNS 31803</td><td>450</td><td></td><td>620</td><td>25</td><td></td><td>27</td><td></td><td></td><td></td><td></td></tr>
</table>

(1) Conventional proof stress; the 0.2% proof stress values are given for information and, unless otherwise agreed, are not required to be verified during the test.

(2) Constant C for flattening test.

(3) Expanding or flanging test; increase of outside diameter D, in %, as a function of Di/D.

6 Mechanical and technological tests

6.1 Unless they are required to be tested on each length, pipes are to be presented in batches, as specified in Sec. 1; Table 9.1.

Two pipes are to be selected from each batch for the required tests, as follows:

a) seamless pipes:

- one tensile test, longitudinal direction
- one flattening test or one bend test with mandrel diameter of 3 t
- 3 Charpy V-notch impact tests, longitudinal direction
- one expansion or flanging test, when required

b) welded pipes:

- one tensile test on base metal, longitudinal direction
- one tensile test transverse to the weld for pipes with D ≥300 mm
- two flattening or two bend tests transverse to the weld with mandrel diameter of 3 t
- 3 Charpy V-notch impact tests, longitudinal direction, when required
- one expansion or flanging test when required.

When required, one tensile test at elevated temperature is to be performed on one sample per cast.

Unless otherwise specified for individual cases, the impact test of austenitic stainless steel is required only for service temperature less than -105°C.

7 Corrosion tests

7.1 For materials used for piping systems for chemicals, the corrosion tests, ASTM A262 Practice E or ASTM A262 Practice C (Nitric acid test), as appropriate, may be required to be carried out on two pipes per batch.

Tests in accordance with other recognized standards are accepted, subject to the agreement of the Society.

Section7 Fittings

1 Application

1.1 The requirements of this Section apply 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 and relevant properties

2.1 Fittings fabricated from pipes are to meet the requirements of Sub-sections of this section, depending on the applications, with respect to manufacture, chemical composition and mechanical properties. Fittings may be hot or cold formed from sections of pipes.

Fittings fabricated from plates are to meet the requirements of the Sections of Ch 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.

2.2 Unless otherwise required, the material used for the fabrication of the fittings is to be covered by a works' certificate (W).

3 Condition of supply

3.1 All fittings are to be in the heat treated or hot working condition specified in the various Sections for the corresponding material.

Fittings in ferritic steel manufactured by hot forming may be delivered in the normalised forming condition in lieu of normalising, 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.

A proposal to deliver fittings in the cold formed condition may be considered by the Society; to this end, the Manufacturer is to submit detailed information relevant to forming procedure, mechanical properties after forming and destination of the products.

The heat treatment procedure of welded fittings is to be defined during the approval tests.

4 Mechanical properties

4.1 The mechanical properties of the finished fittings are to comply with the values specified for the starting materials (plate or pipe).

5 Mechanical and technological tests

5.1 The fittings are to be presented for testing in batches homogeneous for cast and in the number indicated in Table 1.1.9.

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 specified in Sections 2 to 6 depending on the application.

The tensile tests are to be performed on the hardest and softest fittings.

6 Non-destructive examination

6.1 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 higher than 75 mm, at the Surveyor's discretion.

7 Marking and certification

7.1 The requirements specified in Section 1 relevant to marking and certification are to be complied with, as appropriate.

Chapter 7 Iron Castings

Section 1 General Requirements

1 Scope

1.1 This Chapter gives the requirements for both grey and spheroidal or nodular graphite iron castings intended for ship and machinery construction.

1.2 All important iron castings, as defined in the relevant parts of the Rules dealing with design and construction, are to be manufactured and tested in accordance with the rules requirements and the requirements given in the following paragraphs.

1.3 As an alternative to 1.2, castings which comply with National or Proprietary specifications may be accepted, provided that such specifications give reasonable equivalence to these requirements or otherwise are specially approved or required by ACS.

1.4 Where small castings are produced in large quantities, the manufacturer may adopt alternative procedure for testing and inspection, subject to the approval of ACS.

1.5 These requirements are applicable only to castings where the design and acceptance tests are related to mechanical properties at ambient temperature. For other applications additional requirements may be necessary, especially when the castings are intended for service at low or elevated temperatures.

2 Manufacture

2.1 All castings, as designated in 1.2, are to be manufactured at foundries approved by ACS.

2.2 Suitable mechanical methods are to be employed for the removal of surplus material from the castings. Thermal cutting processes are not acceptable, except as a preliminary operation to the 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 could 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 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.

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 be required to be given a suitable tempering or stress relieving heat treatment. This is to be carried out after any refining heat treatment and before machining. The special qualities with 350 [N/mm^2] and 400 [N/mm^2] nominal tensile strength and impact test are to undergo ferritizing heat treatment.

5.3 Where it is proposed to locally harden the surface of castings, full details of the proposed procedure and specifications are to be submitted for approval by ACS.

6 Mechanical tests

6.1 Separately cast test samples are to be used unless otherwise agreed between the manufacturer and the purchaser. The test samples are generally to be one of the standard types detailed in Fig.6.1, Fig.6.2 and Fig.6.3 with a thickness of 25 [mm]. Test samples of dimensions, other than as detailed in Fig.6.1 to Fig.6.3 may, however, be specially required for some components. For grey cast iron the test samples are to be in the form of cylindrical bars of 30 [mm] diameter and of suitable length. When two or more test samples are cast simultaneously in a single mould, the bars are to be at least 50 [mm] apart as indicated in Fig.6.4.

6.2 Integrally cast samples may be used when a casting is more than 20 [mm] thick and its mass exceeds 200 Kgs subject to agreement between the manufacturer and the purchaser.

The type and location of the test sample are to be selected to provide approximately the same cooling conditions as for the casting it represents.

6.3 At least one test sample is to be provided for each casting or batch of castings. A batch consists of castings poured from a single ladle of metal provided they are all of similar type and dimensions. A batch should not normally exceed two tonnes of fettled castings and a single casting will constitute a batch if its mass is two tonnes or more.

6.4 For continuous melting of same grade of cast iron in large tonnages the mass of the batch may be increased to the output of two hours of pouring. 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.

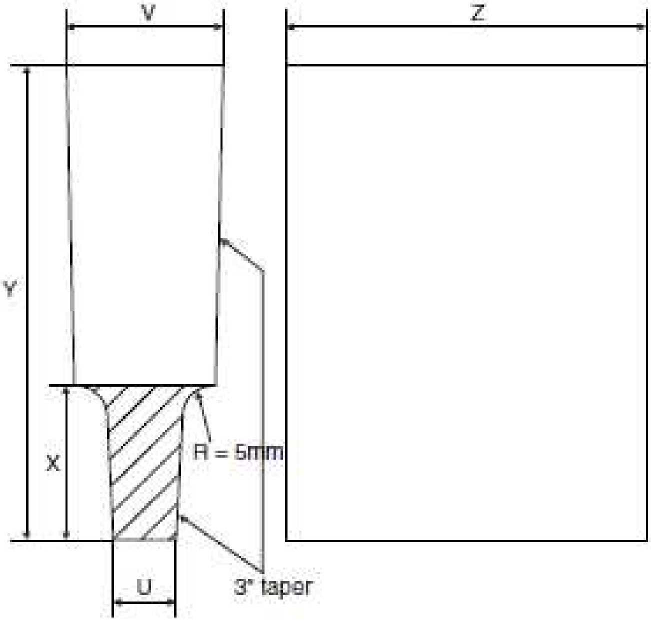
6.5 For large castings where more than one ladle of treated metal is used, additional test samples are to be provided so as to be representative of each ladle used.

6.6 All test samples are to be suitably marked to identify them with the castings which they represent.

6.7 Where castings are supplied in the heat treated condition, the test samples are to be heat treated together with the castings which they represent.

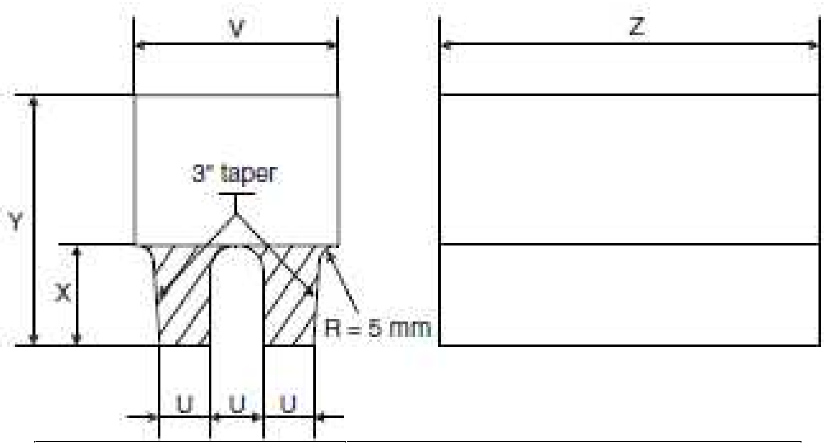
6.8 The test samples are to be cast in moulds made from the same type of material as used for the castings and are not to be stripped from the moulds until the metal temperature is below 500°C.

6.9 One tensile test specimen is to prepared from each test sample. The dimensions of the test specimens and the testing procedures used are to be in accordance with Ch.2.



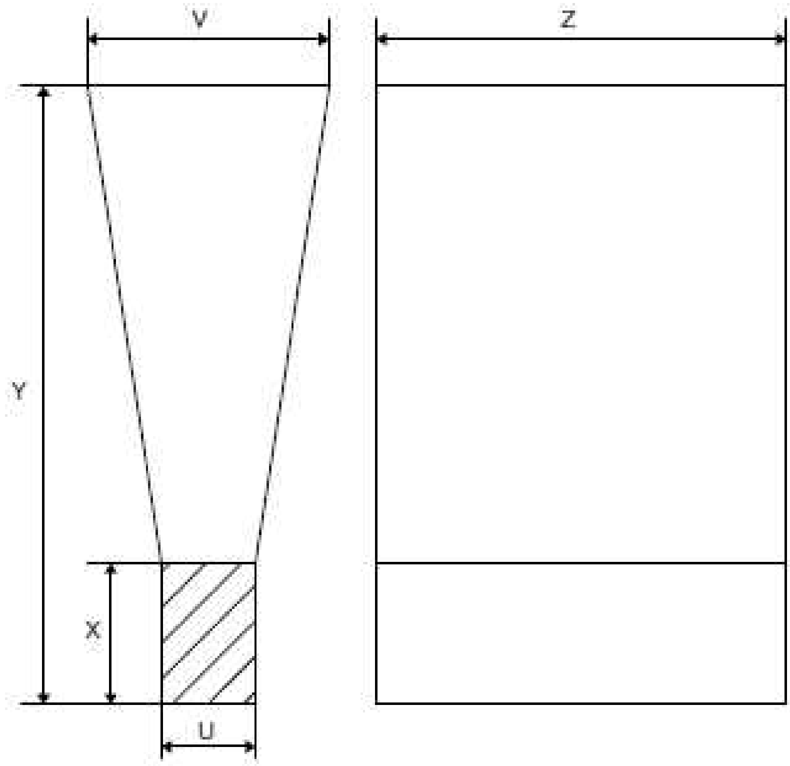
Dimensions	Standard sample (mm)	Alternative sample when specially required (mm)		
U	25	12	50	75
V	55	40	90	125
X	40	30	60	65
Y	140	80	150	185
Z	To suit testing machine			

Fig. 6.1: Standard test specimen



Dimensions	Standard sample (mm)
U	25
V	90
X	40
Y	100
Z	To suit testing machine

Fig.6.2: Standard test specimen



Dimensions	Standard sample (mm)	Alternative sample when specially required (mm)		
U	25	12	50	75
V	55	40	100	152
X	40	25	50	65
Y	140	135	150	175
Z	To suit testing machine			
Thickness of mould surrounding test sample	40 min	40 min	80 min	80 min

Fig.6.3: Standard test specimen

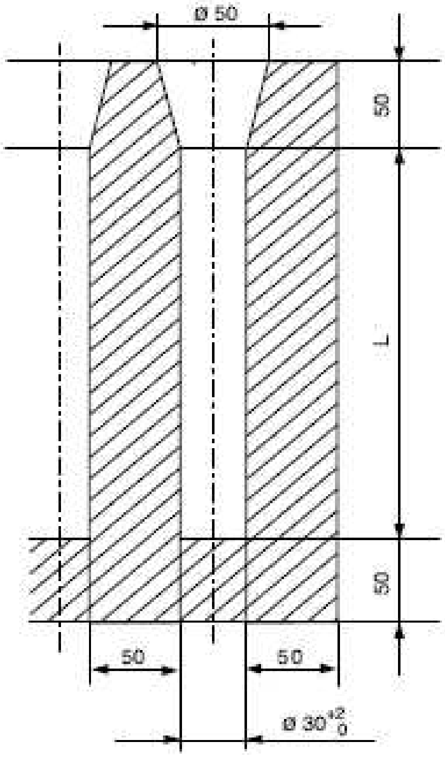


Fig. 6.4: Test sample for grey cast iron (Dimensions in millimeter)

7 Mechanical properties

7.1 For grey iron castings, only the tensile strength is to be determined and the results obtained are to comply with the minimum value specified for the castings being supplied. The specified minimum tensile strength is to be not less than 200 [N/mm^2] and not more than 350 [N/mm^2]. The fractured surfaces of all tensile test specimens are to be granular and grey in appearance.

7.2 For spheroidal or nodular graphite iron castings the tensile strength and elongation are to be determined. The results of all tests are to comply with the requirements of Table 7.1, but subject to any additional requirements of the relevant construction rules. Typical ranges of hardness values are also given in Table 7.1and are intended for information purposes.

7.3 Retest requirements for tensile tests are to be in accordance with 1.10 of Chapter 1.

Table 7.1: Mechanical properties for acceptance purposes (spheroidal or nodular graphite iron)

Specified minimum tensile Strength R_m(N/mm^2)		Yield strength $R_{p0,2}$ (N/mm^2) min.	Elongation on 5 d (%)	Typical Brinell hardness values	Impact energy		Typical structure of matrix
					Test temp(^{0}C)	KV(J)min(2)	
Ordinary Qualities	370	230	17	120-180	-	-	Ferrite
	400	250	12	140-200	-	-	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 or Tempered structure
Special Qualities	350	220	22 (1)	110-170	+20	17 (14)	Ferrite
	400	250	18 (1)	140-200	+20	14 (11)	Ferrite

(1) In the case of integrally cast samples, the elongation may be 2 percentage points less.

(2) Average value measured on 3 Charpy V-notch specimens. One result may be below the average value but not lower than the minimum value shown in brackets

Note 1: For intermediate values of specified minimum tensile strength, the minimum values for 0.2% proof and elongation may be obtained by interpolation.

8 Visual and non-destructive examination

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 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 Cast crankshafts are to be subjected to a magnetic particle inspection. Crack like indications are not permitted.

9 Metallographic examination

9.1 For spheroidal or nodular graphite iron castings, 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 arrangement for the provision of the samples may be adopted provided that they are taken from the ladle towards the end of the casting period.

9.2 Examination of the samples is to show that at least 90 percent of the graphite is in a dispersed spheroidal or nodular form. Details of the typical matrix structure 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 may 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 castings.

10.3 Repairs by welding are generally not permitted, but may be considered in special circumstances. In such cases, full details of the proposed repair procedure are to be submitted for approval prior to commencement of the proposed rectification.

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 with the following particulars:-

a) Grade of cast iron;

b) Identification number, or other marking which will enable the full history of the casting to be traced;

c) Manufacturer's name or trade mark;

d) AC and the abbreviated name of the local office of ACS;

e) Personal stamp of the Surveyor responsible for inspection;

f) Where applicable, test pressure;

g) Date of final inspection.

11.3 Where small castings are manufactured in large numbers, modified arrangements for identification may be specially agreed with ACS.

12 Certification

12.1 The manufacturer is to provide the Surveyor with a written statement giving the following particulars for each casting or batch of castings which has been accepted:-

a) Purchaser's name and order no;

b) Description of castings and quality of cast iron;

c) Identification number;

d) Results of mechanical tests;

e) Where applicable, details of heat treatment;

f) Where specially required, the chemical analysis of the ladle sample;

g) Where applicable, test pressure.

Chapter 8 Copper Alloys

Section 1 General Requirements

1 Scope

1.1 The Rules in this Chapter apply to copper alloys used in castings for valves and fittings, propeller castings and tubes.

1.2 When required by the relevant parts of the Rules, dealing with design and construction, tubes and castings are to be manufactured and tested in accordance with the appropriate requirements of Ch.1 and 2 and the requirements of this Chapter.

1.3 Alternatively, tubes and castings which comply with National or proprietary specifications may be accepted provided these specifications give reasonable equivalence to the requirements of this Chapter and provided that survey is carried out in accordance with the requirements of Ch.1.

1.4 Where it is proposed to use an alloy which is not specified in this Chapter, details of chemical composition, heat treatment and mechanical properties are to be submitted for approval.

Section 2 Castings for Valves and Fittings

1 Scope

1.1 Following requirements make provision for copper alloy castings for valves, liner bushes and other fittings intended for use in ship and machinery construction.

2 Manufacture

2.1 Approval of Works, as required by Ch.1, for the manufacture of castings, covered by this Section, is not required.

3 Quality of castings

3.1 All castings are to be free from surface or internal defects, which could be prejudicial to their proper application in service.

4 Chemical composition

4.1 The chemical composition is to comply with the appropriate requirements of Table 4.1.

4.2 Where a cast is wholly prepared from ingots for which an analysis is already available, and provided that no significant alloy additions are made during melting, the ingot maker's certified analysis may be accepted subject to occasional check tests as requested by the Surveyors.

Table 4.1: Chemical composition

Designation	Chemical composition %								
	Cu	Sn	Zn	Pb	Ni	Mn	P	Fe	Al
90/10 Cu-Sn Phosphor-bronze	Remainder	9.0-11.0	0.5max.	0.75 max.	0.5max.	-	0.50 max.	-	-
85/5/10 leaded bronze	Remainder	4.0-6.0	2.0 max	9.0-11.0	2.0 max	-	0.10 max.	-	-
88/10/2 Gunmetal	Remainder	8.5-11.0	1.0-3.0	1.5 max	1.0 max	-	-	-	-
87/7/3/3 Leaded Gunmetal	Remainder	6.0-8.0	1.5-3.0	2.5-3.5	2.0 max	-	-	-	-
85/5/5/5 leaded Gunmetal	Remainder	4.0-6.0	4.0-6.0	4.0-6.0	2.0 max	-	-	-	-
70/30 Cu-Ni-Fe	Remainder	-			29.0-32.0	0.5-1.50	-	0.4-1.0	-
90/10 Cu-Ni-Fe	Remainder	-			9.0-11.0	0.5-1.0	-	1.0-1.8	-
Ni-Al-bronze	Remainder	0.10-max.	0.10-max.	0.03-max.	3.0-6.0	0.5-4.0	-	2.0-6.0	7.0-11.0

5 Heat treatment

5.1 At the option of the manufacturer castings may be supplied in the 'as cast' or heat treated condition.

6 Mechanical tests

6.1 The test material may be separately cast as a keel block sample in accordance with Sec. 3; Fig.6.1 or as otherwise agreed with the Surveyor. For liners and bushes, the test material may be cut from the ends of the casting.

6.2 Where castings are supplied in a heat treated condition, the test samples are to be similarly heat treated prior to the preparation of the tensile specimens.

6.3 The results of all tests are to comply with the appropriate requirements given in Table 6.1.

Table 6.1: Mechanical properties for acceptance purposes

Designation	0.2% proof stress [n/mm^2] min. (see Note)	Tensile Strength [N/mm^2] min.	Elongation on 5.65√S^0% min.
90/10 Cu-Sn phosphor-bronze	120	250	15
85/5/10 Leaded bronze	100	200	16
88/10/2 Gunmetal	130	270	13
87/7/3/3 Leaded Gunmetal	130	250	16
85/5/5/5 Leaded Gunmetal	100	200	16
70/30 Cu-Ni-Fe	220	420	20
90/10 Cu-Ni-Fe	160	320	20
Ni-Aluminium bronze	240	590	16

Note: The 0.2% proof stress values are given for information purposes only and, unless otherwise agreed, are not required to be verified by test.

7 Visual examination

7.1 All castings must be supplied in a clean fettled condition.

7.2 Before acceptance, all castings are to be presented for visual examination by the Surveyor. This is to include the examination of internal surfaces where applicable.

7.3 The accuracy and verification of dimensions are the responsibility of the manufacturer, unless otherwise agreed.

8 Pressure testing

8.1 Where required by the relevant construction Rules, castings are to be pressure tested before final acceptance. Unless otherwise agreed, these tests are to be carried out in the presence of the Surveyors and are to be to their satisfaction.

9 Rectification of defective castings

9.1 Minor surface defects may be removed by grinding provided that the dimensional tolerances are not exceeded.

9.2 Proposal to repair a defective casting by welding are to be submitted to the Surveyor for approval before this work is commenced. Such proposals are to include details of the extent and positions of all defects. The Surveyor is to satisfy himself the number and size of the defects are such that castings can be efficiently repaired.

9.3 A statement and/or sketch detailing the extent and position of all weld repairs is to be prepared by the manufacturer as permanent record.

9.4 Weld repairs to liners in copper alloys containing more than 0.5 per cent lead are not permitted.

10 Identification

10.1 Before acceptance, all castings which have been tested and inspected with satisfactory results are to be clearly marked with the following details:

a) Identification number, cast number or other markings which will enable the full history of the casting to be traced;

b) AC and the abbreviated name of the ACS local office;

c) Personal stamp of the Surveyor responsible for inspection;

d) Test pressure, where applicable;

e) Date of final inspection.

10.2 Where small castings are manufactured in large numbers, modified arrangements for identification may be specially agreed with the Surveyor.

11 Certification

11.1 The manufacturer is to provide the Surveyor with a written statement giving the following particulars for each casting or batch of castings which has been accepted:-

a) Purchaser's name and order no.;

b) Description of castings and alloy type;

c) Identification number

d) Type of heat treatment, where applicable;

e) Ingot or cast analysis.

11.2 In addition to 11.1 the manufacturer is to provide a signed statement and/or sketch detailing the extent and position of all weld repairs made to each casting.

Section 3 Castings for Propellers

1 Scope

1.1 Following requirements make provision for propeller and propeller blade castings in copper alloys.

2 Manufacture

2.1 All castings are to be manufactured at foundries approved by ACS in accordance with the appropriate requirements of Ch.1.

2.2 An application for approval is to be made to ACS supported by following information:

- Specification of the propeller materials;
- Manufacturing procedures;
- Repair methods;
- NDT inspection procedures;
- Description of the foundry facilities including the maximum capacity of the ladles.

2.3 The extent of tests required for approval is to be agreed upon with ACS. The approval is based on verifying that the chemical and physical properties of the cast test coupons of the propeller material in question comply with the rules.

2.4 The foundry is to have an adequately equipped approved laboratory manned by experienced personnel for carrying out chemical analysis, mechanical testing and microstructure examination of the representative cast test coupons. Provision is also to be made for NDT inspection, if these test facilities are not available at the foundry then details are to be submitted of an approved local laboratory which will provide such services.

3 Quality of castings

3.1 All castings must have a workmanlike finish and are to be free from surface or internal defects which would be prejudicial to their proper application in service. Minor casting defects which may still be visible after machining such as small sand and slag inclusions, cold shuts and scabs are to be trimmed off by the manufacturer.

4 Chemical composition

4.1 The chemical composition of samples from each cast is to comply with the requirements given in Table 4.1.

4.2 The manufacturer is to maintain permanent records of all chemical analysis, which are to be made available to the Surveyor so that he can satisfy himself that the chemical composition of each casting is within the specified limits.

4.3 When a cast is wholly prepared from ingots for which an analysis is already available, and provided that no significant alloy additions are made during melting, the ingot maker's certified analysis can be accepted subject to occasional checks as required by the Surveyor.

4.4 It is recommended for alloys Grade Cu 1 and Cu 2 that the zinc equivalent is not to exceed 45 percent and is to be calculated using the following formula:

$$\text{Zinc Equivalent} = 100 - \frac{100 \times \%Cu}{100+A}$$

Where A is the algebraic sum of the following:

1 x % Sn

5 x % Al

- 0.5 x % Mn

- 0.1 x % Fe

- 2.3 x % Ni.

Table 4.1: Chemical composition of propeller and propeller blade castings

Alloy designation	Chemical composition of ladle samples %							
	Cu	Sn	Zn	Pb	Ni	Fe	Al	Mn
Grade Cu1 Manganese Bronze (high strength brass)	52 - 62	0.1-1.5 max.	35 - 40	0.5 max.	1.0 max.	0.5-2.5	0.5-3.0	0.5-4.0
Grade Cu2 Ni-Manganese Bronze (high strength brass)	50 - 57	0.15 man.	33 - 38	0.5 max.	3.0-8.0	0.5-2.5	0.5-2.0	1.0-4.0
Grade Cu3 Ni-Aluminium Bronze	77 - 82	0.1 max.	1.0 max.	0.03max.	3.0-6.0	2.0-6.0	7.0-11.0	0.5-4.0
Grade Cu4 Mn-Aluminium Bronze	70 - 80	1.0 max.	6.0 max.	0.05max.	1.5-3.0	2.0-5.0	6.5-9.0	8.0-20.0

5 Heat treatment

5.1 At the option of the manufacturer, castings may be supplied in the 'as cast' or heat treated condition.

6 Mechanical tests

6.1 Test samples are to be provided from each cast used for the manufacture of propeller or propeller blade castings.

6.2 The test samples are to be of the keel block type, generally in accordance with the dimensions given in Fig. 6.1 or as agreed with the Surveyor and are to be cast in moulds made from the same type of material as used for castings.

6.3 Where castings are supplied in the heat treated condition, the test samples are to be heat treated together with the castings which they represent.

6.4 The results of all tests are to comply with the appropriate requirements given in Table 6.1.

Note: These properties are a measure of themechanical quality of the metal in each heat and they are generally not representative of the mechanical properties of the propeller casting itself which may be upto 30% lower than that of a separately cast test coupon. For integrally cast test specimens the requirements are to be specially agreed with ACS.

Table 6.1: Mechanical properties for acceptance purposes: propeller and propeller blade castings

Alloy type	Proof stress $R_{p0,2}$ (N.mm^2) min.	Tensile strength R_m (N.mm^2) min.	Elongation A5 (%) Min.
Cu 1	175	440	20
Cu 2	175	440	20
Cu 3	245	590	16
Cu 4	275	630	18

Note: The mechanical properties of other alloys meeting the above limiting values are to be in accordance with a specification approved by ACS.

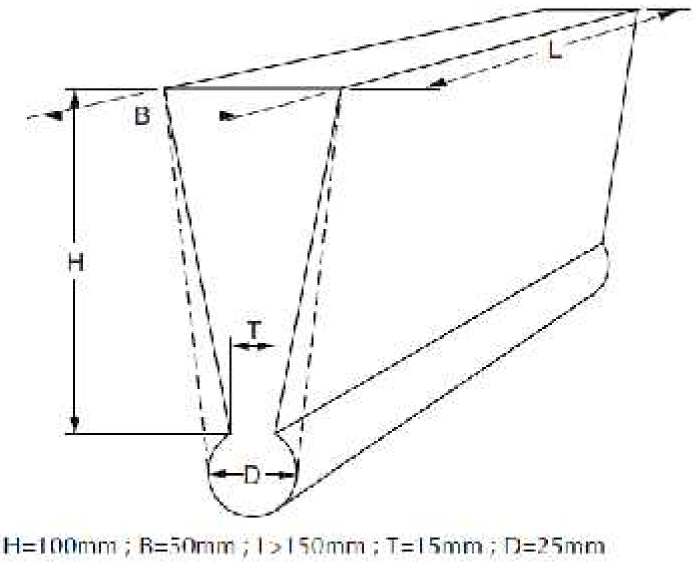


Fig. 6.1 Keel Block test sample

7 Surface quality and dimensions

7.1 All castings are to be fettled, cleaned and adequately prepared for inspection.

7.2 Propeller castings are to be inspected at all stages of manufacture and the whole surface including the bore is to be subjected to a comprehensive visual examination in the finished condition by the Surveyor. The Surveyor may require areas to be etched (e.g. by iron chloride) for purpose of investigating weld repairs.

7.3 The dimensions are to be checked by the manufacturer and the report on the dimensional inspection is to be given to the Surveyor, who may require checks to be made in his presence.

8 Non-destructive examination

8.1 Dye penetrant inspection

a) The severity zones "A" are to be subjected to a dye penetrant inspection in the presence of the Surveyor. For the inspection and acceptance standard, see 10. In zones "B" and "C" the dye penetrant inspection is to be performed by the manufacturer and may be witnessed by the Surveyor upon his request. See 9 for definitions of severity zones.

b) If repairs have been made either by grinding or by welding the repaired areas are additionally to be subjected to the dye penetrant inspection independent of their location and/or severity zone.

8.2 Radiographic and ultrasonic examination

Where serious doubts exist that the castings are not free from internal defects further nondestructive examination is to be carried out upon request of the Surveyor, e.g. radiographic and/or ultrasonic testing. Acceptance criteria are to be agreed between the manufacturer and ACS in accordance with a recognized standard.

Note:

The absorption of the X-rays and gamma-rays is stronger in copper-based alloys than in steel.

For propeller bronzes, 300 kV X-rays can normally be used upto 50 [mm] and Co60 gamma-rays up to 160 [mm] thickness. Due to the limited thicknesses that can be radiographed as well as for other practical reasons radiography is generally not a realistic method for checking of the thickest parts of large propellers.

As a general rule, ultrasonic testing of Cu1 and Cu2 is not feasible due to the high damping capacity of these materials. For Cu3 and Cu4, ultrasonic inspection of subsurface defects is possible.

8.3 Documentation of defects

All defects requiring welding repair on the castings are to be documented preferably on drawings or special sketches showing their dimensions and locations. Furthermore, the inspection procedure is to be documented. The documentation is to be presented to the Surveyor prior to any repair welding.

9 Definition of skew, severity zones

9.1 Skew: The skew of a propeller is defined as follows:

The maximum skew angle of a propeller blade is defined as the angle, in projected view of the blade, between a line drawn through the blade tip and the shaft centreline and a second line through the shaft centre line which acts as a tangent to the locus of the mid-points of the helical blade section. See Fig. 9.1.

High skew propellers have a skew angle greater than 25°, low skew propellers a skew angle of up to 25°.

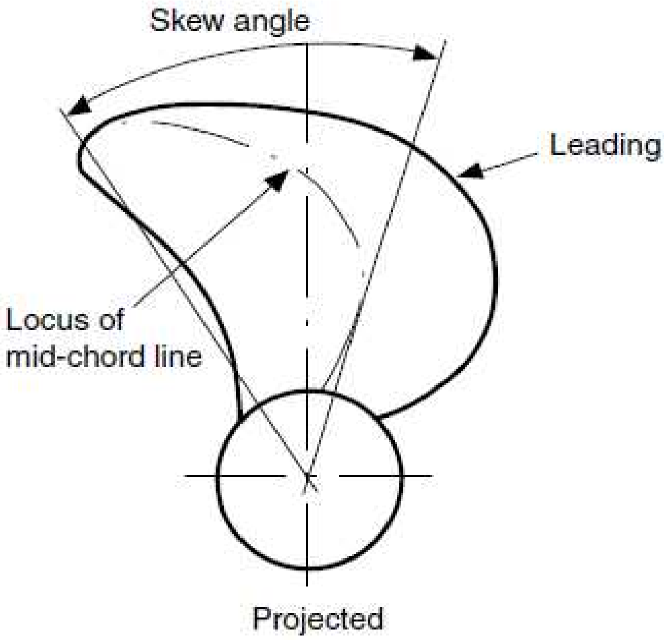


Fig. 9.1 Definition of skew angle

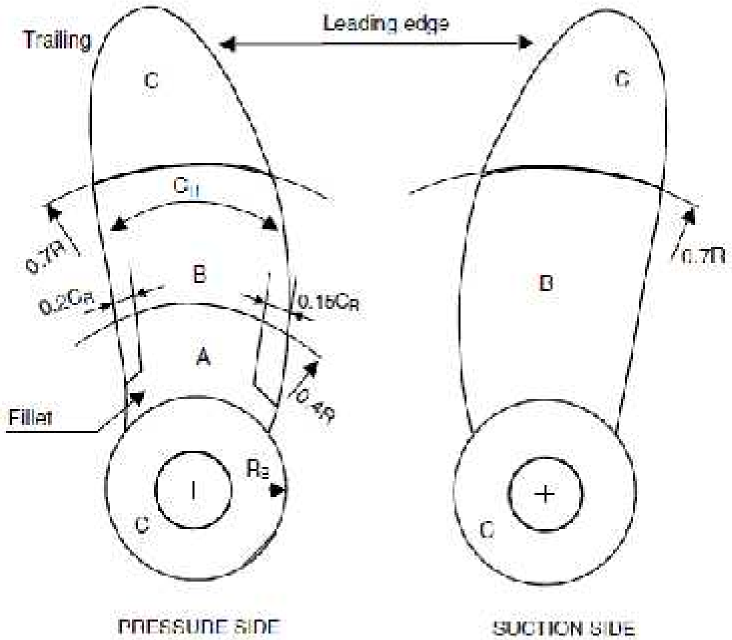


Fig. 9.2 Severity zones for integrally cast low skew propellers
(R= Propeller radius, CR=Cord length at any radius R)

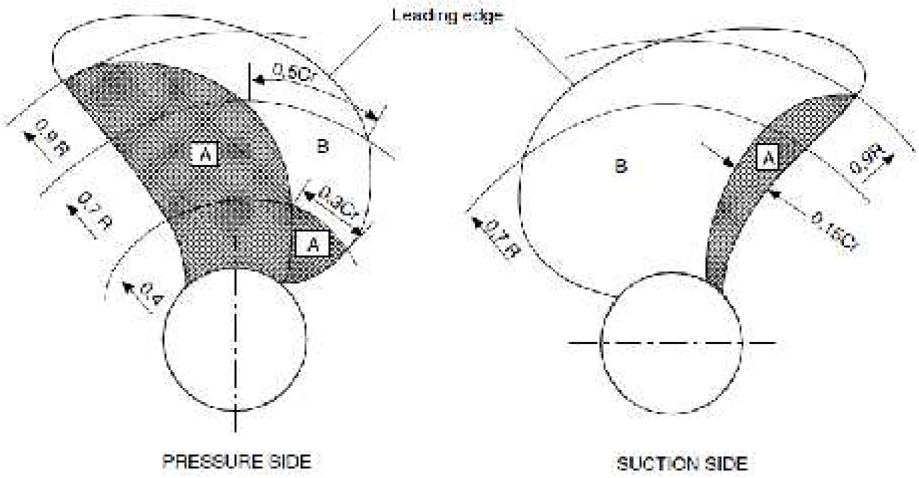


Fig. 9.3 Severity zones in blades with skew angles greater than 25o

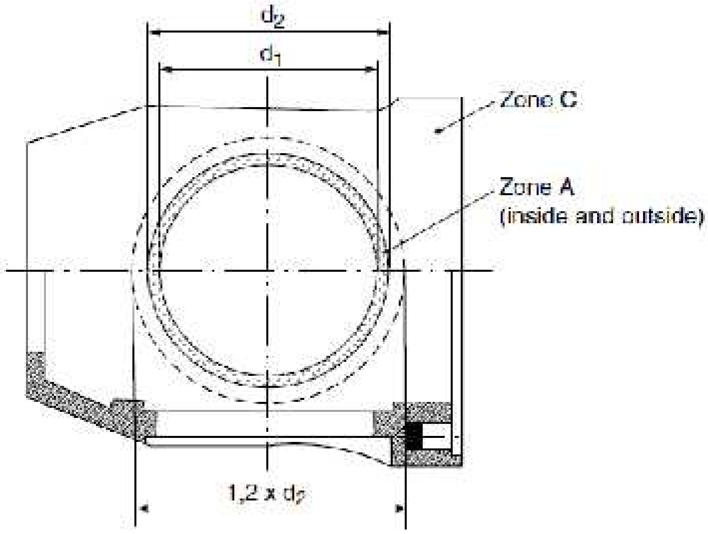


Fig. 9.4 Severity zones for controllable pitch propeller boss

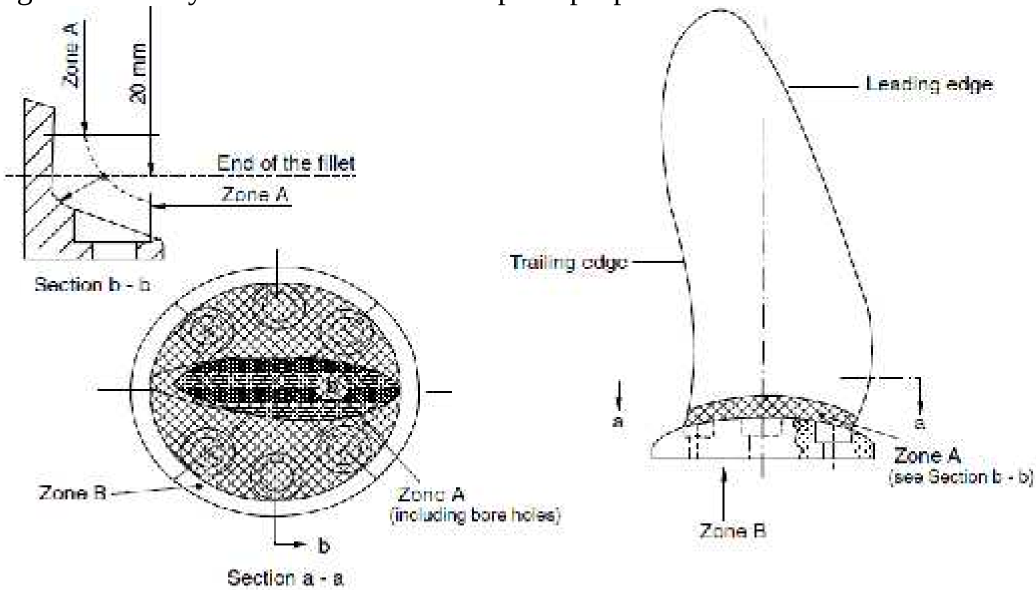


Fig. 9.5 Severity zones for controllable and built up propellers

Note: The remaining surfaces of the propeller blades are to be divided into severity zones as given for solid propellers (Figs. 9.2 and 9.3)

9.2 Severity zones

In order to relate the degree of examination to the criticality of defects in propeller blades and to help reduce the risk of failure by fatigue cracking after repair, propeller blades are divided into the three zones designated A, B and C.

Zone A is the region carrying the highest operating stresses and which, therefore, requires the highest degree of inspection. Generally, the blade thicknesses are greatest in this area giving the greatest degree of restraint in repair welds and this in turn leads to the highest residual stresses in and around any repair welds. High residual tensile stresses frequently lead to fatigue cracking during subsequent service so that relief of these stresses by heat treatment is essential for any welds made in this zone. Welding is generally not permitted in Zone A and will only be allowed after special consideration by the Classification Society. Every effort should be made to rectify a propeller which is either defective or damaged in this area without recourse to welding even to the extent of reducing the scantlings, if this is acceptable. If a repair using welding is agreed, post-weld stress relief heat treatment is mandatory.

Zone B is a region where the operation stresses may be high. Welding should preferably be avoided but generally is allowed subject to prior approval from the Classification Society. Complete details of the defect/damage and the intended repair procedure are to be submitted for each instance in order to obtain such approval.

Zone C is a region in which the operation stresses are low and where the blade thicknesses are relatively small so that repair welding is safer and, if made in accordance with an approved procedure is freely permitted.

9.2.1 Low-skew propellers

a) Zone A is in the area on the pressure side of the blade, from and including the fillet to 0.4R and bounded on either side by lines at a distance 0.15 times the chord length Cr from the leading edge and 0.2 times Cr from the trailing edge, respectively. See Fig. 9.2.

   Where the hub radius (Rb) exceeds 0.27R, the other boundary of Zone A is to be increased to 1.5Rb. Zone A also includes the parts of the separate cast propeller hub which lie in the area of the windows as described in Fig. 9.4 and the flange and fillet area of controllable pitch and built-up propeller blades as described in Fig. 9.5.

b) Zone B is on the pressure side the remaining area upto 0.7R and on the suction side the area from the fillet to 0.7R. See Fig. 9.1.

c) Zone C is the area outside 0.7R on both sides of the blade. It also includes the surface of the hub of a monobloc propeller and all the surfaces of the hub of controllable pitch propeller other than those designated Zone A above.

9.2.2 High-skew propellers

a) 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 0.9R and at passing through the mid-point of the blade chord at 0.7R and a point situated at 0.3 of the chord length from the leading edge at 0.4R. It also includes an area along the trailing edge on the suction side of the blade from the root to 0.9R and with its inner boundary at 0.15 of the chord lengths from the trailing edge.

b) Zone B constitutes the whole of the remaining blade surfaces. c) Zone A and B are illustrated in Fig. 9.3.

10 Acceptance criteria for dye penetrant examination

10.1 Inspection procedure

The dye penetrant inspection is to be carried out in accordance with a standard or specification agreed with the Surveyor.

10.2 Definitions

Indication: In the dye penetrant inspection an indication is the presence of detectable bleed-out of the penetrant liquid from the material discontinuities appearing at least 10 minutes after the developer has been applied.

Shape of Indications: A distinction is made between circular, linear and aligned indications, See Fig. 10.1.

Reference area: The reference area is defined as an area of 100 [cm^2] which may be square or rectangular with the major dimension not exceeding 250 [mm].

Table 10.1: Allowable number and size of indications in a reference area of 100 [cm^2], depending on severity zones

Severity Zones	Max. total number of indications	Type of indication	Max. number of each type (1) (2)	Max. acceptable value for "*a*" or "*l*" of indications (mm)
A	7	Circular linear aligned	5 2 2	4 3 3
B	14	Circular Linear aligned	10 4 4	6 6 6
C	20	Circular Linear aligned	14 6 6	8 6 6

Notes:

1) Singular circular indications less than 2 [mm] for zone A and less than 3 [mm] for the other zones may be disregarded.

2) The total number of circular indications may be increased to the max. total number, or part thereof, represented by the absence of linear/aligned indications.

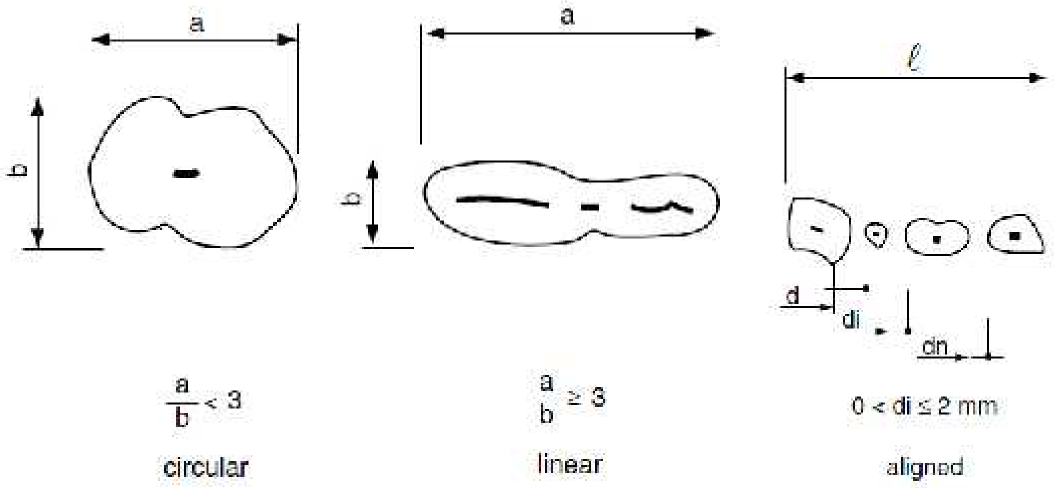


Fig. 10.1: Shape of Indicators

10.3 Acceptance standard

10.3.1 For the judgement, the surface to be inspected is to be divided into reference areas of 100 [cm^2] as given in the definitions, see para 10.2. The indications detected may, with respect to their size and number, not exceed the values given in the Table 10.1.

The area is to be taken in the most unfavorable location relative to the indication being evaluated.

10.3.2 Areas which are prepared for welding are, independent of their location, always to be assessed according to Zone A. The same applies to the welded areas after being finished machined and/or ground.

11 Metallographic examination

11.1 Samples for metallographic examination are to be prepared from propellers and propeller blade castings for Grades Cu1 and Cu2. These samples are to be representative of each cast, and may conveniently be taken from the tensile test specimen. The proportion of alpha-phase determined from the average of at least five counts is to be not less than 25 percent.

12 Rectification of defects

12.1 Indications exceeding the acceptance standard of Table 10.1, cracks, shrinkage cavities, sand, slag and other non-metallic inclusions, blow holes and other discontinuities which may impair the safe service of the propeller are defined as defects and must be repaired.

12.2 Repair procedures

a) In general the repairs are to be carried out by mechanical means, e.g. by grinding, chipping or milling. Welding may be applied subject to the agreement with the Surveyor.

b) 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 minimize cavitation corrosion.

c) Welding of areas less than 5 [cm^2] is to be avoided.

12.3 Repair of defects in zone A

a) In zone A, repair welding will generally not be allowed unless specially approved by ACS.

b) Grinding may be carried out to an extent which maintains the blade thickness of the approved drawing.

c) The possible repair of defects which are deeper than those referred to above will be specially considered by ACS.

12.4 Repair of defects in zone B

a) Defects that are not deeper than dB = (t/40) [mm] (t = minimum local rule thickness [mm]) or 2 [mm] (whichever is greater) below minimum local rule thickness should be removed by grinding.

b) Those defects that are deeper than allowable for removal by grinding may be repaired by welding.

12.5 Repair of defects in zone C

In zone C, repair welds are generally permitted.

13 Balancing

13.1 Static balancing is to be carried out on all propellers. Dynamic balancing is necessary for propellers running above 500 [rpm].

14 Repair welding

14.1 General requirements

14.1.1 Companies wishing to carry out welding work on propellers must have at their disposal the necessary workshops, lifting gear, welding equipment, preheating and where necessary, annealing facilities, testing devices as well as certified welders and expert welding supervisors to enable them to perform the work properly.

Proof is to be furnished to the Surveyor that these conditions are satisfied before welding work begins.

14.1.2 The company concerned is to prepare and submit to ACS a detailed welding specification covering the weld preparation, welding procedure, filler metals, preheating and post weld heat treatment and inspection procedures.

14.1.3 Before welding is started, Welding Procedure Qualification Tests are to be carried out and witnessed by the Surveyors. Each welder/operator is to demonstrate his ability to carry out the proposed welding using the same process, consumable and position which are to be used in actual repair.

14.2 Welding preparation

Defects to be repaired by welding are to be ground to sound material according to the requirements as given under 12. To ensure complete removal of the defects the ground areas are to be examined by dye penetrant methods in the presence of the Surveyor. The welding grooves are to be prepared in such a manner which will allow a good fusion of the groove bottom.

14.3 Welding repair procedure

14.3.1 Metal arc welding is recommended for all types of repair on bronze propellers.

For material thickness less than 30 [mm], gas welding may give a satisfactory weldment for Cu1 and Cu2 materials.

Arc welding with coated electrodes and gasshielded metal arc process (GMAW) are generally to be applied. Argon-shielded tungsten welding (GTAW) is to be used with care due to the higher specific heat input of this process.

Adequate pre-heating is to be carried out with care to avoid local overheating.

Recommended filler metals, pre-heating and stress relieving temperatures are listed in Table 14.1(a).

14.3.2 All propeller alloys are generally to be welded in down-hand (flat) position. Where this cannot be done, gas-shielded metal arc welding is to be carried out. The section to be welded is to be clean and dry.

Flux-coated electrodes are to be dried before welding according to the maker's instructions.

To minimize distortion and the risk of cracking, interpass temperatures are to be kept low especially in the case of Cu3 alloys.

Slag, undercuts and other defects are to be removed before depositing the next run.

Table 14.1(a): Recommended filler metals and heat treatments

Alloy type	Filler metal	Preheat Temp.^{0}C[min]	Interpass Temp.^{0}C [max]	Stress relief Temp.^{0}C	Hot straightening Temp.^{0}C
Cu 1	Al-bronze[1)] Mn-Bronze	150	300	350 – 500	500 – 800
Cu 2	Al-bronze Ni-Mn-Bronze	150	300	350 - 550	500 – 800
Cu 3	Al-bronze Ni-Al-Bronze[2)] Mn-Al-Bronze	50	250	450 – 500	700 – 900
Cu 4	Mn-Al-Bronze	100	300	450 - 600	700 - 850

Notes:

1) Ni-Al-bronze and Mn-Al-bronze are acceptable.

2) Stress relieving not required, if filler metal Ni-Al-bronze is used.

Table 14.1(b): Soaking times for stress relief heat treatment of copper alloy propellers

Stress relief Temperature (^{0}C)	Alloy Grade Cu 1 and Cu 2		Alloy Grade Cu 3 and Cu 4	
	Hours per 25 mm of thickness	Maximum recommended total hours	Hours per 25 mm of thickness	Maximum recommended total hours
350	5	15	-	-
400	1	5	-	-
450	1/2	2	5	15
500	1/4	1	1	5
550	1/4	1/2	1/2	2
600	-	-	1/4 (1)	1 (1)
650	-	-	1/4 (1)	1/2 (1)

Note 1) 550°C and 600°C only applicable for Cu4 alloys

14.3.3 All welding work is to be carried out preferably in the shop free from draughts and influence of the weather.

14.3.4 With the exception of alloy Cu3 (Ni-Albronze) all weld repairs are to be stress relief heat treated, in order to avoid stress corrosion cracking. However, stress relief heat treatment of alloy Cu3 propeller castings may be required after major repairs in zone B (and specially approved welding in Zone A) or if a welding consumable susceptible to stress corrosion cracking is used. In such cases the propeller is to be either stress relief heat treated in the temperature 450 to 500°C or annealed in the temperature range 650 - 800°C, depending on the extent of repair, see Table 14.1(a).

14.3.5 The soaking times for stress relief heat treatment of copper alloy propellers is to be in accordance with Table 14.1(b). The heating and cooling is to be carried out slowly under controlled conditions. The cooling rate after any stress relieving heat treatment shall not exceed 50°C/hr until the temperature of 200°C is reached.

15 Straightening

15.1 Application of load

For hot and cold straightening purposes, static loading only is to be used.

15.2 Hot straightening

Straightening of a bent propeller blade or a pitch modification should be carried out after heating the bent region and approximately 500 [mm] wide zones on either side of it to the suggested temperature range given in Table 14.1.(a).

The heating is to be slow and uniform and the concentrated flames such as oxy-acetylene and oxy-propane are not to be used. Sufficient time is be allowed for the temperature to become fairly uniform through the full thickness of the blade section. The temperature is to be maintained within the suggested range throughout the straightening operation. A thermocouple instrument or temperature indicating crayons are to be used for measuring the temperature.

15.3 Cold straightening

Cold straightening should be used for minor repairs of tips and edges only. Cold straightening on Cu1, Cu2 and Cu4 bronze is always to be followed by a stress relieving heat treatment, See Table 14.1(a).

16 Identification

16.1 Castings are to be clearly marked by the manufacturer in accordance with the requirements of Ch.1. The following details are to be marked on all the castings which have been accepted:

a) Heat number, casting number or other identification mark which will enable the full history of the item to be traced;

b) Alloy grade;

c) AC and the abbreviated name of the local ACS office;

d) Personal stamp of the Surveyor responsible for inspection;

e) Date of final inspection;

f) ACS certificate number;

g) Skew angle for high skew propellers;

h) Ice class symbol, where applicable.

17 Certification

17.1 The manufacturer is to provide the Surveyor with a written statement giving the following particulars for each casting:

a) Purchaser's name and order number;

b) Description of casting;

c) Alloy designation and/or trade name;

d) Identification number of casting;

e) Type of heat treatment.

18 Welding procedure and welder's qualification test

18.1 General

The qualification test is to be carried out with the same welding process, filler metal, preheating and stress-relieving treatment as those intended to be applied in the actual repair work.

18.2 Test sample

A test sample of minimum 30 [mm] thickness is to be welded in down-hand (flat) position. The required test specimens and their dimensions are shown in Fig.18.1.

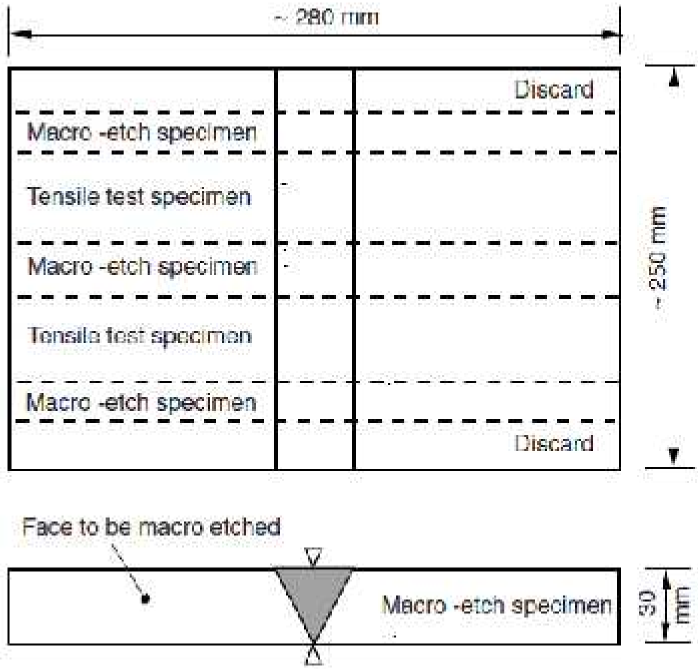


Fig. 18.1 Test specimen

18.3 Qualification testing

18.3.1 Non-destructive testing After completion, the weldment is to be 100% tested by a dye-penetrant method. No cracks are permitted.

18.3.2 Macro-etching

Three macro-etch samples are to be prepared (See Fig. 18.1). A suitable etchant for this purpose is:

5 g iron (III) chloride

30 ml hydrochloric acid (cone)

100 ml water.

Pores greater than 3 [mm] and cracks are not permitted.

18.3.3 Mechanical testing: Two tensile test specimens are to be prepared and the tensile strength requirements in Table 18.1, are to be met.

Alternatively tensile test specimens according to recognized standards may be used.

Table 18.1: Required tensile strength values

Alloy type	Tensile strength [N/mm^2] min
Cu 1	370
Cu 2	410
Cu 3	500
Cu 4	550

Section 4 Tubes

1 Scope

1.1 Following requirements make provision for copper and copper alloy tubes intended for use in heat exchangers, condensers and pressure piping systems.

1.2 Except for pipes for Class III pressure systems all pipes and tubes are to be manufactured and tested in accordance with the requirements of Ch.1 and 2 of this Part and the requirements of this Section.

1.3 Pipes and tubes which comply with national/international or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Section or are otherwise specifically approved for a specific application and provided that survey is carried out in accordance with Ch.1 of this Part.

1.4 At the discretion of the Surveyor, modified testing procedure may be adopted for small quantities of materials. In such cases, these may be accepted on the manufacturer's declared chemical composition and hardness tests or other evidence of satisfactory properties.

1.5 Pipes for Class III pressure systems are to be manufactured and tested in accordance with the requirements of an acceptable national/ international specification. The manufacturer's test certificate will be acceptable and is to be provided for each consignment of material.

2 Manufacture

2.1 Approval of Works, as required by Ch.1, for the manufacture of copper and copper alloy tubes is generally not required.

2.2 Unless otherwise agreed tubes shall be solid drawn.

3 Quality

3.1 Tubes are to have a workmanlike finish and are to be clean and free from such surface and internal defects as can be established by the specified tests.

3.2 The tubes are to be supplied in straight lengths, and the ends are to be cut clean and square with the axis of the tube.

3.3 The tolerance on wall thickness and diameter of pipes and tubes are to be in accordance with an acceptable national/ international standard.

4 Chemical composition

4.1 The chemical analysis is to comply with the requirements of Table 4.1. Residual elements are not to be present in amounts greater than specified in an acceptable national/international standard.

Table 4.1: Chemical composition of tubes1

Designation	Chemical composition %								
	Cu	Fe	Ni	Zn	As	Al	Mn	P	Pb
Phosphorus deoxidized non- arsenical copper	99.90[2)] Min	-	-	-	-	-	-	0.013-0.050	-
Phosphorus deoxidized arsenical copper	99.20[2)] Min	-	-	-	0.30-0.50	-	0.013-0.050	-	-
Al-brass	76.0-79.0	-	-	Remainder	0.02-0.06	1.8-2.3		-	-
Copper-nickel 90/10	Remainder	1.0-1.8	9.0-11.0	-	-	-	0.5-1.0	-	-
Copper-nickel 70/30	Remainder	0.4-1.0	30.0-32.0	-	-	-	0.5-1.5	-	-

Notes:

1) Table shows essential alloying elements only

2) Includes silver also.

5 Heat treatment

5.1 All tubes are to be supplied in the annealed condition. Aluminium brass tubes may additionally be required to be given a suitable stress relieving heat treatment when subjected to a cold straightening operation after annealing.

6 Mechanical tests

6.1 The tubes are to be presented in lots of 600 tubes or 900 Kg, whichever is greater. Each lot is to contain tubes of the same dimensions, material grade and in the same state of heat treatment. From each lot 2 tubes are to be selected for testing.

6.2 Following tests are to be carried out on each tube selected for testing in accordance with the requirements of Ch.2:

a) Tensile test;

b) Flattening test;

c) Drift Expanding test.

6.3 Flattening test is to be carried out until the interior surfaces of the tube meet.

6.4 For the drift-expanding test, the mandrel is to have an included angle of 45°.

6.5 The results of all mechanical tests are to comply with the requirements of Table 6.1.

Table 6.1: mechanical properties for acceptance purposes

Designation	0.2% proof stress [N/mm^2]	Tensile strength [N/mm^2] minimum	5.65√S0% minimum	Drift Expansion test % minimum
Phosphorus deoxidized non-arsenical copper	100	220	35	30
Phosphorus deoxidized arsenical copper	100	220	35	30
Al-brass	110	320	35	30
Copper-nickel 90/10	100	270	30	30
Copper-nickel 70/30	120	360	30	30

7 Visual examination

7.1 All pipes are to be presented for visual examination and verification of dimensions. The manufacturer is to provide adequate lighting conditions to enable an internal and external examination of the tubes to be carried out.

8 Stress cracking test

8.1 This test is applicable to Aluminium brass only. Mercurous Nitrate Test or alternatively at the express agreement between purchaser and manufacturer Ammonia Vapour Cracking Test are to be carried out on test specimen to prove that the tubes are free from internal stresses.

The tests are to be carried out in accordance with an acceptable national/international standard.

8.2 Should a specimen reveal cracks when tested, the manufacturing batch shall be rejected. The manufacturer shall be free to submit the batch to renewed heat treatment before presenting it for retesting.

9 Hydraulic test

9.1 All tubes are to be hydraulically tested by the manufacturer to the following pressure:

$$P=\frac{5\times t\times Rm}{D}$$

where,

P = Test pressure;

t = nominal wall thickness;

D = nominal outside diameter;

Rm = Tensile strength in accordance with Table 6.1.

Unless otherwise stated the pressure need not be greater than 7.0 [N/mm^2].

9.2 The test pressure is to be maintained for sufficient time to permit proof and inspection.

Unless otherwise agreed, the manufacturer's certificate of satisfactory hydraulic test will be accepted subject to 10 per cent of the tubes being retested in the presence of the Surveyor. If one of the tubes in a batch does not pass the test, it will be rejected, and all other tubes in the batch are to be retested.

10 Identification

10.1 Tubes are to be clearly marked by the manufacturer in accordance with the requirements of Ch.1, with at least the following details:

a)AC;

b) Manufacturer's name or trade mark;

c) Grade of material.

10.2 Identification is to be by rubber stamp or stencil. Hard stamping is not to be used.

11 Certification

11.1 The manufacturer is to provide the Surveyor with a written statement giving the following particulars for each lot of material accepted:-

a) Purchaser's name and Order no.;

b) Grade of material;

c) Description and dimensions;

d) Cast number and chemical composition;

e) Mechanical test results and results of stress cracking tests where applicable.

Chapter 9 Aluminum Alloys

Section 1 General Requirements

1 Scope

1.1 This Chapter specifies the requirements for wrought Aluminum alloys for structural applications, Aluminium alloy castings and Aluminum/steel transition joints intended for use in ship and machinery construction.

1.2 This Chapter is not applicable to Aluminum alloys for forgings and to the use of Aluminium alloys at low temperature for cryogenic applications. For these products suitable alloys which comply with recognized standards may be used.

1.3 These requirements are applicable to wrought Aluminum alloy products within a thickness range of 3 [mm] and 50 [mm] inclusive. The application of Aluminum alloys products outside this thickness range requires prior agreement of ACS.

1.4 The numerical designation (grade) of Aluminum alloys and the temper designation are based on those of the Aluminum Association. Temper conditions (delivery heat treatment) are as defined in EN 515 Or ANSI H35.1.

1.5 When required by the relevant Chapters of the Rules dealing with design and construction, structural Aluminum alloys, Aluminum alloy castings and Aluminum/steel transition joints are to be manufactured and tested in accordance with the appropriate requirements of Ch.1 and 2 and those detailed in this Chapter.

1.6 Consideration may be given to Aluminium alloys not specified in this chapter and to alternative temper conditions, complying with recognized national or international standards with specifications equivalent to the requirements of this chapter.

Section 2 Wrought Aluminum Alloys

1 Scope

1.1 This Section deals with wrought Aluminium alloys for structural applications including plates, sections, tubes, bars and rivet bars and rivets.

1.2 Wrought Aluminium alloys are to have a satisfactory resistance to corrosion in marine environment. Grades for welded structures are to be weldable, applying one of the welding methods approved by ACS.

1.3 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.

2 Manufacture

2.1 Aluminium alloys are to be manufactured at Works approved by ACS.

2.2 The alloys may be cast either in ingot moulds or by an approved continuous casting process. Plates are to be formed by rolling and may be hot or cold finished. Bars and sections may be formed by rolling, extrusion or drawing.

3 Quality of materials

3.1 Materials are to be free from surface or internal defects of such a nature as would be harmful in service.

4 Dimensional tolerances

4.1 The dimensional tolerances are to be in accordance with Table 4.1, Table 4.2 and Table 4.3 and are minimum requirements.

4.2 Dimensional tolerances other than those given in Table 4.1, Table 4.2 and Table 4.3 are to comply with a recognized national or international standard.

Table 4.1: Under thicknesses tolerances for rolled products

Thickness tolerances for nominal width [mm]			
Nominal thickness [t] [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

Table 4.2: Under thicknesses tolerances for extruded open profiles

	Thickness tolerance for nominal thicknesses for a diameter of the circumscribing circle [mm]		
Nominal thickness[mm]	Upto 250	From 250 to 400	Above 400
From 3 to 6	0.25	0.35	0.40
From 6 to 50	0.30	0.40	0.45

Table 4.3: Under thicknesses tolerances for extruded closed profiles

Nominal thickness [mm]	Thickness tolerance [mm]
From 3 to 6	0.25
From 6 to 50	0.30

5 Chemical composition

5.1 Samples for chemical analysis are to be taken representative of each cast, or the equivalent where a continuous melting process is involved.

5.2 The chemical composition of these samples is to comply with the requirements of Table 5.1.

Table 5.1: Chemical composition

Grade	Al	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	others(2) Each	others(2) Total	Misc.
	%	%	%	%	%	%	%	%	%	%	%	
5059	Remainder	0.45	0.50	0.25	0.6-1.2	5.0-6.0	0.25	0.40-0.90	0.20	0.05[3)]	0.15[4)]	
5083	Remainder	≤ 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	
5086	Remainder	≤ 0.40	≤ 0.50	≤ 0.10	0.20-0.7	3.5-4.5	0.05-0.25	≤ 0.25	≤ 0.15	≤ 0.05	≤ 0.15	
5383	Remainder	0.25	0.25	0.20	0.7-1.0	4.0-5.2	0.25	0.40	0.15	0.05[3)]	0.15[3)]	
5754	Remainder	≤ 0.40	≤ 0.40	≤ 0.10	≤ 0.50	2.6-3.6	≤ 0.30	≤ 0.20	≤ 0.15	≤ 0.05	≤ 0.15	0.10 ≤Mn + Cr ≤ 0.60
5456	Remainder	0.25	0.40	0.10	0.50-1.0	4.7-5.5	0.05-0.20	0.25	0.20	0.05	0.15	
6005-A	Remainder	0.50-0.9	≤ 0.35	≤ 0.30	≤ 0.50	0.040-0.7	≤ 0.30	≤ 0.20	≤ 0.10	≤ 0.05	≤ 0.15	0.12≤ Mn + Cr ≤ 0.50
6061	Remainder	0.40-0.8	≤ 0.7	0.15-0.40	≤ 0.15	0.8-1.2	0.04-0.35	≤ 0.25	≤ 0.15	≤ 0.05	≤ 0.15	
6082	Remainder	0.7-1.3	≤ 0.50	≤ 0.10	0.40-1.0	0.6-1.2	≤ 0.25	≤ 0.20	≤ 0.10	≤ 0.05	≤ 0.15	

Notes:

1. Slight variations in the content of some elements, compared with values indicated in this Table may be accepted with ACS's agreement.
2. Other metallic elements such as Ni, Ga.V are considered as impurities. The regular analysis need not be made for these elements.
3. Zr: maximum 0.20. The total for other elements does not include Zirconium.
4. Zr: 0.05-0.25. The total for other elements does not include Zirconium.

5.3 The manufacturer's declared analysis will be accepted subject to occasional checks if required by ACS Surveyor, particularly, product analysis may be required where the final product chemistry is not well represented by the analysis from the cast.

5.4 When the Aluminium alloys are not cast in the same works in which they are manufactured into semi finished products, the works is to give a certificate detailing the chemical composition and heat number.

6 Heat treatment

6.1 Temper conditions (delivery heat treatment) are defined in Table 8.1.

7 Test material

7.1 All materials in a lot forwarded for sampling are to be of the same alloy, production batch and product form (plates, sections etc.). The materials in one lot are to be of the same dimensions and in the same delivery condition.

Artificially aged grades are to be from the same furnace batch.

7.2 Wherever practicable, the tensile test pieces for rolled and extruded sections are to be of full section of material. Otherwise, the pieces are to be taken in the range one third to half the distance from the edge to center of the predominant or thickest part of the section.

8 Testing and inspection

8.1 Testing procedures The test specimens and procedures are to be in accordance with Ch.2.

8.2 Verification of proper fusion of press welds for closed profiles. The Manufacturer has to demonstrate by macrosection tests or drift expansion tests of closed profiles performed on each batch of closed profiles that there is no lack of fusion at the press welds.

8.3 Drift expansion tests

8.3.1 Every fifth profile is to be sampled after final heat treatment. One sample is to be selected from the batches of five profiles or less. Every profile is to be selected if the length exceeds 6 [m].

8.3.2 Two samples are to be cut from the front and back end of each production profile.

8.3.3 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 filing.

8.3.4 The length of the specimen is to be in accordance with details given in Ch.2.

8.3.5 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°.

8.3.6 The sample is considered to be unacceptable if the sample fails with a clean split along the weld line which confirms lack of fusion.

8.4 Requirements of mechanical properties for rolled products in different delivery conditions are given in Table 8.1 and are applicable for thickness within the range 3 [mm] to 50 [mm].

For thickness above 10 [mm], however, lower mechanical properties may be accepted.

8.5 Requirements of mechanical properties for extruded products in different delivery conditions are given in Table 8.2 and are applicable for thickness within the range 3 [mm] to 50 [mm].

8.6 Requirements of mechanical properties and delivery conditions for extruded closed profiles are given in Table 8.3.

8.7 Other delivery conditions with related mechanical properties may be accepted by ACS, in each particular case.

Table 8.1: Mechanical properties for rolled products 3 [mm] ≤ t ≤ 50 mm

Grade	Temper condition	Thickness, t	0.2% proof Stress [N/mm^2]	Tensile Strength [N/mm^2]	Elongation % minimum[1)]	
					On gauge Length of 50 [mm]	On gauge Length of 5 × dia
5083	O	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
	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
	H116	3 < t ≤ 20 mm	270	370	10	10
		20 < t ≤ 50 mm	260	360	10	10
	H321	3 < t ≤ 20 mm	270	370	10	10
		20 < t ≤ 50 mm	260	360	10	10
5086	O	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
5456	O	3 < t ≤ 6.3 mm	130-205	290-365	16	
		6.3 < t ≤ 50 mm	125-205	285-360	16	14
		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

Notes:

1) Elongation in 50 mm apply for thicknesses upto and including 12.5 mm and in 5d for thicknesses over 12.5 mm.

2) 8% for thicknesses upto and including 6.3 mm.

Designation Condition

F	As fabricated
O	Annealed, soft
H1	Strain hardened only
H2	Strain hardened and partially annealed
H3	Strain hardened and thermally stabilized
H321	Strain hardened and stabilized
H11	Strain hardened to specified strength
H12	Strain hardened to specified strength
H13	Strain hardened to specified strength
H111	Less strain hardened than H11 e.g. by straightening or stretching
H112	No controlled strain hardening, but there are mechanical property limits
H116	Treatment against exfoliation corrosion
T5	Cooled from an elevated temperature shaping process and then artificially aged
T6	Solution heat treated and then artificially aged.

Table 8.2: Mechanical properties for extruded products 3 [mm] ≤ t ≤ 50 mm

Grade	Temper Condition	Thickness, t	0.2% proof Stress [N/mm^2]	Tensile Strength [N/mm^2]	Elongation % minimum[1)]	
					On gauge Length of 50[mm]	On gauge Length of 5 × dia
5083	O	3 ≤ t ≤ 50 mm	110	270-350	14	12
	H/111	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

Grade	Temper condition	Thickness, t	0.2% proof Stress [N/mm^2]	Tensile Strength [N/mm^2]	Elongation % minimum[2)]	
					On gauge Length of 50 [mm]	On gauge Length of 5 × dia
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 ≤ 50 mm	250	290	6	
		3 ≤ t ≤ 50 mm	260	310	10	8

Notes:

1) The values are applicable for longitudinal and transverse tensile test specimens as well.

2) Elongation in 50 mm applies for thicknesses upto and including 12.5 mm and in 5d for thicknesses over 12.5 mm.

Table 8.3: Mechanical properties for extruded closed profiles (testing transverse to extruding direction)

Grade	Temper condition	0.2% proof stress [N/mm^2]	Tensile strength [N/mm^2]	Elongation % min on gauge length of 5 × dia
6061	T5/T6	205	245	4
6005A	T5/T6	215	250	5
6082	T5/T6	240	290	5

9 Freedom from defects

9.1 The finished material is to have a good finish and is to be free from internal and surface defects prejudicial to the use of the concerned material for the intended application.

9.2 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 4.

10 Corrosion testing

10.1 Rolled 5xxx-alloys of type 5083, 5059 and 5086 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 inter granular corrosion resistance.

10.2 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, is to be established for each of the alloy-tempers and relevant thickness ranges. 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 G66 "Standard test method for visual assessment of exfoliation, corrosion susceptability of 5xxx series Aluminum alloys" (ASSET Test). The samples are also to have exhibited resistance to intergranular corrosion at a mass loss not greater than 15 [mg/cm^2], when subjected to tests described in ASTM G67 "Standard test method for determining the susceptibility to intergranular corrosion of 5xxx series Aluminium alloys by mass loss after exposure to nitric acid". 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 ACS. Production practices are not to be changed after approval of the reference micrographs. Other test methods may also be accepted at the discretion of ACS.

10.3 For batch acceptance of 5xxx-alloys in the H116 and H321 tempers, metallographic examination of one sample selected from mid width at one end of a coil or random sheet or plate is to be carried out. The microstructure of the sample is to be compared to the reference photomicrograph of acceptable material in the presence of the Surveyor. A longitudinal section perpendicular to the rolled surface is to be prepared for metallographic examination. If the microstructure shows evidence of continuous grain boundary network of Aluminum magnesium precipitate in excess of the reference photomicrographs of acceptable material, the batch is either to be rejected or tested for exfoliation-corrosion resistance and intergranular corrosion resistance subject to the agreement of the Surveyor. The corrosion tests are to be in accordance with ASTM G66 and G67 or equivalent standards. If the results from testing satisfy the acceptance criteria stated in paragraph 10.2 the batch is accepted, else it is to be rejected.

As an alternative to metallographic examination, each batch may be tested for exfoliation corrosion resistance and intergranular corrosion resistance, in accordance with ASTM G66 and G67 or equivalent standards.

11 Test materials

11.1 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.

11.2 The test samples are to be taken

- at one third of the width from a longitudinal edge of rolled products.
- in the range 1/3 to 1/2 of the distance from the edge to the centre of the thickest part of extruded products.

11.3 Test samples are to be taken so that the orientation of test specimens is as follows:

a) Rolled products

Normally, tests in the transverse direction are required. If the width is insufficient to obtain transverse test specimen, or in the case of strain hardening alloys, tests in the longitudinal direction will be permitted.

b) Extruded products

The extruded products are tested in longitudinal direction.

11.4 After removal of test samples, each test specimen is to be marked in order that its original identity, location and orientation is maintained.

12 Mechanical test specimens

12.1 Type and location of tensile test specimens are to be in accordance with details given in Ch.2.

13 Number of test specimens

13.1 Tensile test

a) Rolled products

- One tensile test specimen is to be taken from each batch of the product. If the weight of one batch exceeds 2000 Kg, one extra tensile test specimen is to be taken from every 2000 Kg of the product or fraction thereof, in each batch.
- For single plates or for coils weighing more than 2000 Kg each, only one tensile test specimen per plate or coil shall be taken.

b) Extruded products

- For the products with a nominal weight of less than 1 Kg/m, one tensile test specimen is to be taken from each 1000 Kg, or fraction thereof, in each batch. For nominal weights between 1 and 5 Kg/m, one tensile test specimen is to be taken from each 2000 Kg or fraction hereof, 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.

13.2 Corrosion tests

For rolled plates of grade 5083, 5383, 5059 and 5086 delivered in the tempers H116 or H321, one sample is to be tested per batch.

14 Retest procedures

14.1 When the tensile test from the first piece selected in accordance with Sec.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.

14.2 f 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.

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

15 Visual and non-destructive examination

15.1 Surface inspection and verification of dimensions are the responsibility of the manufacturer, and acceptance by the Surveyors of material later found to be defective shall not absolve the manufacturer from this responsibility.

15.2 In general, the non-destructive examination of materials is not required for acceptance purposes. Manufacturers are expected, however to employ suitable methods of non-destructive examination for the general maintenance of quality standards.

15.3 For applications where the nondestructive examination of materials is considered to be necessary, the extent of this examination, together with appropriate acceptance standards, are to be agreed between the purchaser, manufacturer and Surveyor.

16 Rectification of defects

16.1 Local surface defects may be removed by machining or grinding, provided the thickness of the material remains within the tolerances given in para 4. The extent of repairs is to be agreed upon with the Surveyor, and all repairs are to be carried out under Surveyor's supervision, unless otherwise arranged.

16.2 Surface defects which cannot be dealt with as in 12.1 are not allowed to be repaired, unless it can be ensured that repair by welding does not affect the strength and stability of the piece for the intended purpose. Any case of repair by welding is to be specified in detail for consideration and approval by the Surveyor.

Prior to any such repair welding, the defect is to be removed by machining or grinding. After complete removal of the defect and before welding the thickness of the piece at no place is to be reduced by more than 20 per cent. The welding is to be carried out by approved welders. The weld is to be ground flush with the surrounding piece surface. Before repair welding is commenced and after grinding the weld bead, suitable non destructive testing may be required at the discretion of the Surveyor.

17 Identification

17.1 The manufacturer is to adopt a system of identification which will ensure that all finished material in a batch presented for test is of the same nominal chemical composition.

17.2 Products are to be clearly marked by the manufacturer in accordance with the requirements of Ch.1. The following details are to be shown on all materials which have been accepted:

a) Manufacturer's name or trade mark;

b) Grade of alloy;

c) Identification mark which will enable the full history of the item to be traced;

d) Abbreviated designation of temper condition in accordance with para 6;

e) Personal stamp of the Surveyor responsible for the final inspection and also ACS's stamp.

f) Tempered grades that are corrosion tested in accordance with 12 are to be marked “M” after the temper condition, e.g. 5083 H321 M.

17.3 When extruded products are bundled together or packed in crates for delivery, the marking specified in para 17.2 are to be affixed by a securely fastened tag or label.

18 Certification

18.1 Each test certificate or shipping statement is to include the following particulars :

a) Purchaser’s name and order number;

b) Contract number;

c) Address to which material is to be dispatched;

d) Description and dimensions;

e) Specification or grade of alloys;

f) Identification mark which will enable the full history of the item to be traced;

g) Chemical composition;

h) Mechanical test results (Not required on shipping statement); and

i) Details of heat treatment, where applicable.

18.2 Where the alloy is not produced at the works at which it is wrought, a certificate is to be supplied by the Manufacturer of the alloy stating the cast number and chemical composition. The works at which alloys are produced must be approved by ACS.

Section 3 Aluminium Alloy Castings

1 Scope

1.1 Provision is made in this section for Aluminium alloy castings intended for use in the construction of ships, ships for liquid chemicals and other marine structures, liquefied gas piping systems where the design temperature is not lower than minus 165°C. These materials should not be used for piping outside cargo tanks except for short lengths of pipes attached to cargo tanks in which case fire resisting insulation should be provided.

1.2 Castings are to be manufactured and tested in accordance with Ch.1 and Ch.2 and also with the requirements of this Section.

1.3 As an alternative to 1.2, castings which comply with National/International and proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Section or are approved for a specific application. Generally survey and certification are to be carried out in accordance with the requirements of Ch.1.

2 Manufacture

2.1 Castings are to be manufactured at foundries approved by ACS.

3 Quality of castings

3.1 All castings are to be free from surface or internal defects which would be prejudicial to their proper application in service.

4 Chemical composition

4.1 The chemical composition of a sample from each cast is to comply with the requirements given in Table 4.1. Suitable grain refining elements may be used at the discretion of the Manufacturer. The content of such elements is to be reported in ladle analysis.

4.2 Where it is proposed to use alloys not specified in Table 4.1 details of chemical composition, heat treatment and mechanical properties are to be submitted for approval.

4.3 When a cast is wholly prepared from ingots for which an analysis is already available, and provided that no significant alloy additions are made during melting, the ingot maker's certified analysis can be accepted subject to occasional checks as required by the Surveyor.

Table 4.1: Chemical composition for Aluminium alloy castings

Alloy Element%	Grade			
	AlMg3	AlSi12	AlSi10Mg	AlSi7 High Purity
Copper	0.1 max	0.1 max.	0.1 max.	0.1 max.
Magnesium	2.5 – 4.5	0.1 max.	0.15 – 0.4	0.25 – 0.45
Silicon		0.5 max. 11.0 – 13.5	9.0 – 11.0	6.5 – 7.5
Iron	0.5 max.	0.7 max.	0.6 max.	0.2 max.
Manganese	0.6 max.	0.5 max.	0.6 max.	0.1 max.
Zinc	0.2 max.	0.1 max.	0.1 max.	0.1 max.
chromium	0.1 max.	-	-	-
Titanium	0.2 max.	0.2 max.	0.2 max.	0.2 max.
Others				
Each	0.05 max.	0.05 max.	0.05 max.	0.05 max.
Total	0.15 max.	0.15 max.	0.15 max.	0.15 max.
Aluminium	Remainder	Remainder	Remainder	Remainder

5 Heat treatment

5.1 Castings are to be supplied in the following conditions:

Grade Al-Mg 3 As manufactured

Grade Al-Si 12 As manufactured

Grade Al-Si 10 Mg As manufactured or solution heat treated and precipitation hardened

Grade Al-Si 7 Mg Solution heat treated and precipitation (high purity) hardened

6 Mechanical tests

6.1 At least one tensile specimen is to be tested from each cast, where heat treatment is involved, for each treatment batch from each cast. Where continuous melting is employed 500 Kgs of fettled castings may be regarded as a cast.

6.2 The test samples are to be separately cast in moulds made from the same type of material as used for the castings. These moulds should conform to National Standards.

6.3 The methods and procedures for the identification of the test specimens, and the castings they represent, are to be agreed with the Surveyor. The identification marks are to be maintained during the preparation of test specimens.

6.4 Where castings are supplied in the heat treated condition, the test samples are to be heat treated together with the castings which they represent prior to testing.

6.5 The results of all tensile tests are to comply with the appropriate requirements given in Table 6.1 and/or Table 6.2.

Table 6.1: Minimum mechanical properties for acceptance purpose of sand cast and investment cast reference test pieces

Alloy	Temper (see Note)	Tensile strength [N/mm^2]	Elongation %
ALMg3	M	150	5
AISi12	M	150	3
AISi10Mg	M	150	2
AISi10mg	TF	220	1
AISi7Mg	TF	230	5

Note

M - As cast condition

TF - Solution heat treated and precipitation hardened condition

Table 6.2: Minimum mechanical properties for acceptance purpose of chill cast reference test pieces

Alloy	Temper (see note)	Tensile strength [n/mm^2]	Elongation %
AIMg3	M	150	5
AISi12	M	170	3
AISi10Mg	M	170	3
AISi10Mg	TF	240	1.5
AISi7Mg	TF	250	5

Note

M - As cast condition

TF - Solution heat treated and precipitation hardened condition

7 Visual examination

7.1 All castings are to be cleaned and adequately prepared for inspection.

7.2 The accuracy and verification of dimensions are the responsibility of the manufacturer, unless otherwise agreed.

7.3 Before acceptance, all castings are to be presented to the Surveyor for visual examination.

8 Rectification of defective castings

8.1 At the discretion of the Surveyor, small surface blemishes may be removed by local grinding.

8.2 Where appropriate, repair by welding may be accepted at the discretion of the Surveyor. Such repair is to be made in accordance with an approved procedure.

9 Pressure testing

9.1 Where required by the relevant construction rules, castings are to be pressure tested before final acceptance. Unless otherwise agreed, these tests are to be carried out in the presence and to the satisfaction of the Surveyor.

10 Identification

10.1 The manufacturer is to adopt a system of identification which will enable all finished castings to be traced to the original cast and the Surveyor is to be given full facilities for tracing the casting when required.

10.2 All castings which have been tested and inspected with satisfactory results are to be clearly marked with following details :

a) Identification number, cast number or other numbers which will enable the full history of the casting to be traced;

b) AC and the abbreviated name of local office of ACS;

c) Personal stamp of the surveyor responsible for the inspection;

d) Test pressure where applicable; and

e) Date of final inspection.

10.3 Where small castings are manufactured in large numbers, modified arrangements for identification may be specially agreed with the Surveyor.

11 Certification

11.1 The manufacturer is to provide the Surveyor with a written statement giving the following particulars for each casting or batch of castings which have been accepted :

a) Purchaser name and order number;

b) Description of castings and alloy type;

c) Identification number;

d) Ingot or Cast analysis;

e) General details of heat treatment where applicable;

f) Results of mechanical tests; and

g) Test pressure, where applicable.

Section 4 Aluminium/Steel Transition Joints

1 Scope

1.1 Provision is made in this section for explosion bonded composite Aluminium/steel transition joints used for connecting Aluminium structures to steel plating.

1.2 Each design is to be separately approved by ACS.

2 Manufacture

2.1 Transition joints are to be manufactured by an approved producer in accordance with an approved specification which is to include the maximum temperature allowable at the interface during welding.

2.2 The Aluminium material is to comply with the requirements of Sec.1 and the steel is to be of an appropriate grade complying with the requirements of Ch.3.

2.3 Alternative materials which comply with International, National or proprietary specifications may be accepted provided that they give reasonable equivalence to the requirements of 2.2 or are approved for a specific application.

2.4 Intermediate layers between Aluminium and steel may be used, in which case the material of any such layer is to be specified by the manufacturer and will be recorded in the approval certificate. Any such intermediate layer is then to be used in all production joints.

3 Visual and non-destructive examination

3.1 Each composite plate is to be subjected to 100 per cent visual and ultrasonic examination in accordance with a relevant National/ International standard to determine the extent of any unbounded areas. The unbounded areas are unacceptable and any such area and the surrounding 25 [mm] area is to be discarded.

4 Mechanical tests

4.1 Two shear test specimens and two tensile test specimens are to be taken from each end of each composite plate for tests to be made on bond strength. One shear and one tensile test specimen from each end are to be tested at ambient temperature after heating to themaximum allowable interface temperature; the other two specimens are to be tested without heat treatment.

4.2 Shear tests may be made on a specimen as shown in Fig.4.1 or an appropriate equivalent. Tensile tests may be made across the interface by welding extension pieces to each surface or by the ram method shown in Fig.4.2 or by an appropriate alternative method.

4.3 The shear and tensile strengths of all the test specimens are to comply with the requirements of the manufacturing specification.

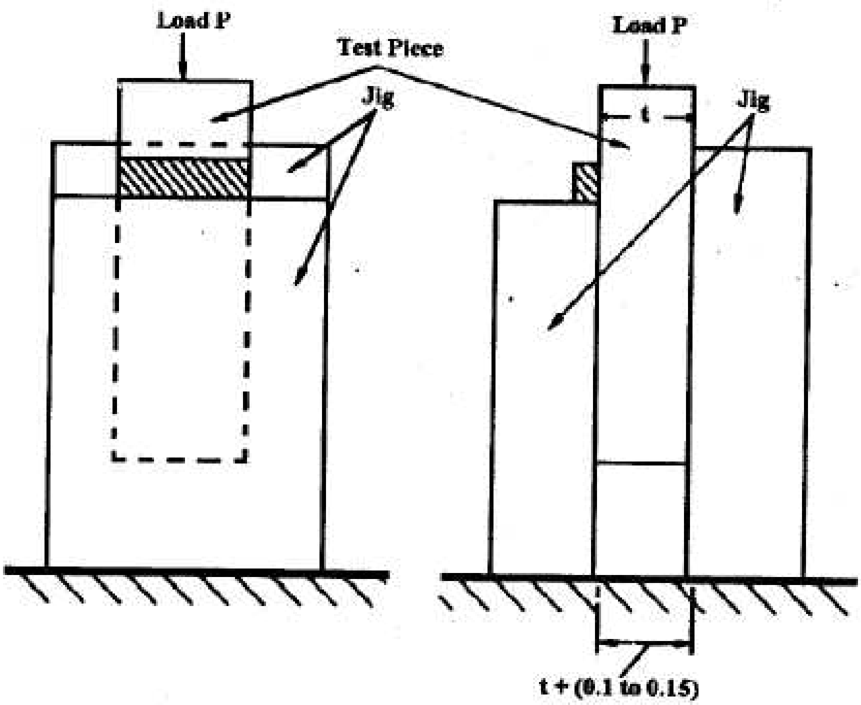


Fig. 4.1 Shear Tests

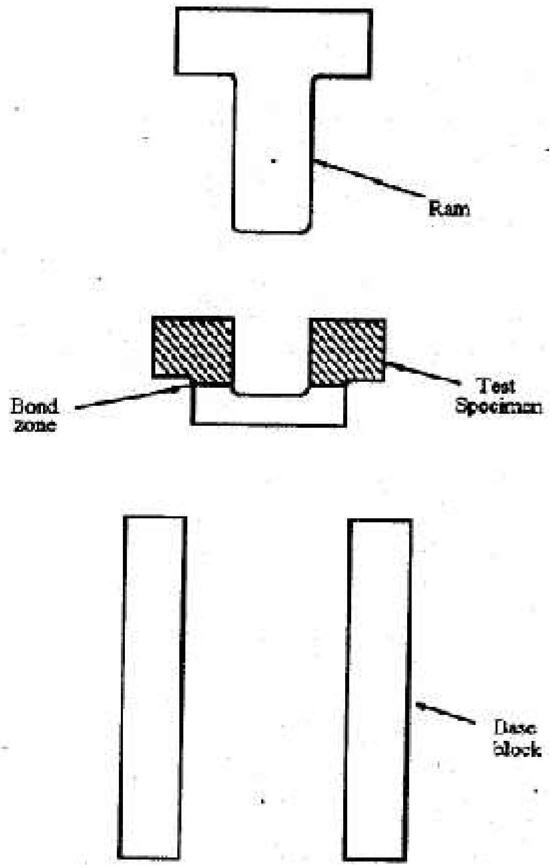


Fig. 4.2 Tensile tests

4.4 If either the shear or tensile test strength of the bond is less than the specified minimum but not less than 70 per cent of the specified minimum, two additional shear and two tensile test specimens from each end of the composite plate are to be tested and, in addition bend tests as described in 4.6 and Table 4.1 are to be conducted.

4.5 If either the shear or the tensile strength of the bond is less than 70 per cent of the specified minimum the case is to be investigated. After evaluation of the results of this investigation ACS will consider the extent of composite plate which is to be rejected.

4.6 Bend tests, when required, are to be made under the following conditions, as listed in Table 4.1:

a) the Aluminium plate is in tension;

b) the steel plate is in tension; and

c) a side bend is applied.

Table 4.1: Bend tests on explosion bonded Aluminium / steel transition joints

Type of test	Minimum bend, degrees	Diameter of former
Aluminium in tension	90	3T
Steel in tension	90	3T
Side bend	90	6T

5 Identification

5.1 Each acceptable transition strip is to be clearly marked with ACS brand AC and the following particulars :

a) Manufacturers name or trade mark;

b) Identification mark for the grade of Aluminium; and

c) Identification mark for the grade of steel.

The particulars are to be stamped on the Aluminium surface at one end of the strip.

6 Certification

6.1 Each test certificate or shipping statement is to include the following particulars :

a) Purchaser's name and order number;

b) The contract number for which the material is intended, if known;

c) Address to which the material is dispatched;

d) Description and dimensions of the material;

e) Specification or grades of both the Aluminium alloy and the steel and any intermediate layer;

f) Cast numbers of steel and Aluminium plates;

g) Identification number of the composite plate; and

h) Mechanical test results (not required on the shipping statement).

Chapter 10 Non-metallic Materials, Fiber Reinforced Plastics and Bonding

Section 1 Requirement for Materials and Production

1 Definitions

1.1 Fiber-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 fiber products which are embedded in a matrix in order to improve certain properties. In doing so, fibers 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 fiber 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 shall 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 colouring 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 shall have good impregnation characteristics when being processed. In a cured stage, they shall be resistant to fuels, river and sea water, and shall exhibit a high resistance to ageing. Furthermore, adequate resistance to hydrolysis shall be ensured when used with permissible additives and filling materials.

When using unsaturated polyesters (UP) as the resin, the resistance to hydrolysis shall 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, colouring pigments etc.) shall be suitable for the thermosetting resin and shall be compatible with it as well as the other additives, such that a complete curing of the resin can be ensured. The additives shall 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, shall be used in accordance with the processing guidelines provided by the manufacturer. For cold-setting systems, catalysts shall 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 ACS Head Office.

2.1.3.3 Filling materials shall not significantly impair the properties of the cured resin. The type and quantity of the filling materials shall be approved by ACS head office and shall not lead to non-compliance with the minimum properties of the resin . In general, the proportion of filling materials in the laminating resin compound shall not 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 shall apply. The proportion of thixotropic agent in the gelcoat resin compound shall not exceed 3 % by weight. Laminates used for fuel and water tanks shall not contain filling materials.

2.1.3.4 Colouring pigments shall be climate-proof and consist of inorganic or non-fading organic dyes. The maximum permissible proportion shall not exceed the value specified by the manufacturer; if no value is specified, then it shall not 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 shall 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.

2.3 Core materials for sandwich constructions

2.3.1 It shall be demonstrated that the core materials used are suitable for the intended purpose. They shall not impair the curing of the laminating resin.

2.3.2 The joining surfaces of local reinforcements made of metallic materials (e.g. inlets, connections) shall be cleaned in the same manner as for a gluing process, in order to ensure optimal bonding (see. DIN 53281, Part 1).

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 ACS Headoffice beforehand.

2.3.4 Rigid foam materials

Rigid foam materials which are used as core material for sandwich laminates, or as shear webs, shall 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 shall 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 shall fulfill the following requirements. It shall

– 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

Fiber reinforcements pre-impregnated with laminating resin shall satisfy the requirements placed on their components. In addition, a minimum resin content of 35 % by volume shall be ensured, as well as adequate tack at the processing temperature.

2.5 Adhesives

2.5.1 When bonding fiber-reinforced plastics together, or with other materials, only solvent-free adhesives shall be used. Preference shall be given to two components reaction adhesives, if possible with the same basis as the laminating resin.

2.5.2 Laminates shall only 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 shall not be exceeded. This applies especially when using single component hot-melt adhesive.

2.5.3 The adhesives shall be used in accordance with the processing guidelines issued by the manufacturer. They shall not affect the materials to be bonded and shall exhibit a high resistance to humidity and ageing. The influence of the operating temperature on the adhesive strength shall be small.

2.5.4 Adhesives shall 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 shall first be assessed and approved by ACS. Approval by other organizations can be recognized following agreement by ACS, provided that the tests required for approval are in accordance with ACS requirements.

3.2 The manufacturer and/or supplier of the material shall apply to ACS Head Office for approval.

3.3 Approval is granted if the material fulfils the requirements of ACS. For this purpose, specific tests are necessary, and they shall either be carried out under supervision of ACS or the results shall be documented in the report of a recognized testing institute. The respective test criteria are given in Section 2.

3.4 Before production starts, the required material approvals shall be submitted to ACS Head Office and/or the responsible ACS inspection office. If no approvals, or not all required approvals have been obtained, then as an exception and following agreement with ACS Head Office, 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 shall bear a reference to the approval.

4 Requirements for Manufacturers

4.1 General

4.1.1 Manufacture of FRP-components shall only be performed by workshops which are approved by ACS for the manufacture of components made from fibre-reinforced thermosetting resins.

4.1.2 The manufacture of FRP-components shall only be carried out by persons with sufficient professional knowledge. This professional knowledge shall in general be verified by certificates of the corresponding training courses. If such certificates are not available, the minimum requirement shall 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 ACS Head Office on the basis of the information to be submitted. The information should consist of 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 shall fulfil 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 shall 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 shall be operated nor any painting or spraying operations carried out. As a matter of principle, such work shall take place in separate rooms.

4.2 Laminating workshops

4.2.1 Laminating workshops shall 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 % shall 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 shall be provided. The equipment shall be set up following agreement with ACS, their number and arrangement depending on operational conditions. The equipment shall be calibrated in accordance with statutory regulations. The recordings shall be kept for at least 10 years and submitted to ACS on request.

4.2.3 Ventilation facilities shall 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 shall 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 shall be stored in accordance with the manufacturer's instructions. If no such instructions are provided, then they shall be stored in dark, dry rooms at a temperature between 10 °C and 18 °C. The temperature of the storage-rooms shall be recorded continuously by means of thermographs.

4.3.2 Prepregs shall be stored in special cold storage rooms in accordance with the manufacturer's instructions.

4.3.3 Hardeners, catalysts and accelerators shall be stored separately in well-ventilated rooms in accordance with the manufacturer's instructions. If no instructions are provided, they shall be stored in dark, dry rooms at temperatures between 10 °C and 18 °C.

4.3.4 Reinforcing materials, fillers and additives shall be stored in closed containers, in dry and dust free conditions.

4.3.5 Storage shall 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 shall be removed immediately from the stores.

4.3.6 Quantities of materials due to be processed shall be brought to the production shops as early as possible to ensure complete adjustment to the processing temperature ($\Delta T \leq 2°$ C), with the containers remaining closed.

4.3.7 Materials taken from the stores and partially used shall only be replaced in the stores in special cases (e.g. hot-curing prepregs) and with the consent of ACS.

5 Guidelines for Processing

5.1 General

5.1.1 As a matter of principle, only materials approved by ACS shall be used. In addition to the choice of suitable and approved materials, special care shall 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 shall also be observed.

5.1.3 Resin, hardener and resin additives shall 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 shall not be exceeded. If such a time is not specified, the pot-life shall be determined by means of a preliminary test and the processing time then established in consultation with ACS.

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 ACS.

5.2 Requirements for moulds

5.2.1 The moulds shall 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 shall additionally be ensured.

5.2.3 The surface of the moulds shall be as smooth as possible and shall have no sharp edges. The mould shall 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 shall be treated with a sufficient quantity of a suitable release agent and brought up to the temperature required for lamination. The surfaces shall 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 shall 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 shall 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 shall be used (e.g. for glass fibres: a maximum of 450 g/m² and a maximum of 30 % glass by weight).

5.3.3 The laminate shall be built up in accordance with the approved technical documentation, whereby ACS shall be consulted about the method. Air shall be adequately removed from the reinforcing layers and these layers shall be compacted in such a manner to ensure that the required proportion of resin is achieved. Resin enrichment shall 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 shall 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 hours 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 shall 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 shall finally be polished using new abrasive paper. The same procedure shall also be applied when treating the surfaces of materials to be bonded.

5.3.7 Transitions between different thicknesses of laminate shall be made gradually. A minimum value (for glass fabric in the fiber direction) of 25 mm per 600 g/m² reinforcing material can be used. In the transition region from a sandwich construction to a solid laminate, the core material shall 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 shall overlap, or reinforcement strips shall be provided. In the butt or seam region of laminates, every reinforcing layer shall overlap by at least 25 mm per 600 g/m².

5.3.9 Different components may be laminated together only while they are not fully cured. Special attention shall be paid to crossings of laminates.

5.3.10 Parallel or insert linings shall be free of all moisture and pollution (dirt). Their bonding surfaces with the laminate shall be prepared in a suitable manner (roughening, coupling agent or similar).

5.4 Glass-fiber resin spraying

Glass-fiber resin spraying, a partly mechanical method of lamination by hand, requires fulfillment of the following specific requirements:

5.4.1 The equipment to be used shall be demonstrated before use and its suitability proven.

5.4.2 The qualification of the fibre-resin sprayer, and where appropriate his assistant, shall be demonstrated to ACS by means of procedure test.

5.4.3 The equipment shall be calibrated in accordance with the guidelines of the manufacturer. Calibration shall 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 shall be between 25 mm and 50 mm.

5.4.5 A powder-bound textile glass mat of maximum 450 g/m² shall be used for the first laminate layer. The glass part of this layer (to be applied manually) shall be less than 30 % by weight.

5.4.6 The glass weight per unit area of the spray laminate layer of a combined laminate shall not exceed 1150 g/m².

5.4.7 After a maximum of 1150 g/m² of fibres have been sprayed, air shall be removed and the composite shall be compacted.

5.4.8 Tests shall 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. ACS 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 shall 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 shall be below the temperature for dimensional stability under heat and shall be agreed on with ACS. Cold-setting systems which are not subsequently tempered shall 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 ACS, provided the relevant manufacturer’s specifications regarding post-curing are available, or postcuring 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 shall generally 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 shall be given with due consideration of the production process.

5.6.1.2 A specification for production and testing shall 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 shall be defined. The adhesive layer thicknesses, tolerances and the maximum size and extent of permissible flaws shall 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 (bondline corrosion) shall 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 shall be totally cured before bonding.

5.6.2 Assembly process

5.6.2.1 The surfaces of the materials to be bonded together shall 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 shall be ensured.

5.6.2.2 Smooth surfaces shall 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.

5.6.2.3 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.

5.6.2.4 The adhesive shall 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 shall be mixed in such a way that they are evenly distributed, care being taken to beat in as little air as possible.

5.6.2.5 The adhesive shall 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.

5.6.2.6 Following application of the adhesive, the materials to be joined shall be brought together without delay and fixed in place.

5.6.2.7 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.

5.6.2.8 After curing, the adhesive joint shall 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 ACS of the internal surveillance as well as of the component quality.

6.1.3 ACS reserves the right to carry out inspections in the production facilities without giving prior notice. The manufacturer shall grant inspectors access to all areas used for production, storage and testing and shall 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 shall 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 shall at least be checked for any damage and for compliance of the details in the certificates with the requirements. Material values shall be checked by random sampling.

6.2.3 The goods shall 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 shall 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 shall be defined clearly.

6.3.2 As the work progresses, the individual production steps shall be signed by the employees responsible for each stage on the basis of the prescribed documentation.

6.3.3 The individuals entrusted with production shall be trained in accordance with their task, and shall work under professionally qualified supervision. In the case of adhesive joints, the responsible supervisors shall have an appropriate qualification in adhesives, and the individuals performing the work shall have undergone suitable training.

6.3.4 The batch numbers of the materials used in the component shall 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 shall 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 shall be taken and tested. If mixing is performed continuously, one sample per batch and production step is sufficient. These samples shall be randomly checked for their degree of curing. The results shall be recorded.

6.3.6 On request by ACS, reference laminates of about 50 x 50 cm shall be produced in parallel. This shall 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 shall be subjected to visual inspections. In particular, attention shall be paid to voids, delamination, warping, discoloration, damage etc. In addition, the general quality, e. g. surface finish, shall be assessed.

6.4.2 By means of suitable testing procedures, the quality of the components shall be determined, if possible during production, and at the latest on completion of production. Special attention shall be paid to the bonding and to the degree of curing of the component.

6.4.3 Following agreement with ACS, individual or random tests shall be carried out on finished components under static and/or dynamic loads.

6.4.4 ACS shall be informed about repairs of any faults relevant to the strength of the component, and the procedure used to carry out the repair shall be in accordance with Section 3.

Section 2 Inspection and Testing of Fiber Composite Materials

1 General

1.1 In accordance with the Rules and Guidelines of ACS, the materials used for manufacturing components made of FRP under the supervision of ACS shall be approved by ACS. Approvals are granted for the following materials:

- gelcoat and/or laminating resins
- reinforcing materials
- prepregs
- core materials
- adhesives

1.2 Applications for approval by ACS Head Office shall be made by the material manufacturer or an agent. Together with the application, the following shall be submitted to ACS Headoffice:

- 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 ACS
- 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.

1.3 The tests shall be carried out in accordance with the standards mentioned in this rule. However, comparable standards of other countries are also acceptable after agreement with ACS Headoffice in each individual case.

1.4 The minimum properties required by ACS for the tests shall be fulfilled by all specimens.

1.5 In the case of inadequate test results of individual specimens, attention shall be paid to the following

(for a basic number of 6 tests):

- If one or two specimens yield inadequate results, the tests shall 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 ACs agrees to this.
- If even one sample yields inadequate results while repeat-testing, then approval is not possible.

1.6 If the material fulfils the ACS requirements, then a statement of material approval is issued by ACS Headoffice. This is generally valid for four years, whereby extensions are possible.

1.7 ACS Head office shall 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.

1.8 A constant material quality shall be provided by the manufacturer through suitable QM measures. If this is not ensured, ACS reserves the right to suspend, or withdraw, the approval.

1.9 ACS 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 ACS.

1.10 The approval refers only to the approved material. The applicability of this material in connection with other approved materials shall be demonstrated independently by the manufacturer, or the user, in a suitable manner. In cases of doubt, ACS reserves the right to require a check of the properties of the material combination.

2 Thermosetting resins

2.1 General

2.1.1 The basic requirements listed in subsection 1, apply for material approval.

2.1.2 A general description of the thermosetting resin, its processing conditions as well as the properties of resin in the processing state shall be submitted. The basic properties of the cured thermosetting resin shall be verified by the test certificate of a recognized testing body. These values shall fulfill specified minimum requirements.

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 ACS Head Office, whereby the required minimum properties are specified by ACS Head Office on an individual basis. However, they shall at least comply with those of UP resins.

2.2 Description

2.2.1 A description of the thermosetting resin shall be submitted in order to allow an unequivocal identification:

- resin type and state
- purpose
- manufacturer
- trade name

2.2.2 In addition, the following shall be indicated:

- storage conditions
- environmental conditions for processing
- type and proportion of allowed additives
- curing conditions, tempering

2.3 Properties in the processing state and during curing

The properties shall 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, DIN EN ISO 2535)
- curing shrinkage (DIN 16945)

2.4 Properties in the cured state

2.4.1 The following properties shall 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

2.4.2 For gelcoat and topcoat resins, the following additional information shall be submitted:

- abrasion resistance (DIN 53754 - ISO 9352) 3 samples
- resistance against seawater, fuels, hydraulic oil, weak acids and alkalis (DIN EN ISO 175)

2.4.3 With regard to the properties, the following shall be verified by the test certificate of a recognized testing body. For this purpose, specimens shall be used which are produced in accordance with the submitted processing guidelines. The specimens shall 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 shall be verified:

- density (DIN EN ISO 1183, method A), 3 specimens
- water absorption (following DIN EN ISO 175, Specimen 50 mm x50 mm x4), 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

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 shall be agreed on with ACS Headoffice.

2.4.5 The testing speed in the case of tensile and bending tests shall be selected in such a way that a specimen or edge-fibre strain of about 1 % / min is ensured. This shall be documented in the test report. The modulus of elasticity shall be determined as a secant modulus between 0,05 % and 0,25 % strain. The water absorption shall be specifically determined at 23 °C after 24 ± 1 h and 168 ± 2 h.

2.5 Minimum properties

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	(—)
bending strength:	80 MPa	(—)
dimensional stability under heat:	60 °C	(60 °C)

The water absorption after 168 h shall not exceed 70 mg for laminating resins and 60 mg for gelcoat resins.

2.5.2 The following minimum properties apply to resin products consisting of EP resins:

tensile strength:	55 MPa	(—)
fracture strain:	2,5 %	(3,5 %)
modulus of elasticity: (tension)	2700 Mpa	(—)
bending strength:	100 Mpa	(—)
dimensional stability under heat:	70 °C	(70 °C)

The water absorption after 168 h for laminating and gelcoat resins shall not exceed 50 mg.

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 shall be determined after 24 h and 168 h at 23 °C. Taking these properties into account and following agreement between ACS Headoffice and the applicant, the following classification is made:
- Resistant
- Conditionally resistant
- Not resistant

3 Reinforcing materials

3.1 General

3.1.1 The basic requirements listed in subsection1, apply for material approval.

3.1.2 A general description of the reinforcing material and of the filament shall be provided. Basic properties of laminate specimens taken from the reinforcing material shall be verified by the test certificate of a recognized testing body. These values shall fulfill specified minimum requirements.

3.1.3 The following applies to fiber reinforcements made of glass and carbon. Products with other reinforcing fibers, e.g. aramide, can also be approved, following agreement with ACS Head Office, whereby the minimum properties are then specified on an individual basis.

3.1.4 Due to the great number of the fiber 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 ACS Head Office.

3.2 Description

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

3.2.2 In addition, the following is required:

- form of supply
- storage conditions
- processing instructions

3.2.3 The filament and its treatment/sizing shall be submitted:

- filament diameter (DIN 53811 - ISO R 137)
- coupling agreed or sizing
- resin compatibility

In the case of glass fibre products, the average filament diameter shall be at maximum 19µm.

3.2.4 In the case of reinforcing products consisting of a combination of different fibre materials and/or filaments, all fibre types shall be indicated.

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 % shall be verified by means of a test certificate from a recognized testing body.

3.3 Properties of the reinforcing products

3.3.1 Rovings

- number of the filaments in the roving
- roving fineness (ISO 4602)

When rovings are used as gun rovings (DIN 52316 - ISO 3375), the stiffness shall be additionally verified by the certificate of a recognized testing body.

3.3.2 Mats (continuous and chopped-strand mats)

- fibre length (for chopped-strand mats)
- linear density of the fiber (ISO 1889)
- weight per unit area (ISO 3374)
- layer thickness (ISO 3616)
- binder (see 3.3.5)

3.3.3 Fabric

- linear density of the fibres, warpwise and weftwise (ISO 1889)
- count, warpwise and weftwise (EN 1049-2)
- weight per unit area (ISO 4605)
- fabric thickness (ISO 4603)
- weave (DIN 61101-T2)

3.3.4 Non-woven fabric

- lay up
- weight per unit area of the individual layers and of the non-woven fabric (ISO 4605)
- 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 fiber length shall be indicated.

3.3.5 A difference shall 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) shall be indicated. In the case of mechanical bond types, the type of weave shall be indicated.

3.3.6 In the case of reinforcing products with different fiber materials, the percentages of materials used in the respective reinforcing directions shall be indicated.

3.4 Laminate properties of the reinforcing products

3.4.1 For laminate production, it is strongly recommended that ACS-approved cold-setting UP resins are to be used. After curing, the specimens shall be tempered for 16 h at 40 °C. If, for special reasons, other (also warm-setting) thermosetting resins are to be used, then this shall be agreed in advance by ACS Head office.

3.4.2 For rovings, tensile test specimens shall be prepared for all fibre materials in accordance with DIN 29965. The test certificate of a recognized testing body shall 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 shall be determined in accordance with DIN 65469 on flat specimens prepared for testing under tension.

3.4.3 For all other reinforcing products, laminate test panels shall be prepared in accordance with DIN EN 2374, Section 5.3 (Method C). In doing so, the reinforcing products shall be arranged in identical alignment. Depending on number of the reinforcing directions, the laminates shall have approximately the following thicknesses: unidirectional laminates 2 mm, bi-directional laminates 4 mm and multi-directional laminates 5 mm.

3.4.4 Appropriate test panels shall be prepared by fiber resin spraying for the use of gun rovings. The length of the gun rovings in this case shall be 35 mm.

3.4.5 The gun prescribed number of specimens shall be cut out of the test panels for each test. In doing so, specimens shall be taken from each reinforcing direction of the laminate in order to test the mechanical properties. For products with randomly distributed reinforcing directions, specimens shall be taken from any two directions, but at right angles to each other.

3.4.6 The specimens shall be tested in accordance with DIN EN ISO 291 after at least 16 h under standard climate conditions.

3.4.7 The following properties shall be verified by the test certificate of a recognized testing body:

- fiber content (DIN 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 shall 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 shall be demonstrated (carbon, Draft DIN EN 2850, test piece A1 with gauge length 8 mm).

3.4.8 The testing speeds shall be selected in such a way to ensure a strain rate of 1 % / min in the test piece or the edge fiber. The testing speed shall be indicated.

3.4.9 Testing shall be carried out in a standard climate 23/50 (23 °C / 50 % relative humidity). If the operating temperatures of the fibers are not between – 20 °C and + 50 °C, then additional testing temperatures shall be agreed on with ACS Head Office.

3.5 Minimum properties

3.5.1 For approval, fibre reinforced products shall fulfill specified minimum values for the mechanical properties. The influence of the fiber 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 shall be done.

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.3.1:

$$X_{min} = \sim\left[X_{ref}\left(\frac{\cdot\cdot}{0.4}\right)\right]$$

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 ≤ φ≤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 fiber weight content of 0.25 ≤ φ ≤ 0.35: are:

tensile strength:

$R_Z = 1278\cdot{}^{2} - 510\cdot + 123$ [MPa]

Young 's modulus (tension) :

$E = (37\cdot -4.75).10^{3}$ [MPa]

bending strength :

$R_B = 502\cdot{}^{2} + 106.8$ [MPa]

3.5.3 In the case of multidirectional lay up of the reinforcing products, the values shall be proved at least for one direction (preferably 0°).

3.5.4 For reinforcing products with different fiber materials in one direction, the values of the material with the lower minimum properties shall be fulfilled.

3.5.5 The minimum values for fabric are 95 % of the specified values for 0° / 90° lay up.

3.5.6 The stiffness of the gun rovings to be verified in accordance with DIN 52316 shall not be below 130 mm.

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 shall therefore not be used to extrapolate measured values.

4 Prepregs

4.1 General

4.1.1 The basic requirements listed under subsection 1, shall apply for material approval.

4.1.2 Since prepregs are based on resin systems which cure under heat, consultation with ACS Headoffice concerning the curing process of the resins is required.

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 shall be agreed on with ACS Head Office.

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 ACS Head Office.

Table 3.1 Coefficients for the determination of the minimum properties

Fibre	Propert	X_{ref} [Mpa]	A			
			0^0	$0^0/90^0$	$0^0/\pm45^0$	$0^0/90^0$ / $\pm45^0$
Glass	Tensile strength Young's modulus of elasticity Bending strength	500 26.000 650	1,00 1,00 1,00	0,55 0,67 0,55	0,50 0,57 0,45	0,45 0,55 0,40
Carbon	Tensile strength Modulus of elasticity Bending strength Compressive strength Modulus of elasticity Compression	900 80.000 725 600 70.000	1,00 1,00 1,00 1,00 1,00	0,55 0,55 0,55 0,55 0,55	0,50 0,45 0,45 0,50 0,50	0,45 0,42 0,40 0,45 0,45

4.2 Prepreg properties

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

4.2.2 The following properties shall be submitted for the non-cured prepreg material:

- mass per unit area (DIN 53854)
- resin percentage by weight (DIN 29971, Section 5.1.1.4)
- layer thickness (DIN 53855-1)
- resin flux percentage by weight (DIN 65090, Section 5.1.1)

4.2.3 The following are necessary for the reinforcing material:

- filament diameter (DIN 53811 - ISO 137)
- count (EN 1049-2)
- bond type (only woven prepregs)

5 Core materials

5.1 General

5.1.1 The basic requirements listed under subsection 1shall apply for material approval.

5.1.2 A general description of the core material shall be submitted. The basic properties shall be verified by the test certificate of a recognized testing body.

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 ACS Headoffice.

5.2 Rigid foams

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

5.2.2 The manufacturer shall provide details of the maximum permissible processing temperatures and the operating temperature limits. The long-term operating temperature shall at least cover the range –20 °C to +50 °C.

5.2.3 The test certificate of a recognized testing body verifying the following properties shall 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

5.2.4 The specimens shall 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 ACS Head Office shall be consulted if there is any doubt.

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
Shea strength [Mpa]	0.5	2,6
Shear modulus [Mpa]	15	65
Water absorption [vol.-%] (after 28 Days)	2	2

5.2.6 In the case of other apparent densities, linear interpolation of the densities shall be used to determine strengths and moduli.

5.3 Cross-grained balsa wood

5.3.1 Adhesion of balsa wood shall not be impaired by impregnation.

6 Adhesives

6.1 General

6.1.1 The basic requirements listed in subsection1 , shall apply for material approval.

6.1.2 A general description of the adhesive shall be provided. Basic properties of the cured adhesive shall be verified by the test certificate of a recognized testing body.

6.1.3 The following specifically considers coldsetting 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 ACS Head Office.

6.2 Description

6.2.1 A description of the adhesive shall 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)

6.2.2 In the case of adhesive films with backing, the backing material shall be specified.

6.3 Properties of the adhesive

6.3.1 In the processing state, the following information shall be provided:

- density (DIN EN ISO 1675)
- viscosity (DIN 53019)

6.3.2 In the case of two-component thermosetting resins which cure at room temperatures, the pot life (DIN 16945, Section 6.3) shall also be indicated.

6.4 Properties in the cured state

6.4.1 The following mechanical properties shall 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 EN 1465) shall 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.

6.4.2 The testing shall 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

6.4.3 For each test and conditioning state, specimens with adhesive layer thicknesses of 0,5 mm and 3 mm shall be used.

6.4.4 All tests shall all be carried out in a standard climate 23 °C / 50 % relative humidity. In addition, the tensile lap-shear strength shall be verified at 50 °C.

6.5 Minimum properties

6.5.1 The following properties shall 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

6.5.2 Strain in creep shall 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.

Section 3 Repair of Components

1 General

1.1 Requirements for operation and personnel

1.1.1 Repairs shall only be performed by workshops which are approved by ACS for the repair of components made from fiber-reinforced thermosetting resins.

1.1.2 The shop approval for manufacturing components made of fiber-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 shall only be carried out by persons with proven professional knowledge. This professional knowledge shall in general be verified by certificates of the corresponding training courses. If such certificates are not available, the minimum requirement shall 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 shall be named explicitly in the shop approval. His professional knowledge shall 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 ACS – is required.

1.1.5 The shop approval is granted by ACS Head office on the basis of the following information to be submitted:

- 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 shall be established and approved by ACS before the start at any repair work. If the same repair is to be carried out several times, a general repair plan can be established and submitted to ACS for approval.

1.2.2 Repairs to the gelcoat resin and (minor) repairs which do not fall under1. 2.1 shall be standardized and approved by ACS 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 shall be submitted to ACS. The repair plan will be examined by ACS Head Office 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 Only materials approved by ACS shall be used for the repair.

1.2.6 The thermosetting resins used for repair shall 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 fastsetting highly reactive thermosetting resins shall be avoided. Unless the original thermosetting resin is used, the elongation at break of the thermosetting resins used for the repair shall 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 shall 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, shall be removed from the area to be repaired.

2.1.2 The region adjacent to the damaged area shall be chamfered. The chamfer ratio (chamfer length ls to chamfer thickness ts) depends on the tensile strength of the repair material, σMat, in the chamfer direction, and the permissible shear stress τ. The minimum chamfer ratio shall be calculated by means of the following formula:

$$\frac{\pm_{Mat}}{2} = \frac{l_s}{t_s} x$$

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 shall 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 shall not be less than 10 mm on all sides.

2.1.4 Because of the required draping ability needed (for curved surfaces and in the chamfered joint area; see Fig. 2.1), the weight per unit area of the reinforcing materials used for repair work shall, as far as possible, not 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).

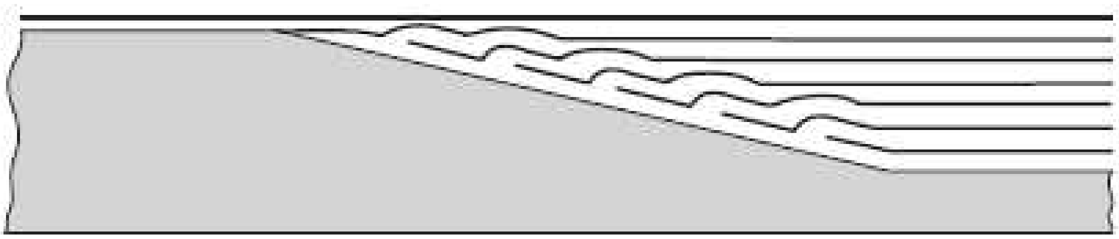


Fig. 2.1 Chamfered joint area for a repair (schematic)

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 shall 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 shall be dried properly before repair work is started.

2.1.8 As far as possible, the area to be repaired shall be relieved of the stress caused by its own weight. In the case of repairs performed in the field, special arrangements shall 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 shall 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 shall be taken against moisture as well as direct UV radiation.

2.1.11 The component temperature, at least within the repair area, shall be kept within the range permitted in 2.2.1.

2.1.12 The mixing ratio of resin to hardener shall 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 shall 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 % shall be maintained. If the resin or adhesive manufacturer has not specified other permissible values, these values shall apply.

2.2.2 Calibrated thermometers and hygrometers shall be used for monitoring in the vicinity of the repair or at a position agreed upon with ACS.

2.2.3 It shall 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 shall 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 fiber orientation shall be identical.

2.2.5 Attention shall be paid to providing good impregnation of the reinforcing material. Voids shall be avoided.

2.2.6 A mat or fabric with a weight per unit area of approx. 225 g/m2 maximum 450 g/m2 for boats) and a low percentage fiber weight content (approx. 30 %) shall be used as the final layer.

2.2.7 The laminate shall 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 shall 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 shall be ensured that no changes in elongation take place in the laminate.

2.3.2 Repaired components shall only 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 shall 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 shall also 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 shall at least 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.

4 Enclosures

- Example of a repair report
- Example of an survey report

Chapter 11 Nonmetallic Materials, Wooden Materials

Section 1 Requirements for Materials, Bonding Methods and Wood Protection

1 General

1.1 Classification according to the field of application

1.1.1 Only proven boatbuilding wood shall 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.

1.1.2 For components not exposed to water or weather, and not requiring strength, timber of lower durability may be used.

1.2 Quality

The timber used in boatbuilding shall be long-grained and of the best quality, i. e. be free from sap, shakes, objectionable knots and other defects. Twisted-grown or rough saw cut wood shall not be used.

1.3 Drying

1.3.1 The timber used shall be well seasoned and sufficiently dried, or shall be correctly dried in a suitable drying kiln.

1.3.2 For this purpose, the timber shall be stacked in piles which are as small as possible, so that uniform drying is guaranteed.

1.3.3 In the case of forced drying, the residual moisture content shall not be more than 10 %. When processing, this content shall not exceed a maximum of 15 % as a result of hygroscopic behavior.

1.3.4 The moisture content shall 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 shall be done in accordance with DIN 52375 or ISO 9425.

2 Types of Wood and Classifications

2.1 Solid wood

2.1.1 Radially sawn timber shall mainly be used for boatbuilding. The angle of the annual rings to the lower sawn edge shall not be less than 45°.

2.1.2 Table 2.1 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

Table 2.1 Plywood strength groups

Timber type	Botanical	Density, air-dried Approx, [g/cm³]	Durability	Mean tensile strength of plywood Longitud. [N/mm²]	Transverse [N/mm²]
Strength group: F1 (for load bearing components					
Teak	Tectona grandis	0.64	I	≥ 40	≥ 30
Makoré	Dumoria hekelii	0.62	I	≥ 40	≥ 30
Douka	Dumoria Africana	0.62	I	≥ 40	≥ 30
Utile	Entandrophragma utile	0.57	II	≥ 40	≥ 30
Spele mahogany	Entandrophragma cylindricum	0.59	III	≥ 40	≥ 30
Oak	Quercus sp.	0.63	II	≥ 40	≥ 30
Strength group : F2 [1]					
Bigleaf mahogany	Switeniamacrophylla	0.49	II	< 40, but > 30	< 30, but > 20
Khaya mahogany	Khayaivorensis	0.45	II-III	< 40, but > 30	< 30, but > 20
Okumé (Gaboon)	Aucoumea klaineana	0.41	IV-V	< 40, but > 30	< 30, but > 20

1) Only for non-load bearing components

2.1.3 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.

2.1.4 In place of the timber listed in Table 2.1, other types can be used if the durability and the technological values are verified and are equivalent. The manufacturer shall always be responsible for the correct selection of the quality and type of wood.

Table 2.2 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	3	1.5 mm	2.6 mm
Over 6 to 10	5		
Over 10 to 15	7		
Over 15 to 20	7	1.5 mm	3.8 mm
Over 20 to 26	9		
Over 26 to 34	11		
Over 34 to 40	13		
Over 40 to 48	15		
Over 48 to 55	17		

2.1.5 Since wood has anisotropic material properties, these shall be taken into account during the design of the components. It shall 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 expansion.

2.1.6 The safety factors used in the strength calculations shall be agreed on in each case with ACS.

2.2 Plywood: General

2.2.1 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 shall consist exclusively of veneer layers.

2.2.2 The plywood panels consist of at least three veneers bonded transversely to each other (Table 2.2) by means of curable synthetic resin adhesives. The resistance of the adhesives to water and weather shall be demonstrated by long-term and outdoor testing. The number of veneer layers is dependent on the thickness and is defined in 3 and 4.

Grades

2.2.3 The plywood panels are divided into two grades AC I and AC II.

2.2.4 Both grades are identical with regard to required strengths, including resistance to adhesives. The only distinction is that the panels of grade AC I are suitable for use in one piece, whilst those of grade AC II may, because of non-permissible defects in the middle and outer layers, only be used separately after removal of the defects.

Panel dimensions

2.2.5 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.

2.2.6 The length of the panels is measured parallel to the grain of the outer layer, and is always specified first. The longitudinal and lateral tolerances are ±5 mm.

2.2.7 The permissible thickness deviation is:

up to 3 mm ±10 %

over 3 mm ±5 %, but maximum ±0,5 mm

Bonding

2.2.8 The plywood panels shall be bonded without flaws (BFU 100 in accordance with DIN 68705). For this purpose, compliance with all decisive factors such as wood moisture content, pressing power, pressing temperature, pressing duration, glue characteristics, charging etc. shall be observed continually and carefully.

At present, the following synthetically-based adhesives are approved by ACS for plywood production:

- Phenolic adhesive (including phenolic adhesive film)
- Melamine resin adhesives
- Resorcinol resin adhesives

2.2.9 If a new glue is used, then faultless, error-free handling and bonding shall be demonstrated to ACS as well as absolute resistance to water and boiling.

Structure and requirements

2.2.10 Different requirements apply to the structures and plywood panels used in boatbuilding as listed in 3.

Certificates

2.2.11 ACS issues certificates for tested and approved plywood panels, and these are handed over to the manufacturer and/or customer.

2.2.12 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.

2.2.13 Independent of the testing by ACS, 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.

Storage of the plywood panels

2.2.14 Finished plywood panels which are placed in storage shall be kept in closed rooms and stored horizontally.

2.2.15 The plywood panels shall only 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.

2.2.16 The individual piles shall be protected against moisture from one side by covering panels.

2.2.17 Non-compliance with these storage requirements can lead to previous tests being declared invalid.

Strength calculations

2.2.18 The safety factors used in the strength calculations shall be agreed on, in each case, with ACS.

3 Boatbuilding Plywood

3.1 General

3.1.1 All plywood components exposed to water and weather, or used in primary structural components (such as the deck, shell and bulkheads), shall be produced from boatbuilding plywood that has been tested and in compliance with 3.10.6.

3.1.2 Boatbuilding plywood consists of at least three veneers bonded crosswise together (Table 2.2) by means of curable synthetic-resin adhesives. The resistance of these adhesives to water and weather shall be demonstrated by long-term and outdoor testing.

3.1.3 As plywood can also be destroyed in suitable conditions by animal or plant pests, timber shall be used which offers a natural resistance.

3.1.4 Independent of the testing by ACS, 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.

3.1.5 The points listed in 2.2 shall be taken into account.

3.2 Structure

3.2.1 The selection of timber and the structure of the panels (number of veneer layers) shall 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 2.1) - with several thin inner layers of veneer shall 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.

3.2.2 In general, veneers of 1,5 mm thickness are used for the outer layers. However, efforts shall be made to use thicker outer layers because of the later reworking necessary in boatbuilding. However, their thickness shall not 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.

3.2.3 Only in special cases and with the explicit permission by ACS this restriction can be waived. Such plywood panels are then assigned to the strength group F2 and marked accordingly in the ACS stamp.

3.2.4 The following table gives a list of the required minimum number and thickness of the veneer layers:

3.2.5 The veneer layers shall be symmetrical around the middle layer, both with respect to the grain as well as to the thickness of the layers.

3.2.6 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.

3.2.7 For the production of boatbuilding plywood panels, only wood which is of the best quality, flawless, healthy, free from sap and spring wood shall be used for the outer and inner layers.

3.3 Veneer joints

3.3.1 The joints shall be sealed perfectly and shall bond the veneers to each other by butt joints. The joints shall be glued on a suitable joint bonding machine.

3.3.2 The strips of veneer of the outer layers shall be put together so that they match with regard to timber and colour.

3.3.3 Sealed joints between all layers are a precondition for boatbuilding plywood panels.

3.3.4 Paper or plastic adhesive strips may not be used to secure or repair inner veneer layers.

3.3.5 The joints of the different veneer layers shall be staggered.

3.3.6 Metal clamps used for securing purposes may only be positioned on the edges of the panels. They shall on no account remain on the panels when they are cut to standard dimensions.

3.4 Strength groups

3.4.1 With regard to their suitability for the production of boatbuilding plywood, the types of timber listed in Table 2.1 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.

3.4.2 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.

3.4.3 All boatbuilding plywood panels which are manufactured according to special specifications and conditions of the customer, or deviate from ACS requirements, are assigned to the appropriate group and stamped according to the plywood type.

3.4.4 Other types of wood may only be used for making plywood panels upon agreement with ACS. The manufacturer shall always remain responsible for the correct selection of the quality and type of wood.

3.5 Plywood grades

3.5.1 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.

3.5.2 The defects of grade II shall be limited to one third of the area of the panel. Two thirds of the panel shall be free of defects and suitable for use. The defects are identified during inspection by marking.

3.5.3 The visible side of the plywood panel shall be manufactured virtually without any defects and, furthermore, the quality, colour and grain shall be combined in such a manner that they match. The hidden surface may have small colour differences or slight blemishes which do not influence the strength of the panel.

3.6 Defects

3.6.1 The following wood and production defects are not permissible in the outer and inner veneer layers:

- any bonding defects
- loose contra-shaving wood; strongly curly grained, short-fibred wood growth at right angles to the run of the grain; cross-cut timber
- larger, more prominent wood discolouration or mould stains which tend to cause rot and all other defects which could have a noticeable affect on the strength of the panel
- wood discolouration on both sides, or strong glue bleeding on both sides
- loose black (dead) knots, holes, loose joints or blocking cracks in the veneer layers
- overlapping of the veneer layers (folding)

The following can be permitted:

- up to three healthy tight knots of 15 mm Φmaximum for each side of the panel
- up to three knots of 25 mm Φmaximum on each side of the panel which have been perfectly repaired
- 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.
- small local edge flaws up to 3 cm length do not have to be considered.

Only one of the 4 types of permissible defects shall be present.

3.7 Repairs

3.7.1 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 shall be carried out at the appropriate temperature under pressing power with a glue which is resistant to water and weather.

3.7.2 Shakes of up to 1/10 of the panel length and 1 mm width, and small knot holes up to 5 mm Φ may be repaired with wood putty of the same colour.

3.7.3 Wider shakes and defects of up to 1/10 of the panel length shall be bonded so that they are weather resistant.

In doing so, care shall be taken when fitting and selecting the strips such that they are from appropriate timber and have the same colour. The repair work shall be carried out under pressure in accordance with DIN 68705 BFU 100.

3.8 Surface treatment

3.8.1 After pressing, the plywood panels shall 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.

3.8.2 The outer layers of the plywood panels cut to their final dimensions shall be at least 1,0 mm (after the pressing and sanding) at the thinnest point. When sanding the panels, special care shall be taken to ensure that this requirement is met.

3.9 Panel dimensions

3.9.1 The dimensions of the plywood panels are specified by the customer if standard dimensions are not used.

3.10 Testing

3.10.1 General

3.10.1.1 In general, the finished boatbuilding plywood panels are tested and approved at the manufacturing shop by surveyor of ACS.

3.10.1.2 The inspection of finished plywood panels outside of the manufacturing shop is carried out by ACS only by way of exception and under stricter test conditions.

3.10.1.3 ACS reserves the right to also monitor the production of the plywood panels in the manufacturing shop.

3.10.2 Inspection of the plywood panels

3.10.2.1 The condition of all boatbuilding plywood panels is inspected and tested by ACS 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.

3.10.2.2 The plywood panels submitted to ACS for inspection shall be examined, pre-graded, finished and then divided into test batches or orders by the manufacturer prior to inspection by the ACS 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 shall not be plugged before the ACS inspection. The ACS surveyor will decide whether these defects can be corrected, or whether the panel shall be rejected or assigned to grade II.

3.10.3 Grading of the plywood panels

3.10.3.1 Grading of the panels shall be in accordance with the differences between grades I and II stipulated in 1.3.5. The panels are marked with the appropriate grade stamp.

3.10.4 Sampling

3.10.4.1 For the inspection of boatbuilding plywood panels, sample panels are taken from test batch intended for inspection and provided with a sample number.

3.10.4.2 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.

3.10.4.3 The required samples are prepared from these sample pieces, and again provided with the sample numbers of the test panel.

3.10.4.4 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.

3.10.4.5 The number of test panels is determined according to the following factors:

- If continuous inspections by ACS 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.
- It is sufficient to select approximately 2 % (by number) of the panels from the current production to be used as samples.
- It shall be ensured that the test panels cover all plywood thicknesses and types.

- If production problems occur, or if the ACS 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.
- If one or several test panels should exhibit inadequate values during the inspection, then an additional two panels from the same test batch shall be tested. If, once again, the minimum requirements are not satisfied during this inspection, then the complete test batch shall be rejected.

3.10.5 Sample type and quantity

From every test panel (or test strip) to be tested, the following samples shall be taken and prepared:

3.10.5.1 Two samples for the delamination test in order to determine, in accordance with DIN 53255, the bonding strength of the glue.

3.10.5.2 Eight samples in accordance with DIN 53255 for the adhesive tensile lap-shear test to check the delamination test. Simple tensile lap-shear samples shall be used in accordance with Fig. 3.1.

3.10.5.3 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.

3.10.5.4 Two kiln-dried samples for the determination of the moisture content of the plywood and the specific weight (apparent density) in accordance with ISO 3130.

3.10.6 Pre-treatment and testing of the samples

3.10.6.1 Glue bonding strength samples

3.10.6.1.1 Two delamination samples and eight tensile lap-shear samples are used for testing the bonding strength of the glue.

3.10.6.1.2 Before testing, these samples shall be subject to a boiling/drying alternation test and a short-time test BFU 100 in accordance with DIN 68705 and shall satisfy the test conditions of 3.10.6.1.3.

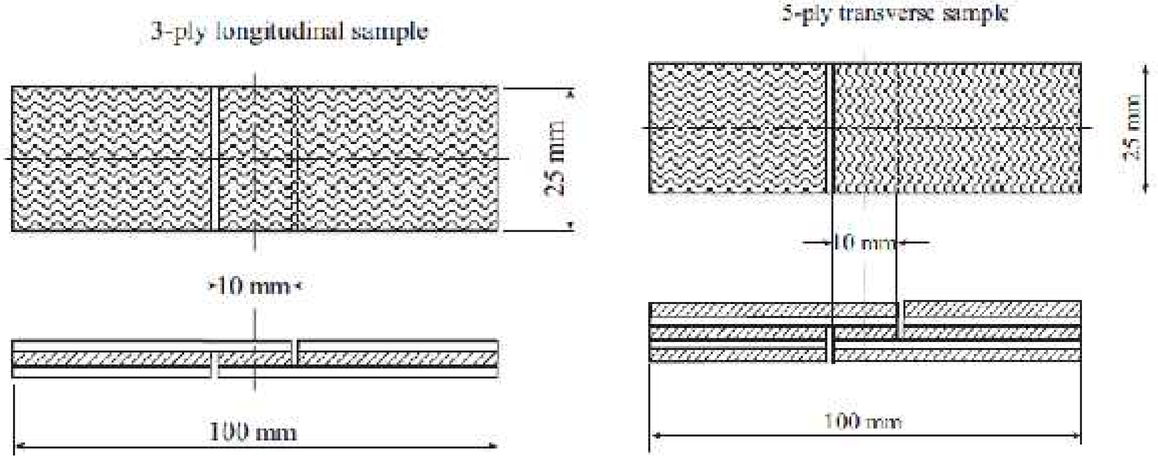


Fig. 3.1 Typical representation of a 3-ply longitudinal and a 5-ply transverse tensile lap-shear sample

3.10.6.1.3 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

3.10.6.1.4 The two delamination samples shall be subjected to a delamination test after this pre-treatment.

The bonding shall offer considerable resistance to the forceful delamination of the veneers by means of a delamination tool, and the fracture area shall exhibit wood fracture and flawless bonding (cf. fracture diagrams DIN 53255).

3.10.6.1.5 The eight tensile lap-shear samples shall 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

3.10.6.2 Plywood strength test

3.10.6.2.1 The six longitudinal tensile-strength samples and the six transverse tensile-strength samples shall undergo acclimatization prior to testing in the testing equipment and their moisture content shall be adjusted to 12 – 15 %.

3.10.6.2.2 From each of the six samples, three longitudinal and three transverse samples shall be tested in the testing machine and the average strength value determined for these three samples.

3.10.6.2.3 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.

3.10.6.2.4 The samples shall have the minimum plywood strengths as specified in Table 2.1.

3.10.6.2.5 Plywood made from other types of timber shall be included in the strength group with which its properties comply.

3.10.6.2.6 If the production and the plywood strength at a manufacturing shop is continually monitored by ACS 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.

3.10.6.2.7 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.

3.10.6.2.8 All boatbuilding plywood panels which are manufactured according to special specifications and conditions of the customers, or which deviate from ACS Rules, are stamped according to their plywood type and strength group. The deviations or special features of such plywood panels shall be recorded in the test certificate.

3.10.6.3 Moisture test

3.10.6.3.1 The two kiln-dried samples are used for determining the moisture content of plywood. They shall be examined in accordance with ISO 3130. The moisture content of the plywood shall be 5 – 12 % ex works.

3.10.6.3.2 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.

3.10.6.4 Determination of specific weight

3.10.6.4.1 For the determination of the specific weight of the plywood panels, the two kiln-dried samples shall be measured and weighed as precisely as possible in dry-air conditions before the kiln-drying.

3.10.6.5 Inspection of the plywood scarf jointing

3.10.6.5.1 The plywood scarf jointing shall be carried out in accordance with the conditions specified in 1.4.2.

and bonded with glues approved by ACS under pressing power and pressing temperature without any flaws. The bonding of the scarf joint shall 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 shall be performed for both sides of the panels.

3.10.6.6 Additional tests

3.10.6.6.1 If for any reason the ACS surveyor has any doubts regarding the production and in particular the bonding of the plywood panels and its scarf jointing, then he shall 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.

3.11 Marking and stamping

3.11.1 All boatbuilding plywood panels inspected by ACS surveyors and found to be in order shall 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 ACS:
- a rectangular ACS stamp, with the following details:
- boatbuilding plywood
- strength group
- plywood grade I (or II)
- ACS
- testing date
- respective certificate

As a rule, the stamping shall be applied on the bottom right of that side of the panel which is of lesser quality (i. e. on the back).

3.11.2 In the case of long scarf-jointed panels, the ACS stamp shall be made on both ends of the panel.

3.11.3 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.

3.12 Certificates

3.12.1 ACS issues certificates for boatbuilding plywood panels which have been tested and approved, and these certificates are given to the manufacturer or customer.

3.12.2 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.

3.13 Storage of the plywood panels

3.13.1 Finished plywood panels which are placed in storage shall be kept in closed rooms and stored horizontally.

3.13.2 The plywood panels shall only 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.

3.13.3 The individual stacks shall be protected against moisture from one side by covering panels.

3.13.4 Non-compliance with these storage requirements can lead to previous tests being declared invalid.

4 Joining of Wood Materials

4.1 Laminated and multilayered components

4.1.1 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.

4.1.2 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 shall not exceed 25 mm in the case of curved parts. In the case of straight parts, the laminate thickness shall not be more than 40 mm.

4.1.3 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 . 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.

4.1.4 The moisture of the wood shall be 12 –15 % at the time of bonding; but must not exceed 18 %. Efforts shall be made to keep the glued joint as thin as possible (0,1 – 0,2 mm).

4.1.5 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.

4.1.6 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.

4.1.7 Sufficiently long clamping times shall be adhered to, depending on the bonding temperature. In the case of curved or welded parts, the clamping time shall be extended accordingly.

4.2 Scarf jointing

4.2.1 The joint ends shall be precisely joined in order to avoid faulty gluing or other defects.

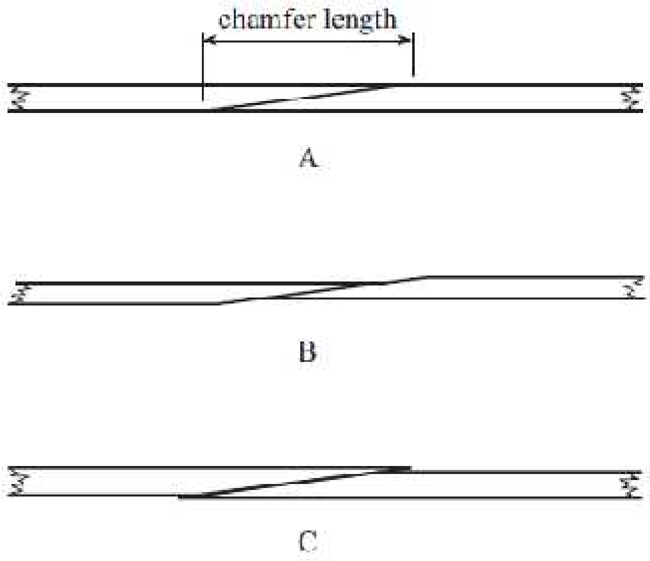


Fig. 4.1 Scarf joints across the thickness

4.2.2 Fig. A illustrates the correct method. Fig. B depicts the incorrect method; it is especially unsuitable, as faulty gluing occurs frequently because of insufficient pressing power. The method illustrated in Fig. 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.

4.2.3 The minimum pressing power shall not fall below 4 kg/cm^2.

4.2.4 Glued scarf-jointing of solid wood shall have a chamfer length which is eight times the panel thickness.

4.2.5 For glued scarf-jointing of plywood, the ratio of the plywood thickness to chamfer length shall be as follows:

- for panels up to 10 mm: at least 1:10
- for panels over 10 mm: at least 1:8

5 Wood Protection

5.1 All timber (with the exception of the timber of the durability group I, Table 2.1) shall 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 vapour pressure.

5.2 All plywood parts shall be protected by several coats of paint or varnish. Special attention shall be paid to plywood edges and drill-holes by pretreating them with recognized and proven edge protection coatings.

Section 2 Requirements for the Core Materials of Sandwich Laminates

1 Cross-Cut Balsa Wood

1.1 General

1.1.1 For material approval, the basic conditions listed in Chapter 10 shall apply.

1.1.2 A general description of the core material shall be provided. The basic properties shall be verified through the test certificate of a recognized testing body.

1.2 Specification

1.2.1 The following details are required for a general description:

- commercial name
- treatment of the wood
- storage conditions

1.2.2 Through the test certificate of a recognized testing body, the following values shall be verified:

- raw density (DIN 52182), 3 samples
- moisture content (ISO 3130), 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

(where: II is parallel to the grain, and

⊥is perpendicular to the grain of the wood)

1.2.3 The following shall apply as minimum properties:

- apparent density	96 kg/m^3
- compressive strength II	5.0 MPa
- compressive strength ⊥	0.4 MPa
- modulus of elasticity (compression) II	2275 MPa
- modulus of elasticity (compression)	35 MPa
- shear strength	1.1 MPa
- shear modulus	105 MPa

1.2.4 The moisture content shall be 12 ± 2 %.

1.2.5 The tests shall 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) shall be used.

Chapter 12 Equipment

Section 1 Anchors

1 General

1.1 These Rules apply to anchors made of forged or cast steel as well as to anchors made of welded components. They are also applicable to the repair of damaged anchors.

Anchor manufacturers and repair shops shall meet the requirements according to Chapters 1 and 2.

The term "anchor" also covers the connecting components which are fixed thereto, such as the anchor shanks, the swivel shackle and also the bolts.

1.2 Anchors conforming to these Rules are divided into three categories according to their holding power:

Category 1: Anchors with normal holding power

Category 2: Anchors with high holding power (HHP anchors)

Category 3: Anchors with very high holding power (VHHP anchors)

1.3 The use of these Rules for the mooring anchors of floating docks and offshore equipment may be agreed.

2 Design and Tests

2.1 The design of the anchors shall be approved by ACS.

To this end, the anchor manufacturer shall submit to ACS 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 shall be designed to withstand at least the test loads of the appropriate anchors.

2.3 Anchors with a high holding power (HHP anchors) may only be used in conjunction with AC-K2 or AC-K3 chains and those with a very high holding power (VHHP anchors) only in conjunction with AC-K3 chains.

2.4 HHP anchors and VHHP anchors and also swivel shackles which are regarded as part of the anchor shall be subjected to a type test in the presence of the Surveyor. In the case of swivel shackles, the proof and breaking loads shall also be demonstrated in accordance with Section 2, Table 1.7.

The scope of the tests performed, including the tests on the HHP and VHHP anchors shall be agreed on a case by case basis between the manufacturers and ACS. This applies particularly to SHHP anchors (anchors with super high holding power).

3 Materials for Anchors and Anchor Components

3.1 Forged anchor components such as shanks and crowns shall be made of weldable carbon or carbon manganese steels with a carbon content not exceeding 0,22 % and shall meet the requirements set out in Chapter 5.

If swivels shall be welded directly to the anchor a welding procedure test in the presence of the Surveyor shall be carried out before hand.

3.2 Cast anchor components such as shanks and crowns shall be made of weldable carbon or carbon manganese cast steel and shall meet the requirements set out in Chapter 4.

3.3 Rolled steels for the manufacture of anchors of welded construction shall be made of weldable steel and shall meet the requirements specified in Chapter 3.

3.4 The choice of material for shackles, swivel shackles, bolts and other connecting components is left to the manufacturer. In this case, the components shall be cast or hot-formed into a form approaching the final dimensions, with a small machining allowance. Excessive machining, such as turning a swivel body made of round steel to a smaller pin diameter is not permitted. All parts shall be produced with the maximum fillet radii possible. Threads shall be produced in such a way that they cannot cause notch effects at their runout.

4 Testing of Materials

4.1 For all anchor components, the anchor manufacturer shall provide the Surveyor with certificates, issued by the manufacturer of the material or fittings, indicating the chemical composition, the heat treatment condition or the condition on delivery, the heat number and the results of the mechanical tests performed on the components.

4.2 All cast steel parts shall be subjected, in the presence of the Surveyor, to a material test as set out in Chapter 4.

Special requirements apply to SHHP anchors, for which the notched bar impact test performed on Charpy V-notch specimens is to be carried out at a test temperature of 0 °C. An impact energy of at least 27 J is to be proven.

4.3 The dimensions of integrally cast specimens is 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 according to Chapter 5.

5 Characteristics of the Anchors

5.1 All anchors shall be free from defects liable to impair their function, e.g. cracks, major casting and forging defects and improperly executed welds.

5.2 After testing at the test load specified in 6, anchors may not reveal any permanent deformations.

In addition, in the case of anchors of composite construction, the freedom of movement of the arms over the whole angle of deflection shall be preserved following the test, and no excessive changes may be caused by deformation of the bearings.

6 Testing of Anchors

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 Non-destructive tests

6.2.1 Before the load test all anchors are to be visually inspected by the manufacturer as well as tested for surface defects and cracks in highly stressed areas of the palms by means of magnetic particle test. If no other requirements regarding quality have been agreed between the orderer and manufacturer, quality level 2 according to EN 12454 is applicable for the visual inspection and quality levels SM2, LM2 and AM2 according to EN 1369 are applicable for the magnetic particle test.

6.2.2 Any defects and/or cracks are to be removed by grinding or welding according to requirements of Chapter 4. In any case the repaired areas have to be retested prior to the load test.

6.2.3 In addition ultrasonic tests have to be carried out with HHP and VHHP anchors in way of cut risers and gating systems and in way of repair welding. On this quality requirements according to EN 12680-1 have to be agreed between orderer and manufacturer considering geometric conditions. If not otherwise agreed, quality level 2 applies.

6.2.4 Weld seams of anchors of welded construction have to be tested according to ACS Rules, if not otherwise agreed between orderer and manufacturer. Highly stressed weld seams of HHP and VHHP anchors have to be tested according to the rules requirements.

6.3 Load test

6.3.1 Anchors with a total weight (including the stock) of 75 kg and over are to be subjected in the presence of a Surveyor to a load test at the appropriate loads shown in Table 1.1 using a calibrated testing machine approved by ACS.

6.3.2 In the case of large anchors weighing 15000 kg and over, other tests may be substituted for the load tests, if the available testing machine is incapable of producing the specified test load. The nature of these tests is to be agreed with ACS.

6.3.3 The test load shall be applied at a point on the arm or palm which, measured from the point of the palm, is located at one third of the distance from the point of the palm to the centre of the anchor crown. With stockless anchors, both arms are to be tested simultaneously in both end positions. In the case of stocked anchors, the test load is to be applied alternately to each arm.

6.3.4 The following anchor weights are to be applied in establishing the test loads in accordance with Table 6.1:

- stockless anchors: the total weight
- stocked anchors: the weight without the stock
- anchors with high holding power (HHP): a weight equal to 1.33 times the actual weight
- anchors with very high holding power (VHHP): a weight equal to 2.0 times the actual weight of the anchor
- mooring anchors: a weight equal to 1.33 times the actual weight, unless specified otherwise

Table 6.1 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, VHHP anchors and mooring anchors, the weight stated in the table is to be multiplied by appropriate factors, as required.

6.3.5 After the load test, anchors are to be submitted to the Surveyor for verification of their delivery condition. Verification comprises visual inspection according to 2. as well as surface crack testing. In case of anchors of composite construction the freedom of movement of the arms is to be demonstrated.

7 Marking

7.1 Anchors which have fulfilled the test conditions are to be marked by the manufacturer as follows:

- manufacturer's symbol
- number of the ACS test certificate
- month and year of test
- total weight
- weight of stock (in the case of stocked anchors)
- the letters HHP in the case of anchors with high holding power
- the letters VHHP in the case of anchors with very high holding power

7.2 The marks are to be impressed with punches on the anchor shank and on the right palm (line of sight anchor base to shackle) as shown in Fig. 7.1.

7.3 For anchors which have met the requirements according to 6. An acceptance test certificate will be issued.

This shall specify at least the following:

- manufacturer
- type of anchor
- total weight
- material
- anchor shank number
- anchor shackle number, where necessary palm marking
- test load
- anchor stamping

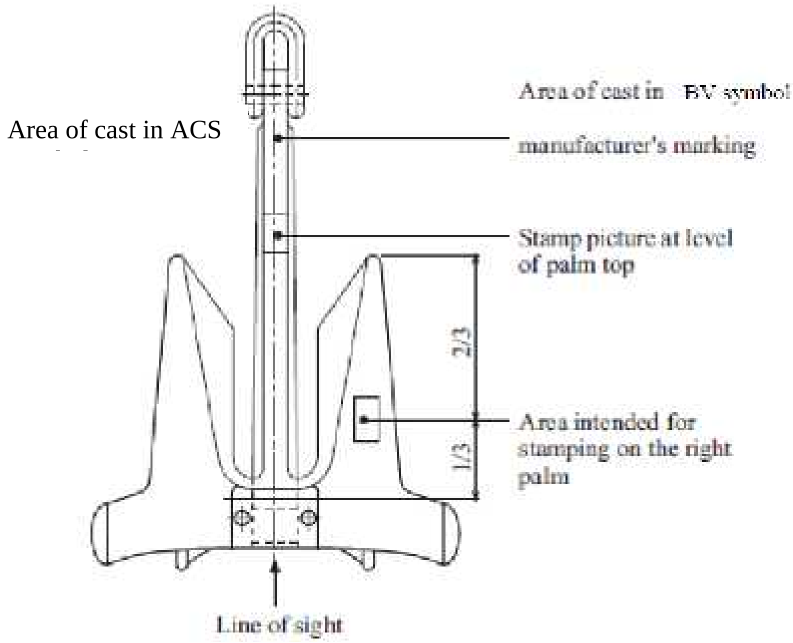


Fig. 7.1 Marking of anchors

8 Repair and Testing of Damaged Anchors

8.1 Damaged anchors may be repaired by straightening and/or welding, provided that the Surveyor approves the method used. Straightening shall be performed hot.

8.2 Welds are to be executed, preferably in the horizontal position and with the welding area preheated accordingly, by certified welders using approved electrodes. After welding, the anchor component concerned is to be stress-relieved. Welds shall be free from defects liable to impair the function of the anchor, e.g. cracks, slag inclusions, serious undercutting and lack of fusion.

8.3 Where welds are performed on steel castings, the requirements specified in Chapter 4 are also to be complied with.

8.4 Repaired anchors are to be retested in accordance with 6.

Section 2 Chain Cables and Accessories

1. Anchor Chain Cables and Accessories

1.1 General rules

1.1.1 Scope

These Rules are applicable to the materials, design, manufacture and testing of stud link chain cables and accessories for ships. Where short-linked studless chain cables are used in exceptional cases with ACS's approval, they shall comply with a recognized standard. For connecting components fixed to the anchor Section 1 is applicable.

1.1.2 Chain cable grades

Depending on the nominal strength of the steel used to manufacture the chain cable, stud link chain cables are classified into the grades AC-K1, AC-K2 and AC-K3.

1.1.3 Approval of chain cable manufacturers

1.1.3.1 Anchor chain cables and accessories may only be manufactured by works approved by ACS.

1.1.3.2 For non-standard accessories, the drawings shall be submitted to ACS for approval.

1.2 Chain cable materials

1.2.1 Scope

1.2.2 Requirements to be met by material manufacturers

1.2.2.1 All materials for the manufacture of anchor chain cables and accessories may only be supplied by manufacturers approved by ACS. Approval tests shall be conducted for this purpose.

1.2.2.2 The manufacturers of the materials or the anchor chain cables shall submit to ACS specifications of the materials to be used.

1.2.2.3 The material specification shall contain all the information required for its evaluation, such as the method of manufacture, method of deoxidation, nominal chemical composition, method of heat treatment and mechanical properties.

1.2.2.4 Rolled products, forgings and castings intended for the manufacture of anchor chain cables and accessories shall meet the required values for the mechanical properties according to Table 1.2.

1.2.3 Rolled steel bars

1.2.3.1 Manufacturing process

The steels shall be manufactured by the basic oxygen, electric furnace or open-hearth process. Grade AC-K1 chain cable steel shall be killed before pouring, while all other grades shall be killed and fine grain treated.

1.2.3.2 Condition of supply

Unless otherwise specified, the steels shall be supplied in rolled condition.

1.2.3.3 Chemical composition

Rolled steel bars are to be supplied with a certificate of the manufacturer about the chemical composition of each heat.

The chemical composition of the steels shall conform to the data in Table 1.1.

1.2.3.4 Testing of mechanical properties

The mechanical tests shall be performed at the chain cable manufacturer's premises. At the request of the chain cable manufacturer, the mechanical testing of the steel bars may be carried out at the rolling mill; the test sections shall be in a heat treated condition corresponding to that of the finished chain cable. In this case, the requirements specified in Table 1.1 shall be met.

1.2.3.5 Dimensional tolerances of rolled steels

The diameter and oval shape of rolled steels shall lie within the permitted dimensional tolerances shown in Table 1.3.

1.2.3.6 External and internal condition

The material shall be free from internal and surface defects which have more than an insignificant adverse effect on their proper working and use. Surface defects may be removed by grinding provided that the permitted tolerances are not exceeded.

Table 1.1 Chemical composition of rolled steel bars

Grade	Chemical composition (heat) [%]					
	C Max	Si	Mn	P Max.	S Max.	Al_{tot}[1] Min.
AC-K1	0,20	0,15 - 0,35	Min. 0,40	0,040	0,040	_
AC-K2[2]	0,24	0,15 - 0,55	Max. 1,60	0,035	0,035	0,020
AC-K3	According to the approved specification					

1) Aluminum may be partly replaced by other grain refining elements.

2) With ACS approval, additional alloying constituents may be added.

Table 1.2 Mechanical properties of chain cable materials

Grade	Yieldstrength R_eH[N/mm^2] Min	Tensile Strength R_m [N/mm^2]	Elongation A [%] in.	Reduction in area [%] Min.	Impact energy	
					Test temperature[^{0}C]	KV[1] [J] Min.
AC-K1	_	370-490	25	_	_	_
AC-K2	295	490-690	22	_	0	27 [2]
AC-K3	410	Min. 690	17	40	0	60
					(-20)	(35) [3]

1) Average value obtained with 3 specimens. One individual value may be below, but not less than 70 % of, the average value.

2) The notched bar impact test may be dispensed with for AC-K2 material if the chain cable is supplied in heat-treated condition.

3) Alternatively, the notched bar impact test may be performed at – 20 °C.

Table 1.3 Permitted tolerances applicable to the diameter and oval shapes of rolled chain cable steel

Nominal diameter [mm]	Diameter tolerance [mm]	Oval shape (d_{max} – d_{min}) [mm]
Below 25	-0 +1,0	0,6
25 – 35	-0 +1,2	0,8
36 – 50	-0 +1,6	1,1
51 – 80	-0 +2,0	1,5
81- 100	-0 +2,6	1,95
101 – 120	-0 +3,0	2,25
121 – 160	-0 +4,0	3,00

1.2.3.7 Identification of the material

The manufacturer shall have an identification system which enables the material to be traced back to its manufacture.

1.2.3.8 Testing

1.2.3.8.1 For the mechanical tests, the steel bars shall be sorted into heats and sizes and grouped into test batches weighing 50 t max. One test section shall be taken from each test batch for the tests stated in 1.2.3.8.3 and 1.2.3.8.4.

Before the test specimens are prepared, the test sections shall be subjected to the heat treatment intended for the finished chain cable, see Table 1.4. The details of the heat treatment shall be established by the manufacturer.

1.2.3.8.2 Tensile and notched bar impact test specimens shall be taken from the test section in the longitudinal

direction in such a way that the longitudinal axis is located at a distance of 1/6 of the diameter from the surface, see Fig. 1.1.

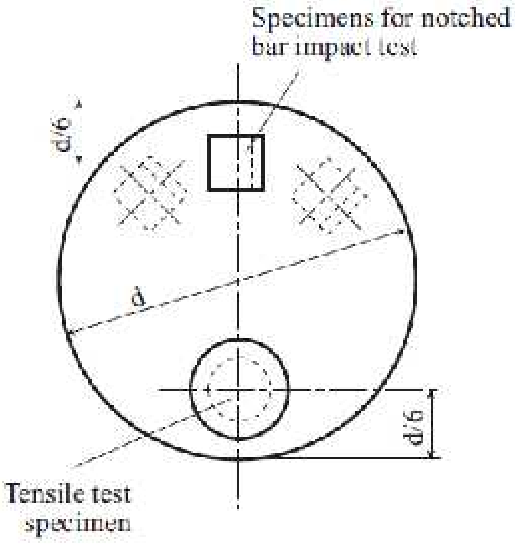


Fig. 1.1 Location of specimens in chain cable steel

1.2.3.8.3 For tensile testing, one specimen shall be taken from each test batch and tested in accordance with Chapters 1 and 2.

1.2.3.8.4 The notched bar impact test on steel bars of grade AC-K3 and, if necessary, grade AC-K2 shall be performed in accordance with Chapter 1 and 2. For this purpose, one set of 3 Charpy V-notch specimens is to be taken from each test batch and tested at the temperature specified in Table 1.2. The notch shall be located radially in the bar.

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

1.2.3.8.6 If specimens subjected to tensile or impact testing fail to meet the requirements, two new specimens or sets of specimens shall be tested for each unsatisfactory test. The specimens for the retests shall be taken from other samples of the same unit test quantity which were not the source of the test sections used for the first test. The unit test quantity is deemed to be accepted if both new specimens or sets of specimens have satisfied the requirements in the retest.

If the unsatisfactory test result is attributable to inadequate heat treatment, a fresh test section may be taken from the same sample and heat-treated again. In this case the entire testing (tensile and impact tests) shall be repeated, the first result being disregarded.

1.2.3.9 Marking

The steels shall be marked, as a minimum requirement, with the manufacturer’s symbol, the grade and an abbreviated designation for the heat. Steel bars up to 40 mm in diameter which are collected into bundles may be marked by means of a permanently attached tag.

1.2.3.10 Works acceptance certificate

For each delivery, the manufacturer shall give the Surveyor a certificate containing, as a minimum requirement, the following data:

- job and/or order no.
- quantity, dimensions and weight of delivery
- grade of steel
- heat number
- method of manufacture
- chemical analysis
- details of heat treatment of test section (where applicable)
- results of mechanical testing (where applicable)
- test specimen numbers (where applicable)

1.2.4 Forged steel

1.2.4.1 General requirements

Forgings intended for the manufacture of chain cables and accessories shall satisfy the requirements specified in Chapter 5, unless otherwise prescribed below.

1.2.4.2 Chemical composition

The chemical composition shall correspond to a specification approved by ACS. The steel manufacturer shall determine and certify the composition of every heat.

1.2.4.3 Condition of supply

The starting material may be supplied in either rolled or forged condition. Finished forgings shall be properly heat-treated, i.e. normalized, normalized and tempered or quenched and tempered.

1.2.4.4 Mechanical properties

Unless other requirements are prescribed according to the specification, the requirements shown in Table 1.2 shall, as a minimum requirement, be met after heat treatment has been carried out.

1.2.4.5 Mechanical tests

For the preparation of test specimens, forgings of approximately the same size which originate from the same heat and heat treatment batch shall be grouped into a test batch. One tensile test specimen and one set of 3 Charpy V-notch specimens shall be taken from every test batch and tested. For the location of the specimens, please refer to 1.2.3.8.2 and Fig. 1.1.

1.2.5 Steel castings

1.2.5.1 General requirements

Steel castings intended for the manufacture of chain cables and accessories shall satisfy the requirements specified in Chapter 4, unless otherwise prescribed below.

1.2.5.2 Chemical composition

The chemical composition shall correspond to a specification approved by ACS. The steel manufacturer shall determine and certify the composition of every heat.

1.2.5.3 Heat treatment

All steel castings shall be properly heat treated, i.e. normalized or quenched and tempered.

1.2.5.4 Mechanical properties

Unless other requirements are prescribed according to the specification, the requirements shown in Table 1.2 shall be met as a minimum requirement.

1.2.5.5 Mechanical tests

For the preparation of test specimens, castings of approximately the same size which originate from the same heat and heat treatment batch shall be grouped into a test batch. One tensile test specimen and one set of 3 Charpy V-notch specimens shall be taken from every test batch and tested.

1.2.6 Material for the studs of chain links

The studs of chain links shall be made of a type of steel which corresponds to the chain cable or of unalloyed rolled, forged or cast low-carbon steels. The use of other materials such as grey or nodular cast iron is not permitted.

1.3 Construction and manufacture

1.3.1 Method of manufacture

1.3.1.1 Stud link chain cables should preferably be manufactured by flash butt welding using rolled steel bars of grades AC-K1, AC-K2 or AC-K3.

Manufacture of the links by drop forging or steel casting is also permitted. On request, pressure butt welding may also be approved for studless chain cables made of grades AC-K1 and AC-K2, provided that the nominal diameter of the chain cable does not exceed 26 mm.

1.3.1.2 Accessories such as shackles, swivels and swivel shackles shall be forged or cast in steel of at least grade AC-K2. Welded constructions are subject to ACS approval.

1.3.2 Construction

Anchor chain cables shall be manufactured according to a standard recognized by ACS, e.g. ISO 1704. Conventional constructions of chain cable links are shown in Figs. 1.4, 1.5 and 1.6. A length of chain cable shall comprise an odd number of links. If the construction does not comply with this provision or if accessories are to be of welded construction, drawings giving full details of the manufacturing process and the method of heat treatment shall be submitted to ACS for approval.

1.3.3 Heat treatment

Depending on the grade of steel, chain cables shall be supplied in one of the conditions specified in Table 1.4. Heat treatments shall always be performed before the tests at proof and breaking loads.

Table 1.4 Heat treatment of chain cables

Grade	Condition of Supply
AC-K1 AC-K2[1]	Untreated or normalized after welding
AC-K2 AC-K3	Normalized, normalized and Tempered or quenched and tempered

1 Chain cables made of grade AC-K2 steel shall generally be normalized. ACS may waive this stipulation if it is proved by means of an approval test that the chain cables meet the requirements. An extended scope of testing may be prescribed for such chain cables.

1.3.4 Mechanical properties

The mechanical properties of the finished chain cable and accessories, i.e. tensile strength, elongation, reduction in area and impact energy, shall meet the requirements shown in Table 1.2.

1.3.5 Requirements applicable to proof and breaking loads

Chain cables and accessories shall be manufactured in such a way that they withstand the proof and breaking loads specified for the respective grade of steel in Table 1.7.

1.3.6 Freedom from defects

1.3.6.1 All individual parts shall have a high-quality surface consistent with the method of manufacture and free from cracks, notches, inclusions and other defects which restrict the use of the product. The flashes produced by upsetting and forging shall be properly removed, see 1.3.7.2.

1.3.6.2 Insignificant surface defects may be leveled by grinding so as to leave a gentle transition to the surrounding surface. Outside the bends of the links, localized grinding up to a depth of 5 % of the nominal diameter is permitted.

1.3.7 Dimensions and dimensional tolerances

1.3.7.1 The dimensions of shackles and swivels shall conform to a recognized standard. Conventional constructions are shown in Figs. 1.7 to 1.10.

1.3.7.2 The following tolerances are acceptable for links:

- Diameter in the area of the link bend (crown)

Up to 40 mm nominal diameter: –1 mm

Over 40 up to 84 mm nominal diameter: –2 mm

Over 84 up to 122 mm nominal diameter: –3 mm

Over 122 mm nominal diameter: –4 mm

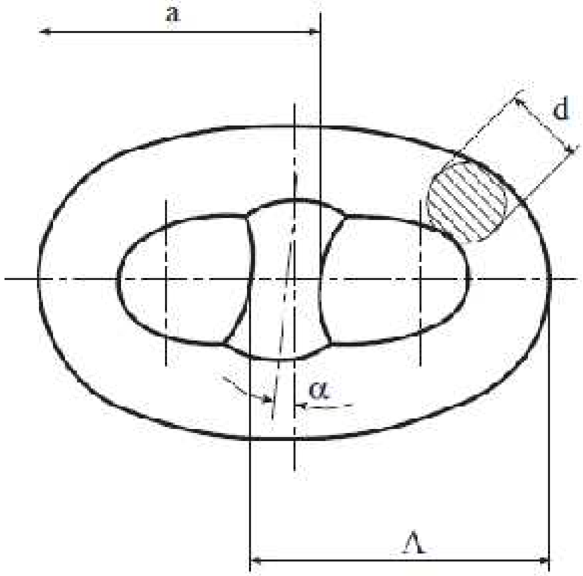
The plus tolerance may be up to 5 % of the nominal diameter. The link bend cross section may not have any negative tolerance.

- Diameter, measured at points outside the link bend (crown):

The diameter may not have a negative tolerance. The plus tolerance may be up to 5 % of the nominal diameter. The plus tolerance in the area of the reinforcement is subject to the chain cable manufacturer's production specification which shall be approved by ACS. (The plus tolerance shall not be more than 8 % of the nominal diameter).

- The maximum tolerance for the chain cable measured over a length of 5 links may be up to + 2,5 % but shall not assume a negative value. This applies to chain cables under 10 % initial load after proof loading.
- All other dimensions are subject to a manufacturing tolerance of up to ± 2,5 %, provided that all parts of the chain cable fit together properly.
- Studs shall be located in the links centrally and at right angles to the sides of the link. The studs of end links may be located off-centre to facilitate the insertion of the shackles. The following tolerances are regarded as being inherent in the method of manufacture and will not be objected to provided that the stud fits snugly and its ends lie practically flush against the inside of the link:
- maximum off-centre distance "X" = 10 % of nominal diameter d
- maximum deviation "α" from the 90° position: 4°

The deviations shall be measured in accordance with Fig. 1.2.



Off - centre distance: $X = \frac{A-a}{2}$

Fig. 1.2 Tolerances for stud position

1.3.7.3 The following dimensional tolerances are applicable to chain cable accessories:

nominal diameter: + 5 %, – 0 %

other dimensions: ± 2,5 %

1.3.8 Welding of studs

Welding of studs shall be carried out according to an approved process, subject to the following conditions:

- The studs shall be made of weldable steel, see 1.2.6.
- The studs may be welded at one end only, i.e. opposite the butt weld of the link. They shall lie against the sides of the links with no appreciable gap.
- The welds, preferably in the horizontal position, shall be executed by certified welders using suitable welding consumables.
- All welds shall be executed before the final heat treatment of the chain cable.
- The welds shall be free from defects liable to impair the use of the chain cable for its intended purpose. Undercuts, end craters and similar defects shall be ground off.

ACS reserves the right to call for a procedure test for the welding of the studs.

1.4 Testing of finished chain cables

1.4.1 Tests at proof and breaking loads

1.4.1.1 All chain cables are to be subjected to the following tests in the presence of the Surveyor. For this purpose, the chain cables shall be free from paint and anti-corrosion media. The test pieces shall not break and shall be free from cracks after testing.

1.4.1.2 Each chain cable length (27,5 m) is to be subjected to a loading test at the proof load appropriate to the particular chain cable as shown in Table 1.7, using an approved testing machine.

1.4.1.3 Sample links comprising three links in the quantity specified in Table 1.5 are to be taken from the chain cables. These are to be tested for at least 30 s at the breaking loads shown in Table 1.7. The links concerned shall be made in a single manufacturing cycle together with the chain cable and shall be welded and heat treated together with it. Only then may they be separated from the chain cable in the presence of the Surveyor.

1.4.1.4 If the tensile loading capacity of the testing machine is insufficient to apply the breaking load for chain cables of large diameter, another equivalent testing method shall be agreed with ACS.

1.4.2 Retests

1.4.2.1 Should a breaking load test fail, a further test specimen may be taken from the same length of chain cable and tested. The test shall be considered successful if the requirements are then satisfied.

1.4.2.2 If the retest fails, the length of chain cable concerned shall be rejected. On request of the manufacturer the remaining three lengths belonging to the test batch may then be individually subjected to test at the breaking load. If one such test fails to meet the requirements, the entire test batch of 4 lengths shall be rejected.

1.4.2.3 If a proof load test fails, the defective links are to be replaced; localized heat treatment of the new links shall then be carried out and the proof load test repeated. In addition, the causes of the failure are to be determined.

1.4.3 Testing of mechanical and technological properties of AC-K2 and AC-K3 chain cables

1.4.3.1 For AC-K3 and, where necessary, for AC-K2 chain cables, one tensile test specimen and one set of 3 Charpy V-notch specimens shall be taken from every fourth length of chain cable and tested. The specimens are to be taken from the parent metal on the side of the link opposite the weld, see also Table 1.5.

In addition, one set of Charpy V-notch specimens with the notch located in the weld shall be taken from AC-K3 chains and non-heat-treated AC-K2 chains and tested.

1.4.3.2 For preparing the test specimens, an additional link (or, where the chains are small, several additional links) shall be provided in a length of chain cable which is not used to supply a specimen for the breaking load test. The sample shall be manufactured and heat-treated together with the length of chain cable.

1.4.3.3 The mechanical properties and the impact energy shall meet the requirements shown in Table 1.6.

Table 1.5 Scope of mechanical and technological testing of finished chain cables

Grade	Method of manufacture	Heat treatment[1]	No. of test specimens from every 4^{th} length of chin cable			
			Breaking lead test[2]	Tensile test parent metal	Notched bar impact test	
					Parent metal	weld
AC-K1	Welding	None	1	–	–	–
AC-K2 AC-K2	Welding Welding	N None	1 1	– 1[2]	– 3	– 3
AC-K3	Welding	N, V	1	1[2]	3	3
AC-K2	Casting or forging	N	1	1	3	–
AC-K3	Casting or forging	N, V	1	1	3	–

1) Heat treatments: N = normalizing, V = quenching and tempering

2) ACS may additionally require a tensile test of the weld if there are doubts as to the characteristics of the chain cable.

Table 1.6 Mechanical properties of finished chain cables

Grade	Parent metal	Weld area		
		Elongation[1] A [%] Min.	Notched bar impact test	
			Test temperature [^{0}C]	Impact energy KV [J][2] Min.
AC-K1	The requirements specified Table 1.2 are to be met.	25	–	–
AC-K2		18	0	27
AC-K3		14	0	50
			(-20)	(27)[3]

1) The tensile strength and the yield strength shall conform to the requirements specified in Table 1.2. No value for the reduction in area is specified for grade AC-K3.

2) Average value obtained with 3 test specimens. One individual value may be lower than, but not less than 70 % of, this required average value.

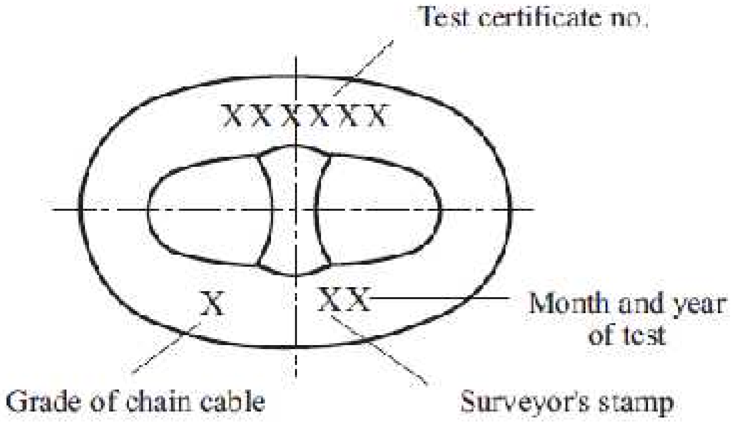
3) Alternatively, the notched bar impact test may be performed at – 20 °C, see Table 1.2.

1.5 Marking

Chain cables which have met the requirements shall be stamped on both end links of each length of chain cable with the following identifying marks, see Fig. 1.3:

- grade of chain cable
- test certificate number
- surveyor's stamp
- month and year of test

Fig. 1.3 Stamping of chain cables



1.6 Testing of accessories

1.6.1 Proof load test

All accessories are to be subjected to the proof load test at the proof load specified for the corresponding chain in Table 1.7.

1.6.2 Breaking load test

1.6.2.1 From each manufacturing batch (same heat, size and heat treatment) of 25 units or less of shackles, swivels, swivel shackles, large 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. Parts tested in this way may not be put to further use.

1.6.2.2 In the case of swivels and swivel and anchor shackles, ACS may waive the breaking load test if:

- The breaking load has been demonstrated on the occasion of the approval testing of parts of the same design;
- The parts are subjected to suitable nondestructive testing.

1.6.2.3 Contrary to the preceding provision, accessories may be used after the breaking load test if they are made of a material which has higher strength characteristics than those specified for the part in question (e.g. AC-K3 materials instead of AC-K2 materials).

1.6.3 Mechanical tests

The parts shall be subjected to mechanical tests in accordance with 1.2.4.5 and 1.2.5.5 in the Surveyor's presence, depending on the nature and grade of the material.

1.6.4 Marking

Accessories which meet the requirements shall be stamped as follows:

- chain cable grade
- test certificate number
- surveyor's stamp
- month and year of test

1.6.4.1 Dimensions for chain links, swivels and shackles (Figs. 1.4 to 1.10)

Note: All dimensions are given as a factor of the nominal diameter d of the standard link:

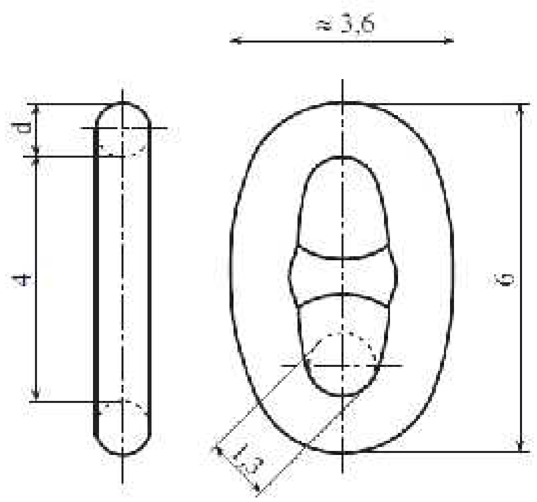


Fig. 1.4 Standard link

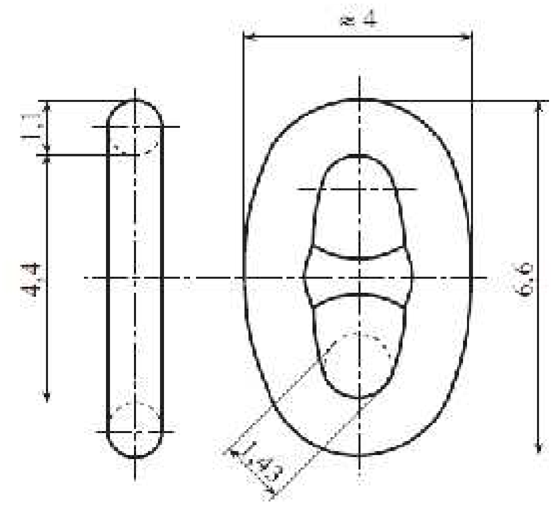


Fig. 1.5 Large link

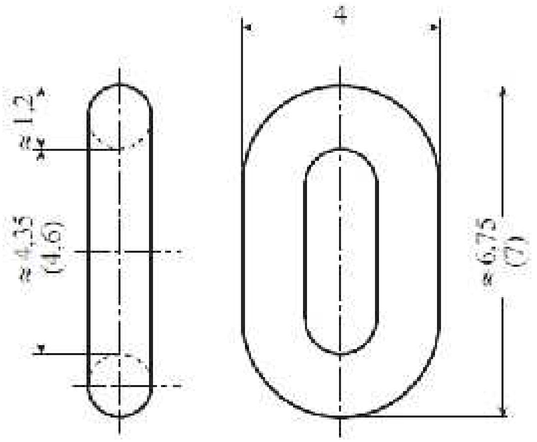


Fig. 1.6 Studless link

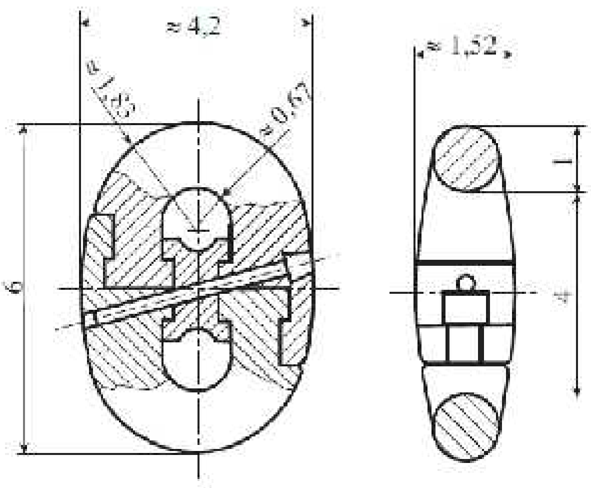


Fig. 1.7 Kenter shackle

Note: The dimensions in brackets may be chosen for studless links in fore runners.

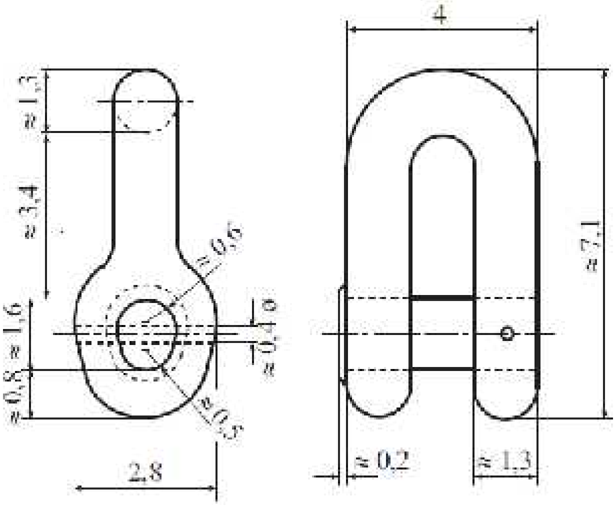


Fig. 1.8 Connecting shackle

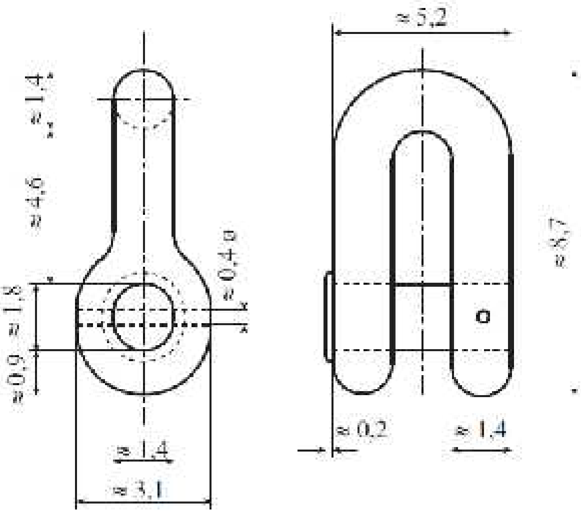


Fig. 1.9 End shackle

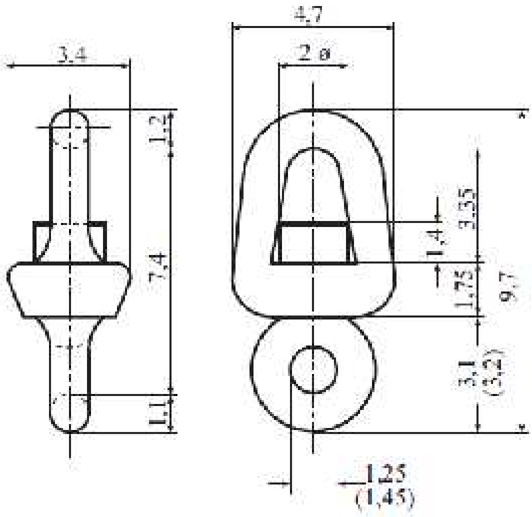


Fig. 1.10 Swivel

Note: All dimensions are given as a factor of the nominal diameter d of the standard link.

Table 1.7 Proof and breaking loads for stud link chain cables

Chain diameter [mm]	Grade AC-K1		Grade AC-K2		Grade AC-K3		Weight Kg/m[1]
	Proof load [KN]	Breaking load [KN]	Proof load [KN]	Breaking load [KN]	Proof load [KN]	Breaking load [KN]	
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
12,5	46	66	66	92	92	132	3,4
14	58	82	82	116	116	165	4,3
16	76	107	107	150	150	216	5,6
17,5	89	127	127	179	179	256	6,7
19	105	150	150	211	211	301	7,9
20,5	123	175	175	244	244	349	9,2
22	140	200	200	280	280	401	10,6
24	167	237	237	332	332	476	12,6
26	194	278	278	389	389	556	14,8
28	225	321	321	449	449	642	17,2
30	257	368	368	514	514	735	19,7
32	291	417	417	583	583	833	22,4
34	328	468	468	655	655	937	25,3
36	366	523	523	732	732	1050	28,4
38	406	581	581	812	812	1160	31,6
40	448	640	640	896	896	1280	35,0
42	492	703	703	981	981	1400	38,6
44	538	769	769	1080	1080	1540	42,2
46	585	837	837	1170	1170	1680	46,3
48	635	908	908	1270	1270	1810	50,4
50	696	981	981	1370	1370	1960	54,8
52	739	1060	1060	1480	1480	2110	59,2
54	794	1140	1140	1590	1590	2270	63,8
56	851	1220	1220	1710	1710	2430	68,7
58	909	1290	1290	1810	1810	2600	73,6
60	969	1380	1380	1940	1940	2770	78,8
62	1030	1470	1470	2060	2060	2940	84,2
64	1100	1560	1560	2190	2190	3130	89,7
66	1160	1660	1660	2310	2310	3300	95,4
68	1230	1750	1750	2450	2450	3500	101,3
70	1290	1840	1840	2580	2580	3690	107,3
73	1390	1990	1990	2790	2790	3990	116,7
76	1500	2150	2150	3010	3010	4300	126,5
78	1580	2260	2260	3160	3160	4500	133,2
81	1690	2410	2410	3380	3380	4820	143,7
84	1800	2580	2580	3610	3610	5160	154,5
87	1920	2750	2750	3850	3850	5500	165,8
90	2050	2920	2920	4090	4090	5840	177,4
92	2130	3040	3040	4260	4260	6080	185,4
95	226	3280	3280	4510	4510	6440	197,6

Table 1.7 Proof and breaking loads for stud link chain cables (continued)

Chain diameter [mm]	Grade AC-K1		Grade AC-K2		Grade AC-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**
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	441,0
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	506,3
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 .d2 (d in mm).

2 Chafing Chains for Emergency Towing Arrangements

2.1 Scope

These requirements apply to the chafing chains for chafing gear of two types of emergency towing arrangements with specified working load of 1000 kN (ETA1000) and 2000 kN (ETA2000). Chafing chains other than those specified here can be used subject to special agreement with ACS.

2.2 Approval of manufacturing

The chafing chain is to be manufactured by works approved by ACS.

2.3 Materials

The materials used for the manufacture of the chafing chain are to satisfy the requirements according to 2.2.

2.4 Design, manufacture, testing and certification of chafing chain

2.4.1 The chafing chain is to be designed, manufactured, tested and certified in accordance with the requirements 1.3 to 1.6.

2.4.2 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. 2.1.

The common link is to be of stud link type grade AC-K2 or AC-K3.

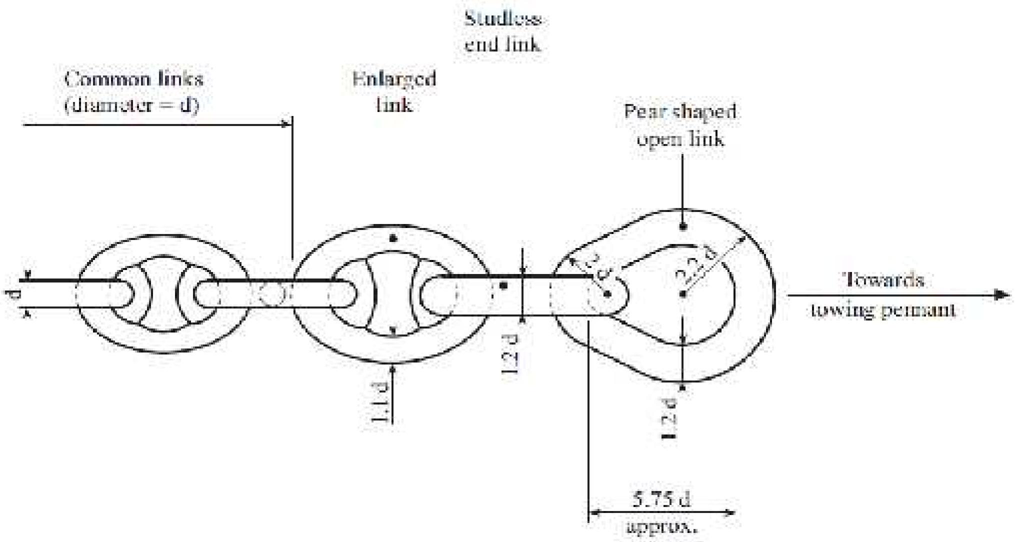
The chafing chain is to be able to withstand a breaking load not less than twice the working load.

For each type of emergency towing arrangement, the nominal diameter of common link for chafing chains is to comply with the value indicated in Table 1.8

Table 1.8 Nominal diameter of common link

Type of ETA	Nominal diameter of common link, d min.	
	Grade 2	Grade 3
ETA 1000	62 mm	52 mm
ETA 2000	90 mm	76 mm

Fig. 2.1 Typical outboard chafing chain end



Section 3 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 shall meet the requirements stated in Chapters of 1 and 2 and shall be approved by ACS.

2.2 Applications for approval are to be submitted to ACS in writing with a description containing at least the following details:

- type, composition and strengths of the ropes concerned
- manufacturing facilities
- testing equipment: copies of the last calibration reports on the testing machines are to be attached

By a works inspection, the manufacturer shall demonstrate the availability of the equipment necessary for the proper manufacture and testing of wire ropes. ACS reserve 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 ACS for the independent testing of wire ropes, this shall also be applied for. ACS will allocate to the manufacturer a special identification number if the conditions for approval are satisfied.

3 Manufacture

3.1 The ropes shall conform to recognized national or international standards (DIN 3057 to DIN 3060, DIN 3064 to DIN 3066 and ISO 2408) and should wherever possible, comply with Table 4.1. Ropes of a different construction and ropes with high nominal breaking strengths, e.g. 1960 N/mm^2, or containing austenitic stainless steel wires may be approved on application provided that they are suitable for the proposed application.

3.2 With the exception of wire ropes made of austenitic stainless steel wires, wire ropes shall normally be manufactured from individually galvanized wires. The use of ungalvanized wires requires the special consent of ACS.

4 Requirements Applied to Wire Ropes

4.1 Nominal breaking strength

Wire ropes shall have the nominal breaking strengths of 1570 and 1770 N/mm^2 specified in Table 4.1.

These values shall not be exceeded by more than the values shown in Table 4.2.

4.2 Ductility

Individual wires shall possess sufficient ductility, measured by their ability to withstand a fixed number of reverse bends and/or twists without starting to crack. These requirements are regarded as fulfilled if the values specified in DIN EN 10264, or in an equivalent standard recognized by ACS are achieved.

4.3 Tolerance on diameter

The tolerance on the diameter of rope wires shall lie within the limits specified in recognized standards, e.g. in DIN EN 10264.

4.4 Galvanizing method

Hawsers and standing rigging shall be manufactured from fully galvanized wires. Normally galvanized wires may be used for all other ropes. The zinc coating shall conform to the data shown in Table 4.3

5 Testing of Wire Ropes

The following tests are to be performed:

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 chemically stripping the coating and measuring the weight loss of the stripped wires according to a recognized method, e.g. in accordance with DIN 51213. Wires of the various diameters shall be removed from the rope for this purpose. ACS reserve the right to repeat this test in case of doubt.

Table 4.1 Usual types of wire ropes approved by ACS

Use	Structure of rope			Construction of strands	Nominal breaking strength [N/mm^2]	Galvanizing method
	Number of strands	Number of wires per strand	Type of rope core			
Standing rigging	6 6	7 19[1]	1fibre or steel core	Standard	1570 And 1770	Fully galvanizing
Hawers (towlines, mooring lines)	6 6 6 6 6	19 } 37 } 24 19 } 36 }	I fibre core (7fibre cores) 1 steel core	Standard Seale or Warrington. Warnigton-Seale	1570	Fully galvanized
Running rigging	6 6 6	36 } 37 } 24	I fibre or steel core 7fibre cores	Warington 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 4.2 Positive tolerances for nominal breaking strengths

Normal 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

5.1.2 The adhesion of the zinc coating shall be verified by the winding test, e.g. to DIN 51215. For this purpose, the wires shall be wound as follows on to a test mandrel of the diameter specified in Table 5.1 so as to form at least 10 adjacent turns. The zinc coating shall continue to adhere firmly to the substrate after winding. At least 5 wires of each size shall be tested.

Table 4.3 Zinc coatings

Normal 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

Table 5.1 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 shall be tested either by the reverse bend test or by the twisting test specified in a recognized standard, e.g. DIN 51211 or DIN 51212. All the wires constituting a strand taken from the rope shall be subjected to this test. The test is considered successful if at least 95 % of the wires withstand the bend or twisting test specified in the relevant standard without breaking.

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 shall be equal to 30 times the diameter of the rope, subject to a minimum of 600 mm. The minimum breaking load shall achieve the value specified for the rope in question in the standard. In the case of manufactured lengths of more than 10000 m, a second test sample is to be taken and tested.

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 shall be determined from the results of tests performed on the individual wires. For this purpose a strand is to be taken from every manufactured length of rope of 5000 m or less, and its constituent wires shall be individually subjected to the tensile test, e.g. to EN 12385. The wire test specimens shall have an initial measured length of 100 or 200 mm. The tensile strength is determined on the basis of the nominal wire diameter.

The test shall be deemed successful if at least 95 % of the rope wires meet the requirements stated in 3.4.1 and the calculated breaking load achieves the values specified in the relevant standard. For this purpose, the individual test values are to be applied to the total number of wires in the rope and multiplied by the realization factor shown in Table 5.2.

5.4 Dimensional check

The diameter of each rope is to be measured at two points located at least 1 m apart in two directions approximately perpendicular to each other. The difference between the smallest and the largest result may not be more than 4 %. The average value of the four measurements shall be considered to be the actual rope diameter and shall lie within the permitted tolerances. The number and diameter of the individual wires shall also be verified.

Table 5.2 Realization factors

Rope construction	Ropes with fibre core	Ropes with steel core
6 × 7	0,9000	0,8379
6 × 19	0,8600	0,8007
6 × 24	0,8700	–
6 × 36	0,8400	0,7821
6 × 37	0,8250	0,7681

6 Verification of Characteristics

6.1 Companies which have been approved by ACS for the independent performance of tests may test wire ropes at their own responsibility. The result of the test shall be certified on a form prescribed by ACS.

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 coloured threads as follows for the purpose of distinguishing

The nominal strength of the wires:

Nominal strength 1570 N/ mm^2: white

Nominal strength 1770 N/ mm^2: green

Nominal strength 1960 N/mm^2: yellow

For special rope constructions in accordance with 3.3.1., the colour of the distinguishing thread shall be specially designated.

7.2 A tape shall also be worked into the ropes bearing the manufacturer's name and, in the case of companies approved by ACS for independent testing, the identification number allocated by ACS. The coloured distinguishing thread may be dispensed with if the tape designating the company is of the colour 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 ACS stamp:

Section 4 Fiber 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 shall meet the requirements stated in Chapters 1 and 2 and shall be approved by ACS.

2.2 Applications for approval are to be submitted to ACS in writing with a description containing at least the following details:

- type, composition and material of the ropes concerned
- manufacturing facilities
- testing equipment: copies of the last calibration reports on the testing machines are to be attached

By a work's inspection, the manufacturer shall demonstrate the availability of the equipment necessary for the proper manufacture and testing of fibre ropes. ACS reserve 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 ACS for the independent testing of fibre ropes (see 5), this shall also be applied for. ACS 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 type, material and structure of the ropes shall conform to a national or international standard recognized by ACS and should, wherever possible, comply with Table 3.1. Ropes of a different type may be approved on application provided that they are suitable for the proposed application.

Table 3.1 Construction of customary rope types approved by ACS

Rope Standards	Material	Rope constructionDIN 83305,Part 1		corresponding ISO-standards[1]
		From	Construction	
DIN-EN 698	Manila	A, B	Hawser laid	1181
DIN-En 698	Sisal	A, B	Hawser laid	1181
DIN-EN 1261	Hemp	A, B, C	Hawser laid cable laid	-
DIN-EN 696	Ployamide	A	Hawser laid	1140
DIN-EN 697	Polyester	A	Hawser laid	1140
DIN-EN 699	Polypropylene	A, B	Hawser laid	R 1346[2]

1) These standards are only applicable to form A ropes.

2) Data only for "3-strand hawser laid" with the same values.

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 ACS.

3.3 Ropes may normally comprise only one material. Excepted from this rule, and approved by ACS, 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 fiber ropes shall fulfill the requirements specified in the standards recognized by ACS.

These include for example: DIN-EN 701 and the complementary DIN and ISO standards mentioned therein, see Table 3.1

5 Testing the Breaking Load of Ropes

5.1 Test method (See EN 919, and ISO 2307)

The breaking load of ropes shall normally be determined by applying a tensile test to destruction to entire test sections of the rope in accordance with 5.3. 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 5.4. This applies, however, only to those ropes whose maximum loading capacity exceeds 30000 daN and for which reduction factors are given in Table 5.1

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 shall be taken from the test lengths:

- test lengths up to 2200 m (or 10 ropes up to 220 m long):
- 1 test section
- excess test lengths up to 30000 m:
- 1 additional test section per 5500 m
- excess test lengths over 30000 m:
- 1 additional test section per 11000 m

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 shall 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 shall be taken from the test sections specified in 5.2. which shall be equal to half the numerical value of the rope diameter in mm, and these shall be subjected to a tensile test. In taking the test specimens, attention shall be paid to the following:

The yarns shall be taken evenly from the outside, middle and inside positions of the strands of the rope.

When taking the yarns, care is to be taken not to alter the twist of the yarns.

5.4.2 The yarns shall 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:

$$F_{SR} = F_G \times n \times r$$

F_G = average breaking load of yarn [daN]

n = number of rope yarns in specimen

r = reduction factor in accordance with Table 5.1

The breaking load of the rope determined in this way shall at least 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.

Table 5.1 Reduction factors

Norminal diameter of rope [mm]	Reduction factor's r for ropes					
	Of natural fibres			Of synthetic fibres		
	Manila,sisal or hemp rope (DIN EN 698 Or DIN EN 1261) Form			Polyamide rope (DIN EN 696) Form	Polyester rope (DIN EN 697) Form	Polypropylene Rope (DIN EN 696) Form
	A	B	C	A	A	A
44				0.68	_	_
48	_	_	_	0.68	0.51	0.82
52	_	_	_	0.68	0.51	0.82
56	_	_	_	0.68	0.50	0.82
60	_	_	_	0.68	0.49	0.82
64	_	_	_	0.67	0.48	0.81
72	0.58		_	0.67	0.48	0.81
80	0.58		_	0.66	0.48	0.80
88	0.57		_	0.66	0.48	0.80
96	0.57			0.65	0.47	0.80

6 Verification of the Properties

6.1 The manufacturers of yarn and rope shall constantly monitor the characteristics of their products and shall ensure that the products meet the requirements specified in the standards. The manufacturers shall keep records of their quality control and shall present these to ACS 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 shall demonstrate at least once a year in the presence of a Surveyor of ACS that he is capable of manufacturing rope with the specified reduction factors. This shall be demonstrated by the tensile test on a test section described in 5.3.

6.3 Rope manufacturers who have been approved by ACS for the independent performance of tests may themselves test the breaking load using the methods described in E. They shall certify the results on a printed form prescribed by ACS. These forms are obtainable from ACS.

7 Marking

7.1 A tape indicating the rope standard designation and the manufacturer's, mark shall be worked into the ropes, each~1m apart. Where companies have been approved for the independent performance of tests, this tape shall additionally bear the identification number allocated to the company by ACS. In addition, a coloured distinguishing thread denoting the yarn material in accordance with Table 7.1 is also to be worked into the rope.

7.2 The coloured distinguishing thread may be omitted where the tape has the colour code stipulated in 7.1.

Table 7.1 Distinguishing threads for fiber ropes

Material	**Colour code**
Manila	Black
Sisal	Red
Hemp	Green
Ployamide	Green
Polyester	Blue
Ploypropylen	Brown

Chapter 13 Approval of Welding Consumables for Use in Ship Construction

Section 1 General Requirements

1 Scope

1.1 General

1.1.1 This Section specifies the general requirements for fabrication by welding, and the other Sections of the Chapter concern the requirements for approval of welding consumables (Sec 2), over weldable shop primers (Sec 3) and welding procedures (Sec 4 and Sec 5).

1.1.2 The requirements are essentially intended for the welding of weldable steels and Aluminium alloy grades covered by the applicable Sub-sections of these Rules.

1.1.3 Different materials, applications and procedures, as well as other standards and specifications, may be considered by the Society on a case-by-case basis.

2 Fabrication by welding

2.1 General

2.1.1 Fabrication by welding is to be carried out in compliance with the applicable Society Rules and according to normal good practice, general or specific to the individual processes, to the Surveyor's satisfaction; in particular the conditions stated at the time of approval and authorization for the use of individual processes are to be complied with.

The welded structures, the relevant details and the size of welds are to comply with the applicable requirements; any other requirements indicated on the approved plans or specified during survey of construction are also to be complied with.

2.2 Approval

2.2.1 Plans

The constructional plans are to be submitted for approval when required by the Rules or in individual cases and are to contain the necessary data relevant to the fabrication by welding of the structures and items represented. In particular, material types, welding details, welding processes and weld size are to be indicated; any details not represented in the plans are, in any case, to comply with the applicable requirements.

2.2.2 Welding procedures and consumables

Welding to be used in hull construction, machinery, pressure systems and equipment subject to the inspection of the Society, is to be carried out with approved welding consumables and in accordance with approved welding procedures. Requirements regarding the use of the various grades of approved consumables are indicated in the parts of the Rules concerning the application or at the time of plan approval.

2.2.3 Welders and welding operators

Welders for manual welding and for semiautomatic welding processes are to be properly trained and are to be certified by the Society, as required in the individual applications, unless otherwise agreed.

The certification is to be in due course of validity. Personnel manning the automatic welding machines are to be competent and sufficiently trained.

2.2.4 Welding supervision

Welders are to be supervised and assisted, in the course of the welding operation, by an adequate number of competent supervisors, such as to ensure efficient control of the welding production. Certification of the welding inspectors is not compulsory and is left to the discretion of the Manufacturer, except in particular cases where it may be required by the Society.

2.2.5 NDT operators

Non-destructive tests are to be carried out by qualified personnel certified or by recognised bodies in compliance with appropriate standards. The qualifications are to be appropriate to the particular application.

2.3 Type of joints, edge preparations and size

2.3.1 General

The types of joints and the edge preparations are to be appropriate to the welding processes adopted, to the particular structures and to the stresses to which they are subjected, to the satisfaction of the Society. Size and design are to be in accordance with requirements given in the Rules relevant to the applications, approved plans, and specific provisions stipulated for hulls and for pressure systems and machinery.

2.4 Welding execution and control

2.4.1 Edge preparation, surface conditions, assembly pre and post- weld heating, welding sequences and inspections of the welded structures are to be in accordance with good practice and, where applicable, are to comply with the requirements given in the Rules relevant to the applications.

Section 2 Approval of Welding Consumables

1 General

1.1 Scope

1.1.1 The requirements of this Section apply to the approval and periodical control tests of consumables for welding carbon and carbon manganese steels, high strength quenched and tempered steels, chromium and chromiummolybdenum steels, nickel steels for low temperature applications, austenitic and austenitic-ferritic stainless steels, and Aluminium alloys.

This Sub-section specifies the requirements common to all the above-mentioned welding consumables, while the appropriate specific requirements are indicated in Sub-section 2 to 14. The following categories of welding consumables are considered:

- covered electrodes for manual and gravity welding
- wire/flux combinations for submerged arc welding
- solid wire/gas combinations for continuous wire arc welding
- flux cored wires for continuous wire arc welding with or without shielding gas
- consumables for electrogas and electroslag welding.

1.2 Grading and designation

1.2.1 General

Consumables are classified depending on the mechanical and chemical properties of the filler metal; different grades or type of consumables may be considered for specific applications or materials on a case-by-case basis.

1.2.2 Consumables for C and C-Mn steels and for QT steels

Welding consumables intended for welding C and C-Mn steels are divided into groups related to the strength level (minimum specified yield strength) of the steel; each group is subdivided into grades depending on the impact test temperatures, as indicated in Table 1.1.

1.2.3 Consumables for Mo and Cr- Mo steels

Consumables intended for welding Mo and Cr-Mo steels are designated by a symbol indicating the nominal Mo and Cr percentage content of the deposited weld metal, as follows:

a) M for Mo = 0,5

b) C1M for Cr =1,25 and Mo = 0,5

c) C2M1 for Cr = 2,25 and Mo = 1

1.2.4 Consumables for Ni steels for low temperature applications

Consumables intended for welding nickel steels are designated by a symbol indicating the type of nickel steel for which the consumables are intended, as follows:

a) N15 for steels with Ni = 1,30 - 1,70 (%)

b) N35 for steels with Ni = 3,25 - 3,75 (%)

c) N50 for steels with Ni = 4,75 - 5,25 (%)

d) N90 for steels with Ni = 8,50 - 10,0 (%)

1.2.5 Consumables for austenitic and austeniticferritic (duplex) stainless steels

Consumables intended for welding austenitic steels are designated by a symbol corresponding to the AWS designation of the weld deposit, as follows: 308, 308L, 316, 316L, 316LN, 317, 317L, 309L, 309, 309Mo, 310, 310Mo, 347.

Consumables intended for welding austenitic-ferritic steels are designated by a symbol indicating the nominal percentage content of Cr and Ni in the deposited metal (e.g. 2205 means 22% Cr and 5% Ni).

Table 1.1: Consumable grades for C-Mn steels

Weld metal strength level	Consumable grades based on impact test temperature at (°C)				
	+20	0	-20	-40	-60
Normal strength	1	2	3	4	-
Higher strength (1) • ≥ 315, < 360 N/mm^2 • ≥ 360, < 400 N/mm^2	1 Y	2Y 2Y40	3Y 3Y40	4Y 4Y40	5Y 5Y40
Extra high strength (1)			3Y42, 3Y46, 3Y50, 3Y55, 3Y62, 3Y69	4Y42, 4Y46, 4Y50, 4Y55, 4Y62, 4Y69	5Y42, 5Y46, 5Y50, 5Y55, 5Y62, 5Y69

(1) The symbol Y, which indicates the high strength groups is followed, for steels having the minimum specified yield strength equal to, or higher than, 355 N/mm^2, by a number related to the minimum specified yield strength value of the weld metal (e.g. 42 for a minimum yield strength of 420 N/mm^2).

(2) Grade not applicable to covered electrodes.

1.2.6 Consumables for Aluminium alloys

Consumables intended for welding Aluminium alloys are designated by the initial letter R or W for rod or wire products, respectively, and by the letters A, B, C, D depending on the alloy type and strength level used for the approval tests.

1.2.7 Additional symbols

Further symbols may be added, as appropriate, as a prefix or suffix to the grade as indicated in the following:

a) Prefix S or SA for semiautomatic welding process

b) Prefix A for automatic welding process

c) Prefix AV for electrogas or electroslag welding process

d) Suffix T, M, TM, U for automatic process with two run (T), multi-run (M), both (TM) or one-side (U) welding techniques

e) Suffix H or H15, HH or H10, HHH or H5 for controlled hydrogen content of weld metal as per Table 2.4

f) Suffix D when mechanical properties on weld metal have also been verified in the stress relieved condition

1.3 Approval procedure

1.3.1 Request for approval

The request for approval is to be submitted to the Society by the Manufacturer, together with the specific information indicated in the Sub-sections relevant to the various consumables.

1.3.2 Quality of manufacturing

The Manufacturer's plant, method of production and quality control of welding consumables are to be such as to ensure reasonable uniformity in manufacture.

The Manufacturer is to ascertain this uniformity by means of analysis and systematic testing on each production batch.

In general, the consumables are to maintain the specified characteristics for a period of time of at least six months after the date of delivery, when properly stored in a dry atmosphere and kept in the original packaging.

The consumables are to be supplied so packaged as to ensure compliance with the above requirement; the packaging is to be sufficiently strong to resist the usual transportation and handling operations.

The Manufacturer is to stamp on each container or bag, as applicable, the markings which are necessary to trace back each production.

1.3.3 Approval tests

The welding consumables are approved subject to a satisfactory inspection of the Manufacturer's works by the Surveyor and to satisfactory results of approval tests. The approval tests required are to be performed on samples of consumables representative of the production.

Sampling procedures are to be agreed with the Surveyor. In general, the approval tests consist of the following checks:

a) check of the mechanical properties of the deposited metal and welded joints and of the chemical composition of the deposited metal

b) check of the hydrogen contents, where required

c) check, at the request of the interested parties, of freedom from hot cracks, under specific test conditions.

Welding and inspection of the test samples and mechanical tests are to be carried out in the presence of the Surveyor.

The tests are to be carried out in laboratories and test rooms recognised by the Society.

Unless otherwise specified, test specimens and procedures are to be in accordance with the applicable Society requirements or standards recognised by the Society.

1.3.4 Certification

Upon satisfactory completion of the approval tests, a certificate of approval, stating the grade under which the consumable has been approved and the terms of validity of the approval, is issued by the Society to the Manufacturer.

The approved welding consumables and relevant grades are entered in the special lists of consumables approved by the Society.

1.3.5 Annual inspections and tests

The workshops where approved materials are manufactured are subject to annual inspections by the Surveyor.

During the inspection, samples of the approved consumables are selected by the Surveyor and subjected to the tests detailed in the Sub-sections relevant to the various products. These tests are to be repeated annually so as to provide an average of at least one test per year.

At the Society's discretion, the consumables to be used in the above tests may be obtained, instead of from the Manufacturer as stated above, from users or dealers; the consumables are to be recently produced (in general less than 6 months).

Alternative procedures based on quality control and quality assurance systems may be considered and accepted subject to special approval by the Society, which will state the relevant acceptance conditions on a case-by-case basis.

1.3.6 Manufacturer's responsibilities

After the approval has been obtained, and irrespective of the periodical tests carried out by the Society, the Manufacturer is fully responsible for the quality of the finished product and compliance with the specified requirements, as verified in the approval and periodical control tests.

The Manufacturer is to keep up-to-date records of the manufacture of the approved consumables, including details of the history of the single productions and results of associated tests. The Society is to have free access to these records at all times.

The Manufacturer is responsible for reporting to the Society any major modifications introduced in the production procedure subsequent to its approval. Full compliance on the part of the Manufacturer with all the requirements stated by the Society in connection with the approval of consumables is an essential condition for granting and renewing such approval.

1.3.7 Firms with several workshops or dealers

When consumables of the same brand are manufactured in different workshops belonging to the same Manufacturer, the complete series of tests is generally performed in one workshop only. In the other workshops, a reduced test program, at least equivalent to annual tests, is permitted if the Manufacturer certifies that the material used and the fabrication process are identical to those used in the main works.

1.3.8 Different brand names

When a consumable already approved at a manufacturer is transfered for sale under a different brand name to the manufacturer or to a dealer, the manufacturer and the dealer where applicable have to certify that the consumable with the alternative brand name is strictly identical to the consumable already approved.

1.3.9 Changes in grading

Changes in grading of welding consumables are to be considered only at the Manufacturer's request, in general at the time of annual testing. For upgrading, tests from butt weld assemblies are generally required as a minimum in addition to normal annual tests, as specified here below.

For upgrading referring to impact properties, Charpy V notch impact tests are to be performed at the upgrade temperature on the respective butt weld assemblies required for approval.

For upgrading referring to higher strength steels, all butt weld tests required for the approval are to be effected using higher strength steel as parent metal. For upgrading referring to hydrogen content, tests according to 2.4 are to be carried out as appropriate.

Downgrading or withdrawal of the approval occurs when the prescribed tests and re-tests fail to meet the requirements.

1.3.10 Additional tests

The Society may, in some specific cases, request additional tests or requirements as deemed necessary.

1.4 Preparation and welding of test assemblies

1.4.1 Base material

The base material used for the test assemblies is to be of the steel grade appropriate to the consumable grade as specified in the various Sub-sections.

For the preparation of all weld metal test assemblies, any grade of structural steel may be used. When the chemical composition of welded metal is substantially different from the base material, an overlay of side walls and backing strip may be carried out, as deemed necessary.

For the preparation of butt welded assemblies, steel grades are to be chosen depending on the grade of consumables. When a welded joint is performed, the edges of the plates are to be bevelled either by mechanical machining or by oxygen cutting; in the latter case, a descaling of the beveled edges is necessary.

1.4.2 Welding conditions and type of current

Welding conditions used, such as amperage, voltage, travel speed etc., are to be within the range recommended by the Manufacturer for normal good welding practice. Where it is stated that a filler metal is suitable for both alternating current (a.c.) and direct current (d.c.), alternating current is to be used for welding the test assemblies for mechanical tests. When samples for checking the operating characteristics are required, both types of current are generally to be used. When samples for hot cracking tests arerequired, direct current is to be used.

Direct current is identified in the approval documentation with the symbols:

- CC+ or DCEP for positive electrode
- CC - or DCEN for negative electrode.

1.4.3 Post-weld heat treatment

Post-weld heat treatment of the welded assemblies is not allowed where the consumables are to be approved for the as welded condition only.

1.5 Mechanical tests

1.5.1 General

The test specimens for mechanical tests are to be taken from the welded assemblies as indicated in the various Sub-sections; specimen preparation and test results are to comply with the requirements from 1.5.2 to 1.5.6. The requirements relevant to the calibration of the equipment, preparation of test specimens and testing procedure, detailed in Chapter 2, are also to be complied with, as appropriate.

1.5.2 Tensile tests

Round test specimens for longitudinal tensile tests and flat test specimens for transverse tensile tests are to be taken as described below:

a) round specimen:

The longitudinal axis is to coincide with the centre of the weld and mid-thickness of the weld in the all weld metal assemblies and second run in the two run welded assemblies. The specimen is to be in accordance with Chapter 2, the specimen may be heated to a temperature not exceeding 250°C for a period not exceeding 16 hours, for hydrogen removal prior to testing. The yield stress, tensile strength and elongation are to be determined and are to comply with the requirements specified for the various consumables; the reduction of area is to be determined and reported for information.

b) flat tensile specimen:

The test specimen is to be in accordance with Chapter 2. The tensile strength is to be determined together with the fracture position and is to comply with the requirements specified for the various consumables.

1.5.3 Transverse bend tests

Face and root bend test specimens having 30 mm width and full plate thickness are to be machined transverse to the welded joint. The upper and lower surfaces of the weld are to be filed, ground or machined flush with the surface of the plate and the corners in tension rounded to a radius not exceeding 2 mm.

Two bend specimens are required; one specimen is to be tested with the face of the weld in tension and the other with the root of the weld in tension. If the plate thickness exceeds 25 mm, it may be reduced to this size by machining on the compression side of the test specimen.

Alternatively, two side bend specimens may be taken in lieu of root and face bend specimens; side bend specimens may also be required in addition to or in lieu of root and face bend specimens for specific applications as specified in 1.5.4.

Bend test specimens are to be bent without fracture or cracks through an angle of 120°, unless a different angle is specified over a former having diameter as indicated in the various Sub-sections; however superficial cracks or open defects not exceeding 3 mm may be disregarded.

1.5.4 Side bend tests

Side bend test specimens, having full plate thickness and width 10 mm, are generally required in addition to the root and bend tests for the approval of wire/gas combinations, and are required in lieu of the root and bend tests for electrogas or electroslag assemblies.

1.5.5 Longitudinal bend tests

When longitudinal face or root bend tests are required, test specimens in accordance with an appropriate standard are accepted.

1.5.6 Impact tests

Charpy V-notch impact specimens are to be cut with their longitudinal axis transverse to the weld joint and positioned as follows:

a) for deposited metal and butt weld test assemblies with multi-run technique: at mid-thickness of the weld

b) for two run welded test assemblies: on the second run side, 2mm below the surface

c) for electroslag and electrogas welded test assemblies: 2 mm below the surface

d) for one side automatic welding processes: 2 mm below the face side and 2 mm below the root side of the test assemblies; for thicknesses ≥ 30 mm, specimens at midthickness are also to be taken.

The notch is to be cut in the face of the specimen perpendicular to the surface of the plate and to be positioned in the centre of the weld. For electrogas and electroslag welding, an additional set with the notch at 2 mm from the fusion line in the weld metal is to be taken. A set of three specimens is to be prepared and tested. The average impact energy is to comply with the values specified for the various consumables and only one individual value may be lower than the average required, provided it is not lower than 70% of it.

1.6 Test samples for checking the chemical composition of deposited weld metal

1.6.1 For some products (see 11, 12, 13), the chemical composition of weld metal deposited with electrodes is required to be verified on samples welded for this purpose.

1.6.2 The test samples consist of a test plate of the specified steel having minimum sides 80x80 mm^2 and 15mm thickness.

On the above test plate, whose surface is to be cleaned by grinding to remove any trace of oxide, grease and paint, a weld pad is deposited in layers by welding in the flat position, each layer being formed by flanked beads. The minimum dimensions of the pad are to be as indicated in Table 1.2.

Table 1.2: Pad dimensions

Diameter of tested electrode (mm)	Minimum length and width of the pad (mm)	Minimum thickness of the pad (mm)
2,5	30 x 30	13
3,25 - max.	40 x 40	16

The width of each bead of each layer is to be 1,5 to 2,5 times the diameter of the electrode. It is recommended that each layer should be deposited in a direction perpendicular to the previous one. The current adopted for welding the test samples is to be within the range recommended by the Manufacturer; in the case of electrodes for use both with a.c. and d.c. current, the welding is to be carried out with alternating current.

After each layer has been deposited, the pad may be cooled to room temperature by immersion in water for 30 seconds. The surface of each layer is to be free from slag inclusions and blow holes.

1.6.3 After the welding is completed, the top surface of the pad is to be removed by mechanical means and discarded. Shavings sufficient for checking the chemical composition are then to be taken in such a manner that no metal is removed closer to the surface of the base plate than the distance indicated in Table 1.3.

The use of lubricating oils during the mechanical machining for taking out the shavings is to be avoided.

Table 1.3: Sampling method

Diameter of tested electrode (mm)	Minimum distance from the base plate for taking out the shavings (mm)
2,5	6
3,25 - max.	8

1.7 Re-test procedures

1.7.1 General

When for one or more test samples the execution of the weld, the external examination, the radiographic examination or the fracture produce results which are not considered satisfactory in some respects, and when the respective causes may be traced back to the operator or operating conditions, the test samples may be allowed to be repeated, in duplicate if deemed necessary, with the same procedure. In other cases, as well as when cracks are detected, the consumable will not be approved.

The operating conditions for the re-test samples are to be agreed with the Surveyor, as deemed appropriate.

For the approval of the consumable, or for the continuation of the testing program, the re-test samples are to produce satisfactory results.

1.7.2 Tensile and bend tests

Where the result of a tensile or bend test does not comply with the requirements, duplicate test specimens of the same type are to be prepared from the same sample and satisfactorily tested. Where insufficient original welded assembly is available, a new assembly is to be prepared using welding consumables of the same batch. If the new assembly is made with the same procedure (in particular the same number of runs) as the original assembly, only the duplicate re-test specimens need to be prepared and tested. Otherwise, all test specimens are to be prepared for re-testing.

1.7.3 Charpy V-notch impact test

Reference is made to Ch 2, Sec 3.

2 Covered electrodes for manual metal arc welding of C and C-Mn steels

2.1 Scope

2.1.1 General

The requirements of this Sub-section apply to covered electrodes for manual metal arc welding of hull structural steels, of the corresponding grades of steel forgings and castings and of comparable steels intended for other structural applications or pressure systems.

2.1.2 Designation

Electrodes are divided, for the various strength levels, into the following grades as defined in 1.2.2 :

a) 1, 2, 3, 4 for normal strength grades

b) 2Y, 3Y, 4Y, 5Y for high strength grades with specified minimum yield strength up to 355 N/mm^2

c) 2Y40, 3Y40, 4Y40, 5Y40 for high strength grades with specified minimum yield strength up to 390 N/mm^2.

Depending on the hydrogen content of the weld metal, the symbol H15 or H, H10 or HH, H5 or HHH is added to the grade mark as in 1.2.7.

The symbols H15, H10, H5 indicate the hydrogen content determined with the mercury method.

2.1.3 Information and documentation to be submitted

The following information and supporting documentation, as appropriate, are generally to be submitted together with the request for approval:

a) trade name of the electrode

b) type of covering

c) grades for which the application is made, including additional symbols

d) typical chemical composition of the deposited metal

e) type of current and welding positions

f) proposed range of application and operating characteristics

g) previous approvals granted to the electrodes with the necessary references.

2.2 Approval tests

2.2.1 General

The approval tests specified in 1.3.3 are to be performed as indicated in 2.3 to 2.6 and summarized in Table 2.1.

2.3 Tests for checking the mechanical properties

2.3.1 General

The following tests indicated in Table 2.1 are to be performed.

2.3.2 Deposited metal test assemblies

Two deposited metal test assemblies are to be welded in the flat position as shown in Fig 1, one with 4 mm diameter electrodes and the other with the largest size manufactured. If an electrode is available in one diameter only, one test assembly is sufficient. Any grade of ship structural steel may be used for the preparation of the test assembly.

The weld metal is to be deposited in a single or multi-run layers according to normal practice, and the direction of deposition of each layer is generally to alternate from each end of the plate, each run of weld metal being not less than 2 mm and not more than 4 mm thick. Between each run the assembly is to be left in still air until it has cooled to less than 250°C but not below 100°C, the temperature being taken in the centre of the weld on the surface of the seam.

After being welded, the test assemblies are not to be subjected to any heat treatment, except where approval has been requested also in the stress relieved condition 2.3.5. In such case the symbol D is to be added to the grade designation.

Table 2.1: Test assemblies and mechanical tests required

Test assembly						Tests required (1)
Type	Welding position (2)	Electrode diameter (mm) (3)	Number of samples	Thickness (mm)	Dimensions	
Deposited metal	Flat	4	1 (4)	20	Fig 2.1	1TL- 3KV
		Max.	1			
Butt weld	Flat	First run: 4 - Intermediate: 5 Last two layers: max	1 (5)	15-20	Fig 2.2	1TT-1RB-1FB-3KV
	Vertical Upward	First run: 3,25 Remaining runs: 4	1			1TT-1RB-1FB-3KV
	Horizontal (6)	First run: 4 Remaining runs: 5	1			1TT-1RB-1FB-3KV
	Overhead	First run: 3,25 Remaining runs: 4	1			1TT-1RB-1FB
Fillet (7)		First side: min. diam.	1	15-20	Fig 2.4, Fig 2.5	Macr Fracture Hardness
		Second side: max.diam.				

(1) Abbreviations: TL: longitudinal tensile test; TT: transverse tensile test; RB: root bend test; FB: face bend test; KV: Charpy V-notch impact test.

(2) When the approval is requested only for one or more specified welding positions, the butt test samples are to be welded in such positions.

(3) In the case of high efficiency (≥130) electrodes, electrodes having diameter 3,25 mm and 4 mm are to be used instead of 4 mm and 5 mm, respectively.

(4) If only one diameter is to be approved, only one test assembly is required.

(5) For electrodes to be approved in flat position only, an additional test sample is to be welded using electrodes having diameter 4 mm for the first pass, 5 mm for the second pass and the maximum diameter to be approved for the following passes.

(6) The test sample in the horizontal position is not required when the same test sample is welded in flat and vertical positions.

(7) See 2.5.

The specimens shown in Fig 2.1 are to be taken for the following tests:

a) one longitudinal tensile test

b) three Charpy V-notch impact tests.

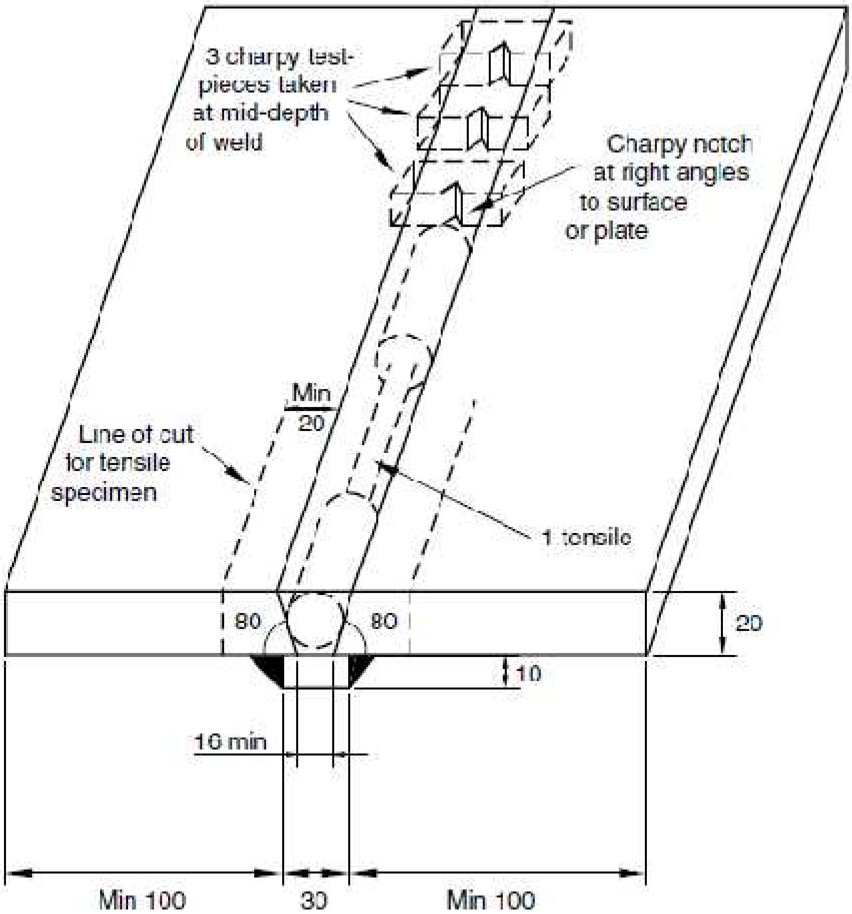


Figure 2.1: Deposited metal test assembly (All the dimensions are in mm, unless otherwise indicated.)

The results of the tests are to comply with the requirements of Table 2.3, as appropriate.

The chemical analysis of the deposited weld metal in each test assembly is to be supplied by the Manufacturer and is to include the content of all significant alloying elements, if any.

2.3.3 Butt weld tests

Butt weld test assemblies as shown in Fig 2.2 are to be welded as indicated from a) to e).

a) Flat position

one test sample welded using 4 mm electrodes for the first pass, 5 mm electrodes for the intermediate passes, and electrodes of the maximum diameter to be approved for the last two passes

one test sample welded using 4 mm electrodes for the first pass, 5 mm electrodes for the second pass, and electrodes of the maximum diameter to be approved for the remaining passes. This additional test sample is required in the case of electrodes to be approved for the flat position only.

b) Vertical position upward technique

one test sample welded using 3,25 mm electrodes for the first pass and 4 mm electrodes for the remaining passes, or 5 mm if this is recommended by the Manufacturer for welding in vertical position.

c) Vertical position downward technique

one test sample welded using electrode diameters recommended by the Manufacturer, when the approval with the downward technique has been requested

d) Overhead position

one test sample welded using 3,25 mm electrodes for the first pass and 4 mm electrodes (or possibly 5 mm if this is recommended by the Manufacturer) for the remaining passes

e) Horizontal position

one test sample welded using 4 mm electrodes for the first pass and 5 mm electrodes for the remaining passes.

This test sample need not be welded in the case of electrodes for which the execution of the same test sample in flat and vertical positions is required. The grade of steel to be used for the preparation of the test assemblies is related to the grade of the electrodes as indicated in Table 2.2.

For electrodes to be approved under grades 4 and 5, in lieu of the hull steels specified in Table 2.2, C-Mn steels for pressure vessels of grades L40 and L60, respectively, and strength appropriate to the electrode strength may be used.

The use of other type of steel is to be agreed with the Society on a case-by-case basis.

The welding is to be performed with the usual technique in compliance with the requirements specified in 2.3.2 for the deposited metal test, as applicable. For all assemblies, the back sealing run is to be made with 4 mm diameter electrodes, in the welding position appropriate to each test sample, after back gouging to sound metal. For electrodes suitable for downhand welding only, the test assemblies may be turned over to carry out the backing seal.

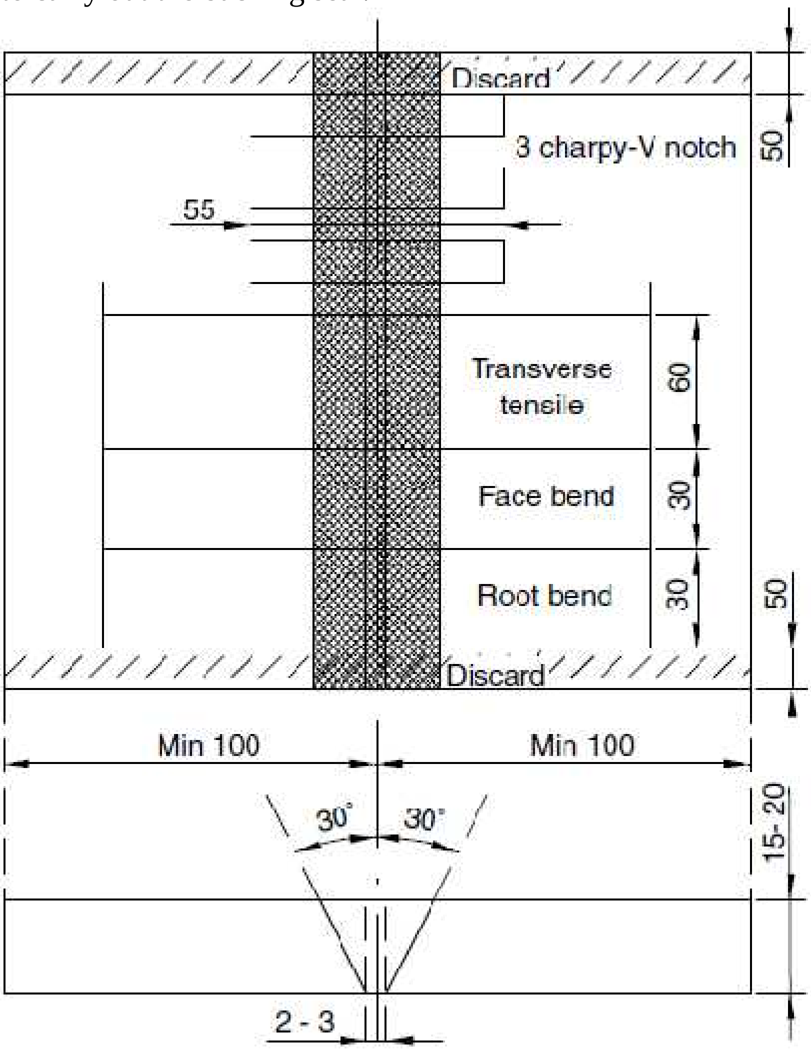


Figure 2.2: Butt weld test assembly (All the dimensions are in mm, unless otherwise indicated.)

Table 2.2: Grade of steel used for test assemblies

Electrode grade	Steel grade (1)
1	A
2	A, B, D
3 – 4	A, B, D, E
2Y	AH32-36, DH32-36
3Y	AH32-36, DH32-36, EH32-36
4Y – 5Y	AH32-36, DH32-36, EH32-36, FH32-36
2Y40	AH40, DH40
3Y40	AH40, DH40, EH40
4Y40 - 5Y40	AH40, DH40, EH40, FH40

1) The tensile strength of grades AH32 to FH32 is to be greater than 490 N/mm^2.

After being welded, the test assemblies are not to be subjected to any heat treatment except where approval has been requested also in the stress relieved condition 2.3.5. In such case the symbol D is to be added to the grade designation. It is recommended and may be required that the welded assemblies should be subjected to a radiographic examination to ascertain if there are any defects in the weld prior to the preparation of test specimens.

The test specimens shown in Fig 2.2 are to be taken for the following tests:

a) one longitudinal tensile test

b) three Charpy V-notch impact tests

c) one root and one bend test specimen.

2.3.4 Test requirements

The required results of tensile and impact tests on deposited metal and butt weld tests are indicated in Table 2.3.

Bend tests are to be performed on a mandrel having a diameter equal to three times the thickness of the specimen; the results are to comply with requirements in 1.5.3.

2.3.5 Approval in the stress relieved condition

When the approval of the electrode is required with the additional symbol D, relevant to the checking of the mechanical properties in the stress relieved condition, the following additional tests are to be performed on samples submitted to stress relieving in the furnace for 1 hour at 600-650°C:

- one longitudinal tensile test and 3 Charpy V-notch impact tests on the deposited metal test assembly welded with the maximum diameter to be approved
- alternatively or in addition, at the Surveyor's discretion, 3 Charpy V-notch impact tests on the butt weld test welded in flat and vertical position.

The impact tests are to be carried out at the temperature specified for the respective grades of electrodes.

Table 2.3: Mechanical properties

Grade	Tensile test on deposited metal			Tensile test on butt weld	Charpy V-notch impact test Minimum average energy (J)		
	Yield stress R_{eH} (N/mm^2) min.	Tensile strength R_m (N/mm^2)	Elong A_5 (%) min.	Tensilestrength R_m (N/mm^2) min.	Test temp. (°C)	Flat, Horizontal, Overhead	Vertical
1	305	400 – 560	22	400	+20	47	34
2					0		
3					-20		
4					-40		
2Y	375	490 – 660	22	490	0	47	34
3Y					-20		
4Y					-40		
5Y					-60		
2Y40	400	510 - 690	22	510	0	47	39
3Y40					-20		
4Y40					-40		
5Y40					-60		

2.4 Tests for checking the hydrogen content

2.4.1 General

When electrodes are to be approved with symbol H or H15, HH or H10, HHH or H5, tests are to be carried out to determine the hydrogen content of the weld metal. Low hydrogen electrodes are to subjected to a hydrogen test.

The hydrogen content is to be checked with the mercury method according to ISO standard 3690-2000 or another comparable method with the Society's consent. The use of the glycerine method described in 2.4.2 may be admitted by the Society for symbols H and HH. For the assignment of the designation HHH, the hydrogen content is, in any case, to be checked with the mercury method according to the above ISO standard.

2.4.2 Glycerine method

Four test samples are to be prepared measuring 12 x 25mm^2 in cross-section by about 125 mm in length. The parent metal may be any grade of structural steel and, before welding, the samples are to be weighed to the nearest 0,1 gram.

On the 25 mm width surface of each specimen, a single bead of welding is to be deposited by a 4 mm electrode burning a length of about 150 mm of the electrode. The welding is to be carried out with an arc as short as possible and with current of about 150 amp. Alternating current a.c. is to be used when the electrode is proposed for approval with both a.c. and d.c. Before welding, the electrodes may be submitted to the normal drying process recommended by the Manufacturer. The procedure for determining the hydrogen content is as follows:

a) within 30 seconds after the completion of the weld, the slag is to be removed and the samples quenched in water at approximately 20°C

b) after 30 seconds in water, the samples are to be cleaned and deposited in an apparatus suitable for the collection of the hydrogen by the displacement of glycerin (or paraffin) . During the test, the glycerin is to be maintained at 45°C. All four samples are to be welded and subjected to the hydrogen test within 30 minutes.

c) the samples are to be kept soaking in glycerin for 48 hours; after being removed from the machine, the samples are to be cleaned by means of water and alcohol, dried and weighed to the nearest 0,1 gram in order to determine the amount of deposited metal

d) the amount of gas developed is to be measured to the nearest 0,05 cm^3 and corrected for temperature and pressure to 20°C and 760 mm Hg, respectively;

e) the individual and average diffusible hydrogen content of the four specimens is to be reported and the average value in cm^3, per 100 grams of deposited metal, is not to exceed the values specified for the symbol of the electrode concerned.

2.4.3 Hydrogen test requirements

The hydrogen content determined with the mercury or glycerine test is not to exceed the values given in Table 2.4.

Table 2.4: Diffusible hydrogen content of weld metal

Symbol	Mercury method	Glycerine method
H15 (H)	15	10
H10 (HH)	10	5
H5 (HHH)	5	(1)

(1) Glycerine method is not allowed

2.5 Fillet weld test assemblies

2.5.1 Fillet weld test assemblies are required for electrodes submitted for approval for fillet welding only and may be required, during the first approval tests at the Surveyor's discretion, for electrodes submitted for approval for both butt and fillet welding. In the latter case, only one sample in horizontal-vertical position is generally to be welded.

When the electrode is proposed for fillet welding only, fillet weld assemblies for each welding position (horizontal-vertical, vertical upward, vertical downward or overhead) recommended by the Manufacturer and deposited weld metal test as indicated in 2.3.2 are to be welded. The test assemblies, as shown in Fig 2.3, are to have a length L sufficient to allow at least the deposition of the entire length of the electrode being tested.

Plates in normal hull structural steel having thickness 15-20 mm are used.

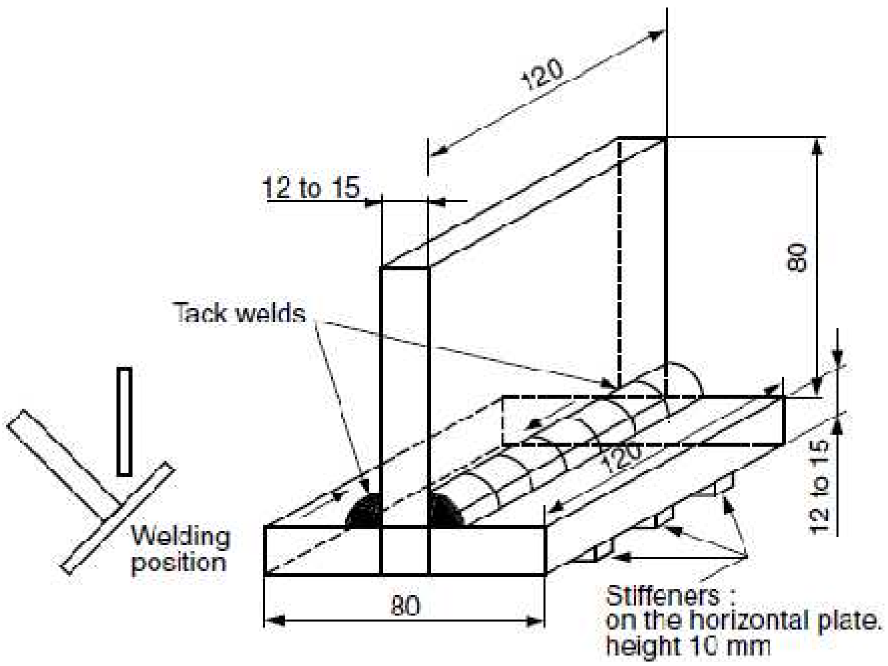


Figure 2.3: Fillet weld test assembly

2.5.2 The test sample is to be welded on both sides; the first side is to be welded with the maximum diameter and the second side with the minimum diameter. The sizes of the beads are about 9 x 9 and 6 x 6 mm2 for the first and second beads, respectively.

2.5.3 After visual examination and assessment, three sections for macrographic examination are to be taken from each test sample as indicated in Fig 4 (one in the middle and one at each end). These are to be examined for root penetration, satisfactory profile, freedom from cracking and reasonable freedom from porosity and slag inclusions.

Vickers hardness measurements are to be carried out to the Surveyor's satisfaction on the above sections in the positions indicated in Fig 5.

The hardness of the weld metal obtained is to be:

- ≥120 HV for normal strength level
- ≥150 HV for high strength level up to R_{eH} = 355 N/mm^2
- ≥170 HV for high strength level up to R_{eH} = 390 N/mm^2.

The hardness of both heat affected zone H.A.Z. and base metal is also to be determined and is to be reported for information.

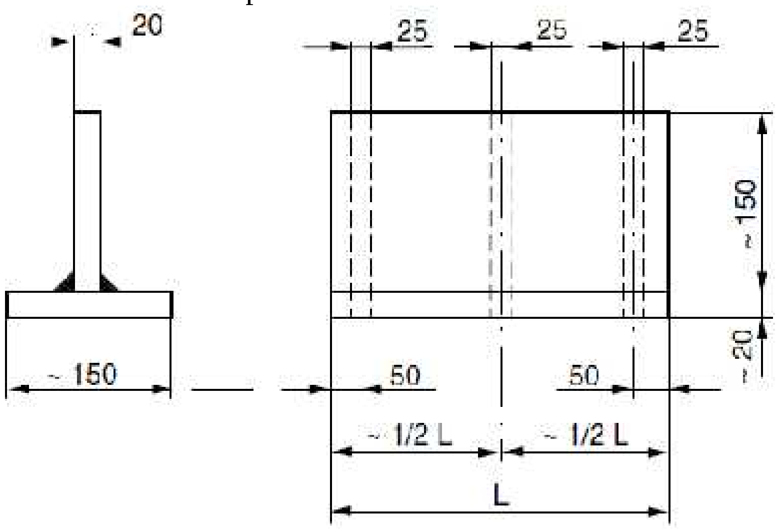


Figure 2.4: Sections for macrographic examination

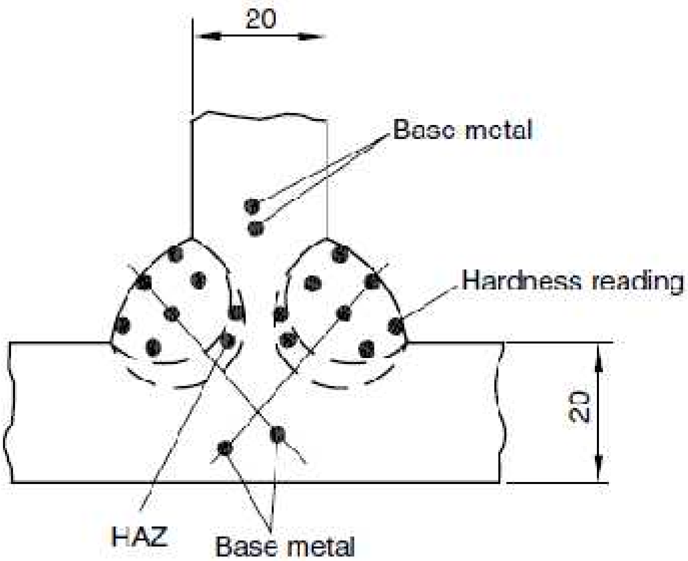


Figure 2.5: Hardness readings (The dimensions are in mm.)

2.5.4 The two parts obtained up on sectioning the sample are to be subjected to fracture as in 2.3.2 after having previously removed the welding bead from one side (on one part the first and on the other the second deposited beads). The fractured surfaces are to be examined for root penetration, satisfactory profile, freedom from cracks and reasonable freedom from porosity.

2.5.5 These tests may partially replace the T fillet joints when required in 2.3.2.

2.6 Annual control tests

2.6.1 The annual tests are to include at least the following:

a) two deposited metal test assemblies are to prepared in accordance with 2.3.2 and the required tests (one longitudinal tensile test and 3 Charpy V-notch impact tests) are to be conducted. For electrodes approved for fillet weld only, and not suitable for butt-joints, only one deposited metal test with the maximum diameter is to be carried out.

b) at the discretion of the Society, a butt weld test to be welded in vertical position may be required in lieu of the deposited metal test with electrodes of 4 mm

c) the check of the hydrogen content may be required for electrodes approved with symbol HH (or H10) and is required for electrodes approved with symbol HHH (or H5)

d) the chemical composition may be required to be checked under conditions corresponding to those of the approval tests.

The welding and test procedures, the type of current, the materials, the test results and the re-test procedures, where applicable, are regulated by the requirements relative to the approval tests.

3 Covered electrodes for gravity or contact welding

3.1 Scope

3.1.1 The requirements of this Sub-section apply to covered electrodes when submitted for approval for use in gravity welding, using automatic gravity or similar welding devices.

3.2 Approval tests

3.2.1 Where the electrode is submitted for approval for the gravity welding technique only, deposited metal tests 2.3.2, fillet weld tests 2.5 and, where appropriate, butt weld tests 2.3.3 similar to those for manual electrodes are to be carried out with such technique.

3.2.2 Where the electrode is submitted for approval for the gravity welding technique in addition to normal manual welding, fillet weld tests and, where appropriate, butt weld tests are to be carried out with the gravity process, in addition to the normal approval tests.

3.2.3 The fillet weld test is to be gravity welded using the longest size of electrode manufactured. The Manufacturer's recommended current range is to be reported for each electrode size.

The results of the tests are to comply with the requirements specified in 2.5.3 and 2.5.4.

3.3 Annual control tests

3.3.1 Where the electrode is approved only for gravity welding, the annual test is to consist of at least one deposited weld metal test assembly using such process. If the electrode is approved also for manual arc welding, the annual test is to be performed as indicated in 2.6.1.

4 Covered electrodes for deep penetration manual welding of C and C-Mn steels

4.1 Scope

4.1.1 The requirements of this Sub-section apply to deep penetration electrodes to be used for downhand butt and fillet welding and horizontal-vertical fillet welding.

Deep penetration electrodes may be approved as grade 1 electrodes only and are to be given the additional symbol D.P. Approvals limited to butt-joints only may be considered. In these cases, the test sample specified in 4.2.2 is not required.

4.1.2 The welding of butt-joints in flat position is to be performed on square groove edges.

When the Manufacturer requires that the approval is extended to cover butt-welded joints having a single Vee edge preparation, all the tests required in 2.2 for normal type electrodes used in flat position are to be carried out, in addition to the tests required in this Sub-section.

4.1.3 Test samples relative to the approval of deep penetration electrodes are to be welded with the type and the intensity of current recommended by the Manufacturer. When it is intended that the approval is valid for use with both d.c. and a.c. currents, the test samples are to be welded with a.c. current.

4.1.4 As regards the procedure for the approval, the preparation and welding of samples, the specimens and testing, the requirements specified in 2 for ordinary electrodes are to be complied with, in so far as applicable.

4.2 Approval tests

4.2.1 Butt weld test assembly

The following test sample in grade A structural steel or equivalent steel to the Surveyor's satisfaction is to be welded:

- one butt-welded sample, with square groove edges, made of two plates having width ≥100 mm and a thickness equal to twice the diameter of the core of the electrode plus 2 mm; such sample is to be welded in flat position with the maximum electrode diameter for which the approval has been requested, with a single pass on each side (see Fig 4.1).

The edges are to be accurately cut and in good contact (not more than 0,25 mm between edges for the full length of the joint).

The specimens for the following tests are to be taken after having discarded a length of 35 mm from each end:

- two transverse tensile tests
- one face and one root bend
- three Charpy V-notch impact tests
- two macrographic examinations.

4.2.2 Fillet weld test assembly

The following test sample in grade A structural steel or equivalent steel to the Surveyor's satisfaction is to be welded:

- one Tee-joint sample having length ≥160 mm and thickness about 12-15 mm, to be welded in horizontal position with a 4 mm electrode on one side and with an electrode of the maximum diameter to be approved on the other side.

The edges are to be accurately cut and the gap between the plates is to be not more than 0,25 mm for the full length of the joint as shown in Fig 4.2.

Two cross-sections are to be obtained from the sample at about 35 mm from each end; the two cross-sections are to be subjected to a macrographic examination (see Fig 4.2).

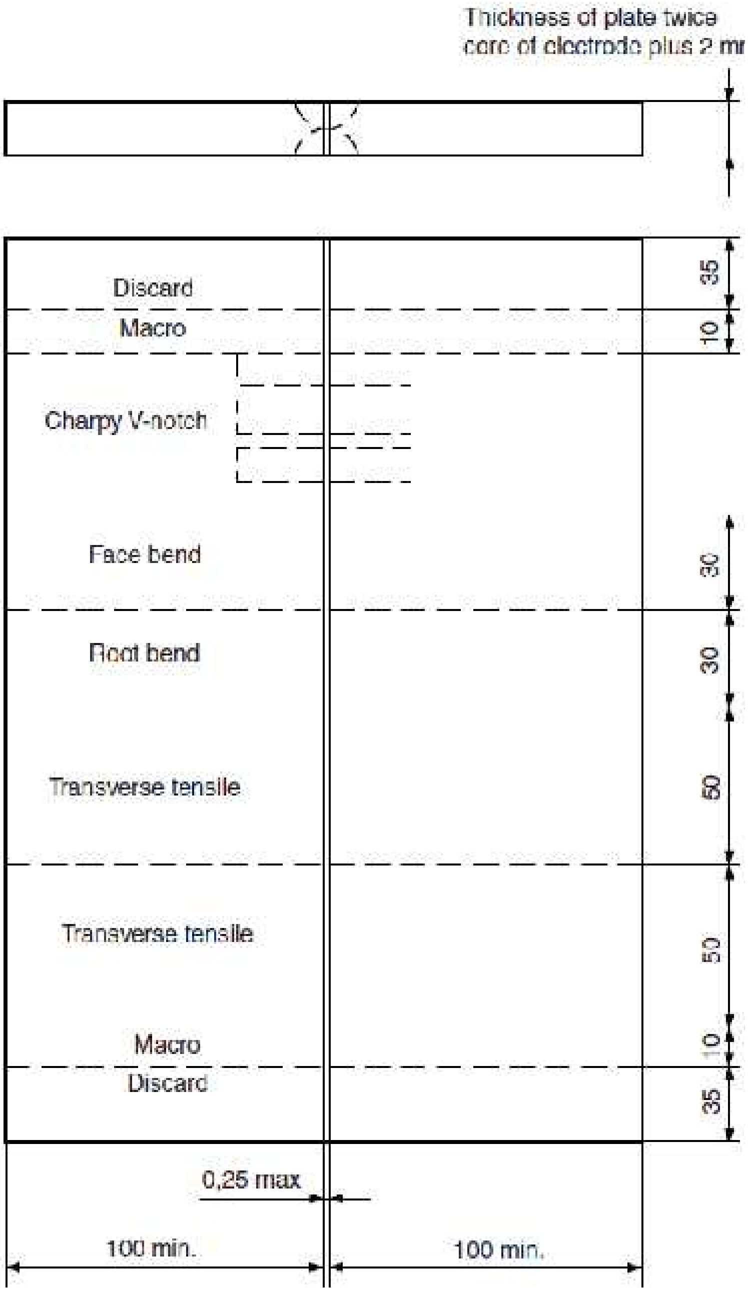


Figure 4.1: Deep penetration butt weld test assembly (All the dimensions are in mm.)

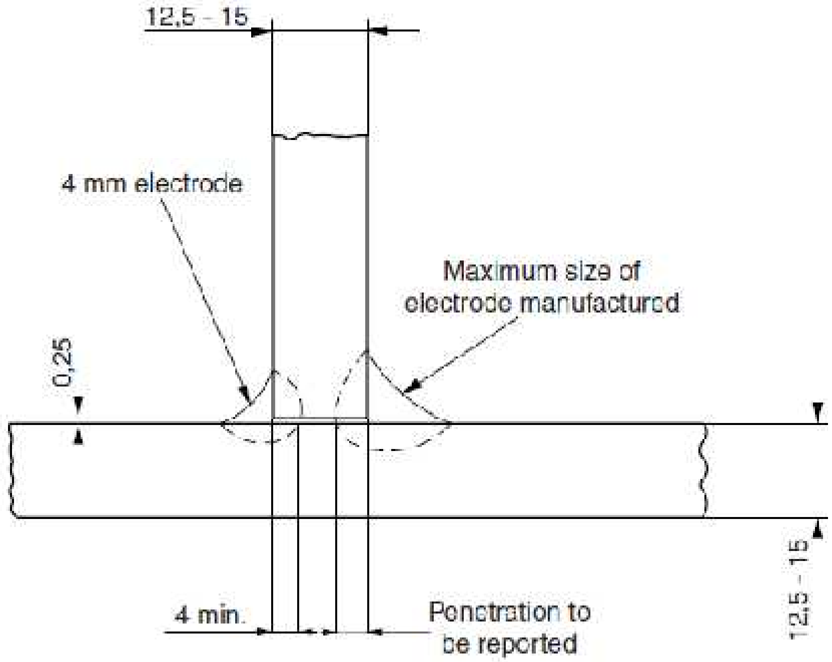


Figure 4.2: Deep penetration fillet weld test assembly

4.2.3 Test requirements

The results required for the tests mentioned in 4.2.1 and 4.2.2 are specified in the following items a) and b):

a) Butt weld test assembly:

- bend tests on a mandrel having diameter equal to three times the thickness of the sample: bend angle $\alpha \geq 120°$
- transverse tensile test: Rm $\geq$ 410 N/mm2
- impact tests at about +20°C; minimum absorbed energy (average value of three tests): KV $\geq$ 47J
- the macrographic examinations are to show a complete penetration of the welds on the two sides.

b) Fillet weld test assembly:

- the fillet deposited with the 4 mm electrode is to show a penetration not less than 4 mm (see Fig 4.2)
- the penetration obtained by the fillet deposited with the maximum diameter of electrode on the other side is to be measured and reported for information purposes only.

4.2.4 Maximum thickness which can be welded

Upon satisfactory completion of the tests mentioned in the above paragraphs, the Manufacturer is to prepare and submit to the Society a table showing the maximum thickness which can be welded, with square groove edges, with each diameter of electrode included in the approval and with the intensity of current necessary for the relevant electrode.

The table, which forms an integral and essential part of the approval documentation, is to substantially conform to the maximum thickness value verified in the test in 4.2.1.

4.3 Annual control tests

4.3.1 One test sample, as illustrated in Fig 4.1 or Fig 4.2 as applicable, is required; such sample is to be welded with electrodes having the maximum approved diameter.

The required tests and the relevant requirements are those indicated in 4.2.1, 4.2.2 and 4.2.3; however, only one transverse tensile test is required. For electrodes approved for both normal and deep penetration welding in the downhand position, a deep penetration weld test, as above, is to be carried out in addition to the deposited weld metal tests required for normal penetration.

5 Flux-wire combination for submerged arc welding of C and CMn steels

5.1 Scope

5.1.1 General

The requirements of this Sub-section apply to wire flux combination for submerged arc welding of hull structural steels, of the corresponding grades of steel forgings and castings and of comparable steels intended for other structural applications or pressure systems.

Approvals granted in accordance with these requirements are valid for standard single wire welding.

Other techniques, such as tandem or multi-wire welding, and one side welding on flux or backing, are to be submitted to separate approval tests. These tests are generally to be carried out in accordance with the requirements of this Sub-section and are detailed, on a case-by-case basis, depending on the welding procedure proposed.

5.1.2 Type of wires

Types of wires identified by the chemical composition shown in Table 5.1 are generally to be used. Chemical composition of wires other than those given in Table 5.1 are to be submitted.

5.1.3 Designation

Wire flux combinations are divided, for the various strength levels, into the following grades as defined in 1.2.2 :

a) 1, 2, 3, 4 for normal strength grades

b) 1Y, 2Y, 3Y, 4Y, 5Y for high strength grades with specified minimum yield strength up to 355 N/mm^2

c) 2Y40, 3Y40, 4Y40, 5Y40 for high strength grades with specified minimum yield strength up to 390 N/mm^2.

The prefix A is added to the grade. Depending on the welding technique, the following symbols are added as a suffix to the grade:

- T for use with two-run technique
- M for use with multi-run technique
- TM for use with both techniques.

5.1.4 Information and documentation to be submitted

The following information and supporting documentation, as applicable, are generally to be submitted together with the request for approval:

a) commercial name of the flux, for which the approval is requested; type of flux (fused or conglomerate)

b) commercial name of the associated wire, limits of chemical composition and diameters to be approved

c) grading under which the approval is requested; type of current and welding positions

d) typical chemical composition of the deposited metal, with particular reference to the contents of Mn, Si and alloying elements

e) recommendations, where applicable, regarding the range of the welding parameters (current, voltage and welding speed)

f) previous approvals granted to the proposed wire-flux combination.

Table 5.1: Wire chemical composition

Type of wire	Chmical Composition									
	C max.	Mn	Si Max.	P Max	S Max.	Al Max.	Cr Max.	Ni Max.	Cu Max.	Mo
1	0.13	0.40–0.65	0.15(2)	0.03	0.03	0.03	0.15	0.25	0.30	(3)
2	0.15	0.80-1.20								
3	0.15	1.30-1.70								
4	0.15	1.80-2.20(1)								
5	0.16	2.30-2.70								

(1) A content lower by not more than 0,05% is acceptable.

(2) Wires having chemical composition 1 may be of rimmed steel; the other wires may be of Si and/or Al killed or semi-killed steels. Approval may be granted to wires having Si content up to 0,40%, depending on the type of wire concerned.

(3) For all wires Mo may be included in the proposed composition in the range 0,45-0,60 %; the content is to be stated by the Manufacturer at the time of the request for approval of the wire-flux combination.

Table 5.2: Test assemblies and mechanical tests required

Welding technique	Test assembly				Tests required (1)
	Type	Number	Thickness(mm)	Dimensions	
M	Deposited metal test	1	20	Fig 5.1	2TL - 3KV
	Butt weld test	1	20-25	Fig 5.2	2TT - 2RB - 2FB - 3KV
T	Butt weld test	1	12-15	Fig 5.4	2TT - 2RB - 2FB - 3KV
	Butt weld test	1	20-25	Fig 5.4	1TL-2TT - 2RB - 2FB - 3KV
	Butt weld test	1	30-35	Fig 5.4	1TL-2TT - 2RB - 2FB - 3KV
TM					(2)

1) Abbreviations: TL = longitudinal tensile test; TT = transverse tensile test; RB = root bend test; FB = face bend test; KV = Charpy V-notch impact test.
2) Tests for both techniques are required; only one longitudinal tensile test is required on the deposited metal test.

5.2 Approval tests

5.2.1 General

The test assemblies required for approval are specified in 5.2.2 to 5.2.7 and summarised in Table 5.2, depending on the welding technique to be approved. A few preliminary samples may be required by the Surveyor to be welded, in order to check the operating characteristics and set up the welding parameters.

5.2.2 Multi-run technique (M)

Where approval for use with multi-run technique is requested, deposited weld metal and butt weld tests are to be carried out as indicated in 5.2.3 and 5.2.4, respectively.

5.2.3 Deposited metal test

One deposited metal test is to be welded, as shown in Fig 5.1, in general with a wire having diameter of 4 mm.

Any grade of ship structural steel may be used for the preparation of the test assembly. The welding conditions (amperage, voltage and travel speed) are to be in accordance with the recommendations of the Manufacturer and are to conform with normal good welding practice.

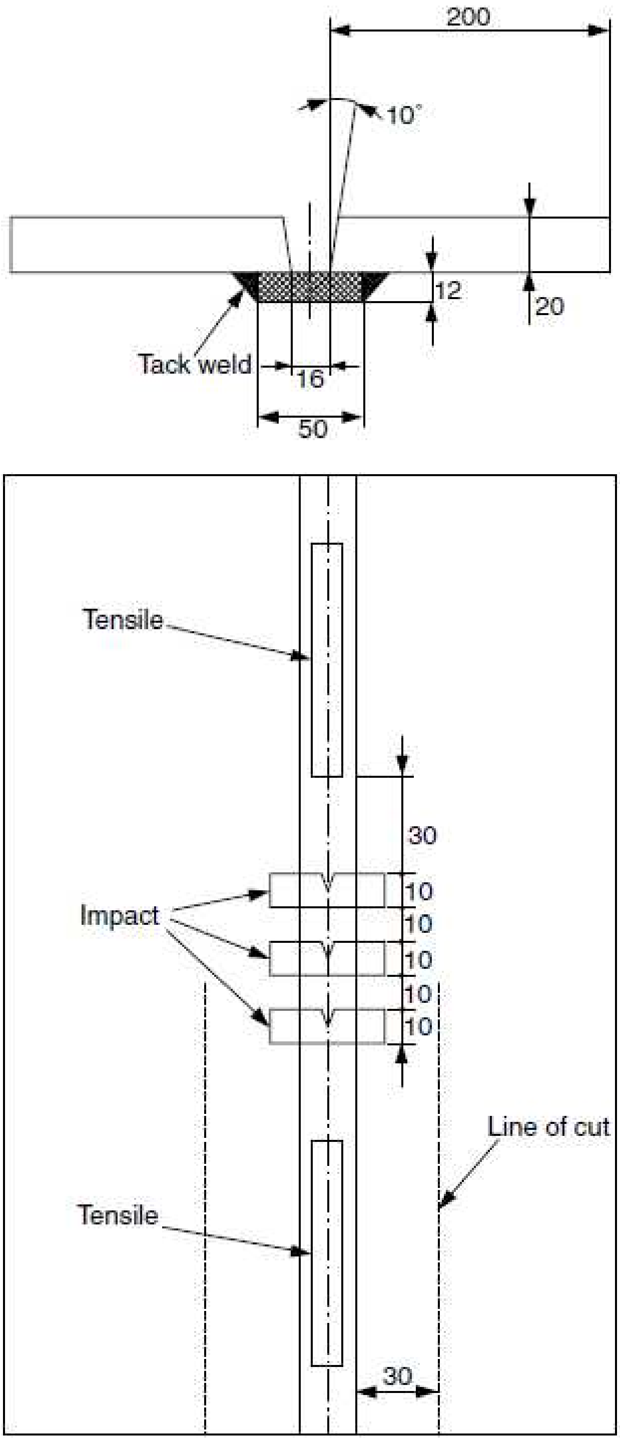


Figure 5.1: Deposited metal test

(All the dimensions are in mm, unless otherwise indicated.)

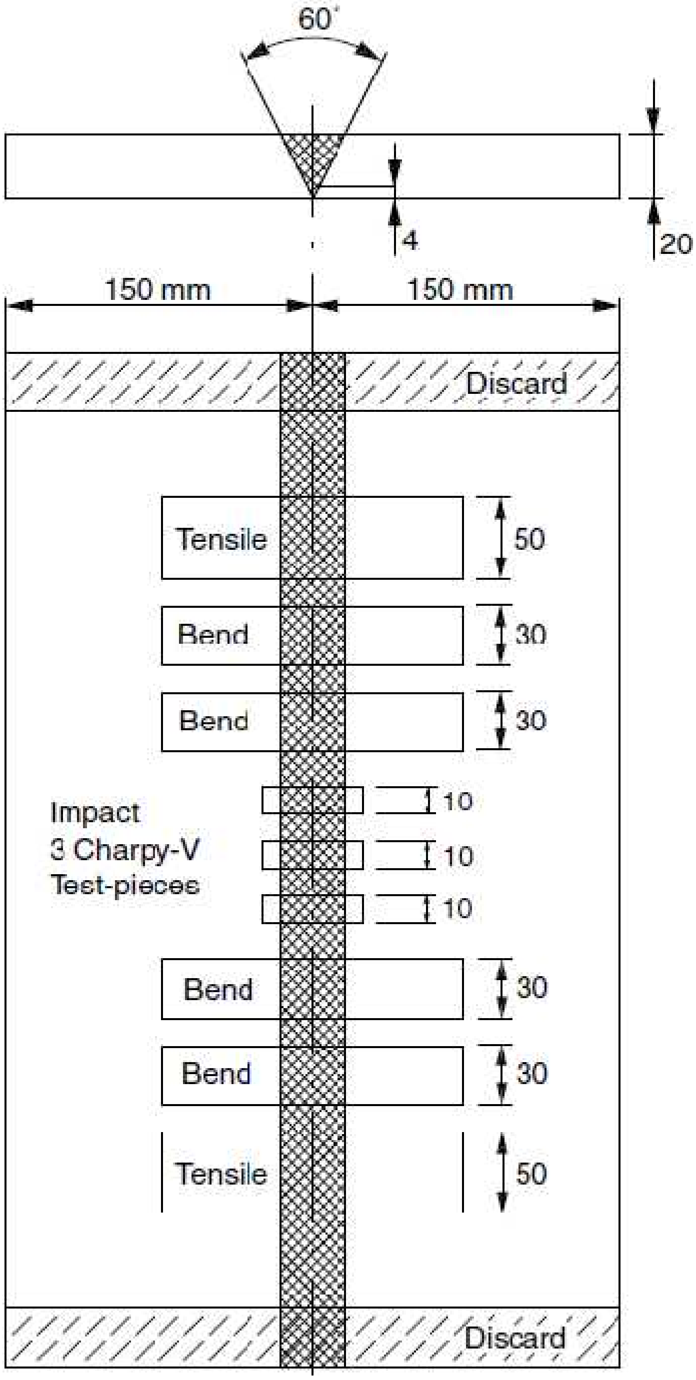


Figure 5.2: Butt weld test assembly

(All the dimensions are in mm, unless otherwise indicated.)

The weld metal is deposited in multi-run layers and the direction of deposition of each layer is in general to alternate from each end of the plate. After completion of each run, the flux and welding slag are to be removed. Between each run, the assembly is to be left in still air until it has cooled to less than 250°C but not below 100°C, the temperature being taken in the centre of the weld on the surface of the seam.

The thickness of each layer is to be neither less than the diameter of the wire nor less than 4mm. After being welded, the test assemblies are not to be subjected to any heat treatment, except where approval has also been requested in the stress relieved condition. In such case the symbol D is to be added to the grade designation. The specimens shown in Fig 5.1 are to be taken for the following tests:

a) two longitudinal tensile tests

b) three Charpy V-notch impact tests.

The results of the tests are to comply with the requirements of Table 5.5, as appropriate. The chemical analysis of the deposited weld metal of the test assembly is to be supplied by the Manufacturer and is to include the content of all significant alloying elements, if any.

5.2.4 Butt weld tests for multi-run technique

One butt weld test assembly is to be welded as shown in Fig 5.2 in general with a wire having diameter of 4 mm.

The grade of steel to be used for the preparation of the test assemblies is related to the grade of the wire-flux combination as indicated in Table 5.3.

At the discretion of the Society, approval of multi-run welding of both normal and higher strength steel may be obtained by making a butt weld on higher tensile steel only. For flux to be approved under grades 4 and 5, in lieu of the hull steels specified in Table 5.3, C-Mn steels for pressure vessels of grades L40 and L60, respectively, and strength appropriate to the wire flux combination strength may be used. The use of other types of steel is to be agreed with the Society on a case-by-case basis. The welding is to be performed by the multi-run technique

and the welding conditions are to be the same as those adopted for the deposit weld metal assembly. The back sealing run is to be made with the welding parameters used for the filling pass, after back gouging to sound metal.

After being welded, the test assemblies are not to be subjected to any heat treatment except where approval has also been requested in the stress relieved condition 5.2.7. In such case the symbol D is to be added to the grade designation.

It is recommended that the welded assemblies should be subjected to a radiographic examination to ascertain if there are any defects in the weld prior to the preparation of test specimens. The test specimens, shown in Fig 5.2, are to be taken for the following tests:

a) two transverse tensile tests

b) three Charpy V-notch impact tests

c) two root and two bend tests.

The results of the tests are to comply with the requirements of 5.2.6, as appropriate.

Table 5.3: Grade of steel used for test assemblies

Wire flux combination grade	Steel grade (1)
1	A
2	A, B, D
3 – 4	A, B, D, E
1Y	AH 32-36
2Y	AH 32-36, DH 32-36
3Y	AH32-36, DH32-36, EH32-36
4Y - 5Y	AH32-36, DH32-36, EH32-36, FH32-36
2Y40	AH40, DH40
3Y40	AH40, DH40, EH40
4Y40 - 5Y40	AH40, DH40, EH40, FH40

(1) The tensile strength of grades AH32 to FH32 is to be greater than 490 N/mm^2 .

5.2.5 Two-run technique (T)

Where approval for use with two-run technique only is requested, two butt weld test assemblies are to be carried out as indicated in Table 5.4 and no deposited metal test is requested. The grade of steel to be used for the preparation of the test assemblies is related to the grade of the wire flux combination as indicated in Table 5.3.

Each strength level requires separate approval.

For flux to be approved under grades 4 and 5, in lieu of the hull steels specified in Table 5.3, C-Mn steels for pressure vessels of grades L40 and L60, respectively, and strength appropriate to the wire flux combination strength may be used .

Table 5.4: Two-run technique butt weld test assemblies

Grade	Plate thickness (mm)	Recommended preparation (2)	Maximum diameter of wire(mm)
1 - 1Y	12 – 15	Fig 5.3 (a)	5
	20 – 25	Fig 5.3 (b)	6
2, 3, 4, 2Y, 3Y, 4Y, 5Y, 2Y40, 3Y40,4Y40,5Y40	20 – 25 (1)	Fig 5.3 (b)	6
	30 – 35 (1)	Fig 5.3 (c)	7

(1) A limitation of the approval to the lower and medium thickness range (up to the maximum welded plate thickness) may be agreed to by the Society and the test pieces are then to be welded from plates of thickness 12-15 mm and 20-25 mm, irrespective of the quality grade.

(2) Minor deviations in the weld preparation are admissible; the root gap is to be practically constant and generally is not to exceed 0,7 mm.

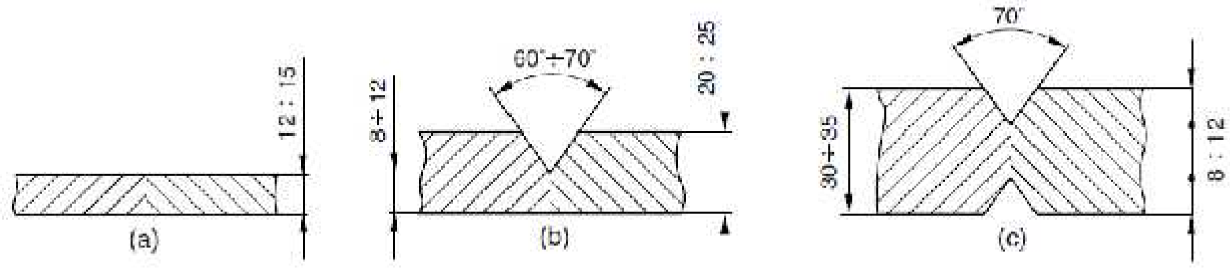


Figure 5.3: Recommended edge preparation for two-run technique

The use of other types of steel is to be agreed with the Society on a case-by-case basis.

The welding is to be performed in two runs, one from each side, using voltage and travel speed in accordance with the recommendation of the Manufacturer and normal good welding practice. In general, the following values of current parameters are to be complied with for welding the second run:

- 700-800 A for samples having thickness 12-15 mm
- 900-1000 A for samples having thickness 20-25 mm
- 1100-1200 A for samples having thickness 30-35 mm.

After the completion of the first run, the flux and welding slag are to be removed and the assembly left in still air until it has cooled to 100°C, the temperature being taken in the centre of the weld, on the surface of the seam. After being welded, the test assemblies are not to be subjected to any heat treatment except where approval has also been requested in the stress relieved condition. In such case the symbol D is to be added to the grade designation.

The test assemblies are to be subjected to radiographic examination to ascertain freedom from lack of penetration or other defects in the weld, prior to the preparation of test specimens.

The test specimens, shown in Fig 5.4, are to be taken for the following tests:

a) two transverse tensile tests

b) three Charpy V-notch impact tests

c) two root and two bend tests.

Where the approval is required for two-run technique only, one longitudinal tensile specimen is to be taken from the thicker plate, as shown in Fig 5.4. The results of the tests are to comply with the requirements of 5.2.6, as appropriate. The chemical analysis of the weld metal of the second run in each test assembly is to be supplied by the Manufacturer and is to include the content of all significant alloying elements, if any.

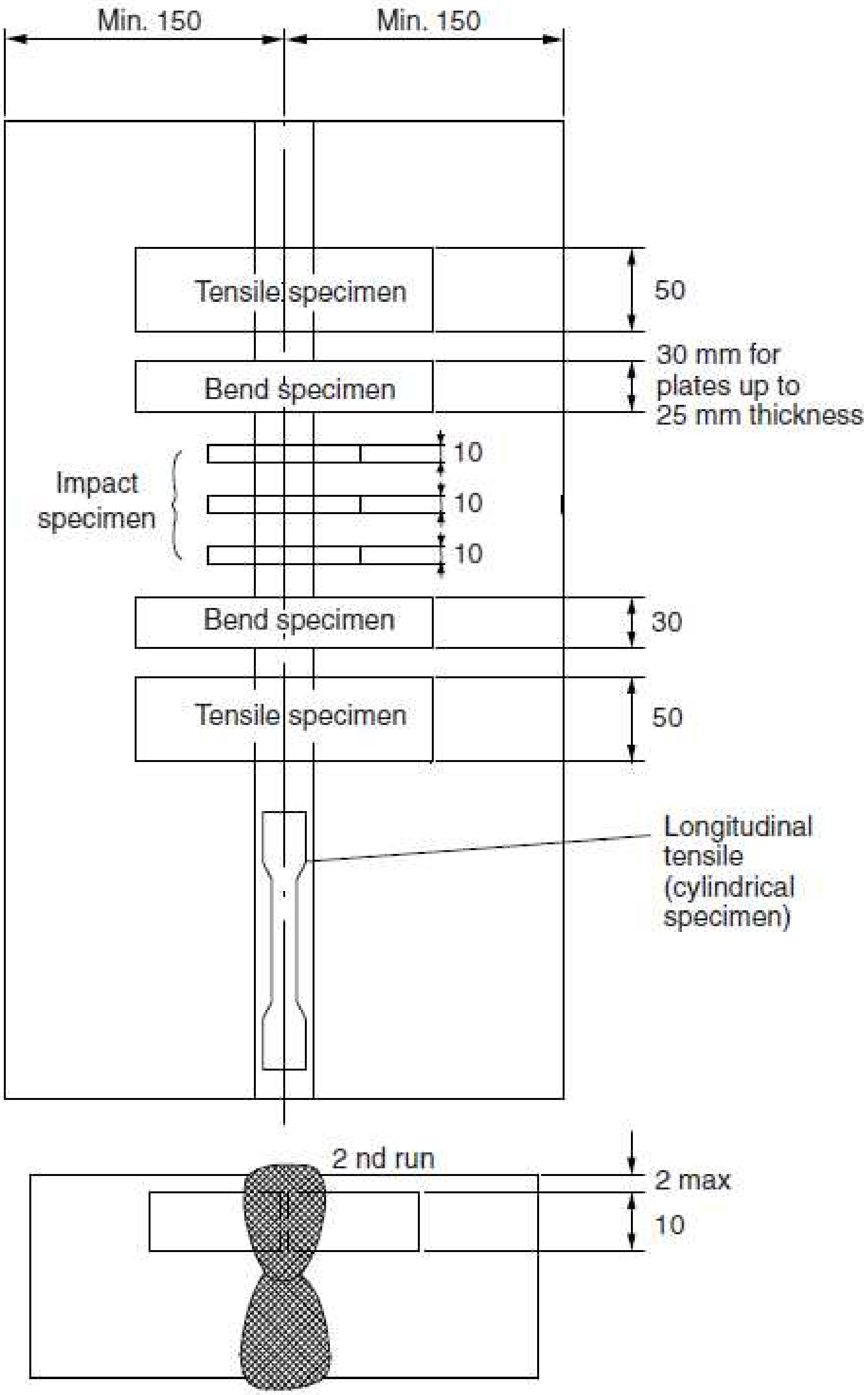


Figure 5.4: Butt weld test assembly for two-run technique (All the dimensions are in mm.)

Table 5.5: Required mechanical properties

Grade	Tensile test on deposited metal			Tensile test on butt weld	Charpy V-notch impact test	
	Yield stress R_{eH} (N/mm^2) min.	Tensile strength R_m (N/mm^2)	Elong A5 (%) min.	Tensile strength R_m (N/mm^2) min.	Test temp. (°C)	Minimum average energy (J)
1	305	400 – 560	22	400	+20	34
2					0	
3					-20	
4					-40	
1Y	375	490 – 660	22	490	+20	34
2Y					0	
3Y					-20	
4Y					-40	
5Y					-60	
2Y40	400	510 - 690	22	510	0	39
3Y40					-20	
4Y40					-40	
5Y40					-60	

5.2.6 Tests requirements

The required results of tensile and impact tests on deposited metal and butt weld tests are indicated in Table 5.5.

Bend tests are to be performed on a mandrel having a diameter equal to three times the thickness of the specimen; the results are to comply with requirements in 1.5.3.

5.2.7 Approval in the stress relieved condition

When the approval of the wire flux combination is required with the additional symbol D, relevant to the checking of the mechanical properties in the stress relieved condition, the following additional tests are to be carried out on samples submitted to stress relieving in the furnace for one hour at 600-650°C:

a) Two-run technique (T)

- one longitudinal and one transverse tensile test, three Charpy V-notch impact tests on the face and root side of the butt welded assembly having the maximum thickness.

b) Multi-run technique (M)

- one longitudinal tensile test on the deposited metal test and one transverse tensile test on the butt weld test
- three Charpy V-notch impact tests on deposited metal and butt weld tests.

5.3 Annual control tests

5.3.1 The periodical control tests are to include at least the following:

a) Two-run technique (T)

- one butt weld test assembly with plate thickness 20- 25 mm from which one transverse tensile, two bend tests (one root and one face bend) and three impact tests are to be taken. One longitudinal tensile test is also to be prepared for wire flux combinations approved solely for the two-run technique.

b) Multi-run technique (M)

- one deposited metal test assembly from which one all weld metal longitudinal tensile test and three Charpy V-notch impact tests are to be taken.

c) T and M techniques (TM)

- the test assemblies and relevant tests required for T and M techniques are to be carried out. The longitudinal tensile test specified in a) for T technique is not required.

5.3.2 The weld and test procedures, the type of current, the materials, the test results and the re-test procedures, where applicable, are regulated by the requirements relative to the approval tests.

Where a wire flux combination is approved for welding both normal strength and higher strength steels, the steels of the highest strength approved are to be used for the preparation of the butt weld assembly required by the T technique, in order to also cover the lower strength levels.

6 Flux-wire combinations for one side submerged arc welding of butt-joints of C and C-Mn steels

6.1 Scope

6.1.1 The requirements of this Sub-section apply to flux- wire combinations for submerged-arc welding processes with high current, used for one side welding (U welding technique) of butt-joints with one or more layers (in general not more than two layers).

The welding machine may have one or more welding heads. A suitable backing support, for example a flux layer and support equipment, may be adopted. The requirements of Sub-section 2.5 are also to be complied with, as applicable, unless otherwise stated in this Sub-section.

6.2 Designation

6.2.1 The prefix A and the suffix U are added to the grade as defined in 1.2.7.

6.3 Approval tests

6.3.1 The edge preparation of the various samples and the welding parameters to be used are those proposed by the Manufacturer and they are to be reported in the approval certificate; they are to be appropriate to ensure complete fusion and satisfactory surface appearance. The specimens which are required to be obtained from the samples are the same as indicated in 2.5.2.5 except for impact test specimens, which are to be taken as follows (see Fig 6.1):

a) for samples of thickness s = 12-15 mm: three specimens at mid-thickness

b) for samples of thickness s = 20-25 mm: six specimens, three near each surface

c) for samples of thickness s = 30-35 mm: nine specimens, three near each surface and three at mid-thickness.

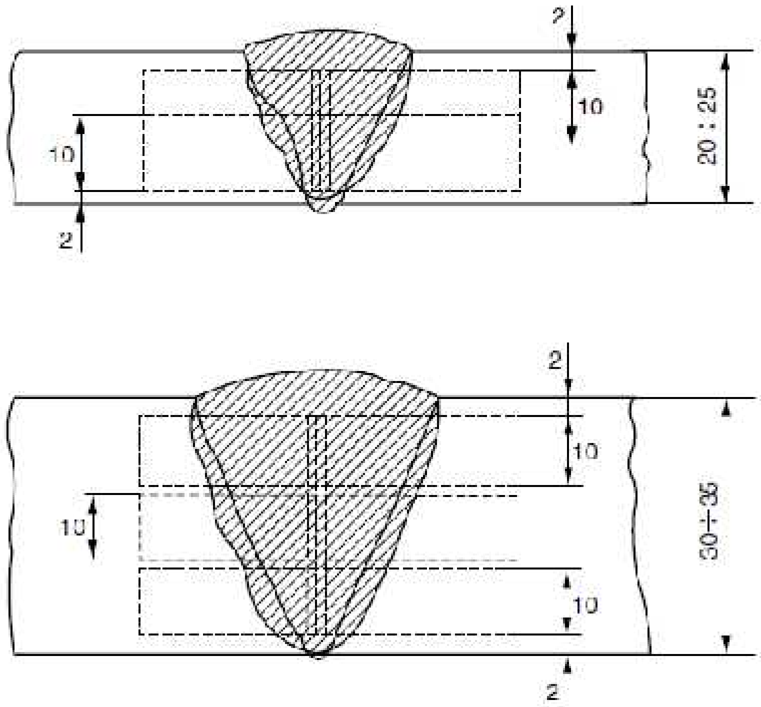


Figure 6.1: Position of Charpy V-notch impact test for one side automatic welding

Table 6.1: Solid wire chemical composition

Type of wire	Chemical Composition								
	C max.	Mn	Si	P Max.	S Max.	Cr Max.	Ni Max.	CuMax. (1)	Mo
G2Si	0.14	0.9-1.30	0.50-0.80	0.025	0.025	0.15	0.15	0.35	-
G3Si1	0.14	1.30-1.60	0.70-1.00						
G4Si1	0.14	1.60-1.90	0.80-1.20						
G4Mo	0.14	1.70-2.10	0.50-0.80						0.40-0.60
G4Si	0.14	1.60-1.90	0.80-1.20						-

(1) Including surface lining

(2) Al, Ti, Zr may be added by the Manufacturer and the values are to be submitted to the Society for consideration at the time of the request for the approval;

7 Wires and wire-gas combination for semiautomatic welding of C and C-Mn steels

7.1 Scope

7.1.1 The requirements of this Sub-section apply to bare wire gas combinations and flux cored or flux coated wires with or without shielding gases, to be used for semiautomatic welding of hull structural steels, of the corresponding grades of steel forgings and castings and of comparable steels intended for other structural applications or pressure systems.

The term semiautomatic is used to describe processes in which the weld is made manually by a welder holding a gun through which the wire is continuously feed. For the purpose of the approval designation, this technique is identified by the symbol S.

7.2 Type of wires

7.2.1 The chemical composition of bare wires normally used is shown in Table 6.1.

Types G3Si1 and G4Si1 are particularly intended for welding processes under CO2 shielding gas and the other types for welding processes where mixtures of shielding gases are used. Chemical composition of wires other than those given in Table 6.1 are to be submitted to the society.

7.3 Shielding gases

7.3.1 Where applicable, the composition of the welding gas is to be reported.

For the purpose of the approval, the type of gas and mixture of gas are grouped as indicated in Table 6.2.

Unless otherwise required for specific applications, gas mixtures in the same group are considered equivalent for approval purposes.

7.4 Designation

7.4.1 Wire gas combinations are divided, for the various strength levels, into the following grades as defined in 1.2.2:

a) 1, 2, 3, 4 for normal strength grades

b) 1Y, 2Y, 3Y, 4Y, 5Y for high strength grades with specified minimum yield strength up to 355 N/mm^2

c) 2Y40, 3Y40, 4Y40, 5Y40 for high strength grades with specified minimum yield strength up to 390 N/mm^2.

The prefix S or SA is added to indicate semiautomatic welding technique.

7.4.2 Flux cored or flux coated wires may be required to be submitted to the hydrogen test as detailed in 2.4, using the Manufacturer's recommended welding conditions and adjusting the deposition rate to give a weight of weld deposit per sample similar to that deposited when using manual electrodes.

On the basis of the test results, the welding consumables may be given one of the symbols H (or H15), HH (or H10), HHH (or H5), as appropriate.

Table 6.2: Composition of gas mixtures for continuous wire welding process

Group symbol	Composition of gas mixtures in volume (%)			
	Ar (1)	H_2	$C0_2$	0_2
C 1			100	-
C 2			70 – 99	1 – 30
M 11	90 – 98	1 – 5	1 – 5	-
M 12	95 – 99	-	1 – 5	-
M 13	97 – 99	-	-	1 – 3
M 14	92 – 98	-	1 – 5	1 – 3
M 21	75 – 94	-	6 – 25	-
M 22	90 – 96	-	-	4 – 10
M 23	67 – 93	-	6 – 25	1 – 8
M 31	50 – 74	-	26 – 50	-

M 32	85 – 89	-	-	11 – 15
M 33	35 – 85	-	6 – 50	9 – 15

(1) Argon may be replaced by Helium up to 95% of the argon content.

Table 6.3: Test assemblies and mechanical tests required

Test assembly						Tests required (1)
Type	Welding position(2)	Wire diameter (mm)	Number of Samples	Thickness (mm)	Dimensions	
Deposited metal	Flat	Max.	1 (3)	20	Fig 2.1	1 TL - 3KV
		1,2 or min.	1			
Butt weld	Flat	First run: 1,2 or min. Remaining run: max	1	15 – 20	Fig 7.1	2TT - 1RB - 1FB - 3KV
	Vertical upward		1 (4)			2TT - 1RB - 1FB - 3SB - 3KV
	Vertical downward		1			2TT - 1RB - 1FB - 3SB - 3KV
	Horizontal		1			2TT - 1RB - 1FB - 3SB - 3KV
	Overhead		1			2TT - 1RB - 1FB - 3SB - 3KV
Fillet	(5)	First side: min. diam.	1	15 - 20	Fig 2.3 Fig 2.4 Fig 2.5	Macro- Fracture- Hardness
		Second side: max. diam.				

(1) Abbreviations: TL = longitudinal tensile test; TT = transverse tensile test; RB = root bend test; FB = face bend test; SB = side bend test; KV = Charpy V-notch impact test.

(2) When the approval is requested only for one or more specified welding positions, the butt test samples are to be welded in such positions.

(3) If only one diameter is to be approved, only one test assembly is required.

(4) When the approval is requested in flat position only, two test samples are to be welded - the first sample with the maximum wire diameter and the second with increasing diameter from the first to the last pass.

(5) Fillet weld samples are to be welded in the position required for approval.

7.5 Information and documentation to be submitted

7.5.1 The following information and supporting documentation, as appropriate, are generally to be submitted together with the request for approval:

a) commercial name, type of wire, limits of chemical composition in the case of bare wires

b) grading under which the approval is requested; type of current, welding positions

c) type of shielding gas or gas mixture; commercial brand and Manufacturer, in the case of gas mixtures of special types

d) typical chemical composition of the deposited metal, with particular reference to the contents of Mn, Si and alloying elements

e) recommendations, where applicable, regarding the range of the welding parameters (current, voltage and welding speed)

f) previous approvals granted to the proposed gas wire combination.

7.6 Approval tests

7.6.1 General

Deposited metal and butt weld tests are to be performed as indicated in 7.6.2 and 7.6.3, and summarised in Table 6.3.

A few preliminary samples may be required by the Surveyor to be welded, in order to check the operating characteristics and set up the welding parameters. These tests may be limited to the fillet test assemblies required in 7.6.7.

7.6.2 Deposited metal test

Two deposited metal test assemblies are to be welded in the flat position as shown in Fig 2.1, one using a wire of 1,2mm or the smallest size to be approved and the other using a wire of 2,4 mm or the largest size to be approved. If only one diameter is available, one test assembly is sufficient.

Any grade of hull structural steel may be used for the preparation of the test assembly.

The preparation is to be in accordance with Fig 2.1; however, the angle of the bevel and the gap at the root may be modified depending on the welding process.

The weld metal is to be deposited in multi-run layers according to the normal practice (with wide beads extending for the full width of the bevel), as far as this is correctly feasible, regardless of the diameter of the wire; the direction of deposition of each layer is in general to alternate from each end of the plate, each run of weld metal having thickness in the range 2 mm to 6 mm (compenetration included).

Between each run the assembly is to be left in still air until it has cooled to less than 250°C but not below 100°C, the temperature being taken in the centre of the weld on the surface of the seam. After being welded, the test assemblies are not to be subjected to any heat treatment except where approval has also been requested in the stress relieved condition. In such case the symbol D is to be added to the grade designation.

The specimens shown in Fig 2.1 are to be taken for the following tests:

a) one longitudinal tensile test

b) three Charpy V-notch impact tests.

The chemical analysis of the deposited weld metal in each test assembly is to be supplied by the Manufacturer and is to include the content of all significant alloying elements, if any.

In general the chemical composition (C, Mn, Si) is determined near the surface of the final pass and is to be reported for information.

7.6.3 Butt weld tests

Butt weld test assemblies as shown in Fig 6.1 are to be welded for each welding position (flat, horizontal, vertical upwards and downards and overhead) for which the wire gas combination is to be approved.

One test sample is to welded in downhand position using, for the first run, a wire of 1,2 mm or the smallest diameter to be approved and, for the remaining runs, wires of the maximum diameter to be approved.

Where wires are intended for flat position only, one additional test sample is to be welded, if possible using wires of different diameters from those required above. The other test assemblies are to be welded in the vertical upwards, downwards, horizontal and overhead positions, using for the first run a wire of 1,2 mm or the smallest diameter to be approved, and for the remaining runs the largest diameter to be approved for the position concerned.

The grade of steel to be used for the preparation of the test assemblies is related to the grade of the electrodes as indicated in Table 2.2.

For the electrodes to be approved under grades 4 and 5, in lieu of the hull steels specified in Table 2.2, C-Mn steels for pressure vessels of grades L40 and L60, respectively, and strength appropriate to the electrode strength may be used.

The use of other types of steel is to be agreed with the Society on a case-by-case basis.

The welding is to be performed with the usual technique in compliance with requirements specified in 7.6.2 for the deposited metal test, as applicable. For all assemblies, the back sealing run is to be made with the same diameter of wire or with the largest diameter of wire used for the weld on the other side.

After being welded, the test assemblies are not to be subjected to any heat treatment except where approval has also been requested in the stress relieved condition. In such case the symbol D is to be added to the grade designation.

It is recommended and may be required that the welded assemblies should be subjected to a radiographic examination to ascertain if there are any defects in the weld prior to the preparation of test specimens.

The specimens shown in Fig 7.1 are to be taken for the following tests:

a) one longitudinal tensile test

b) three Charpy V-notch impact tests

c) one face and one root bend tests.

Three additional side bend tests 1.5.4 may be required by the Surveyor to be carried out for samples welded in vertical, horizontal and overhead positions.

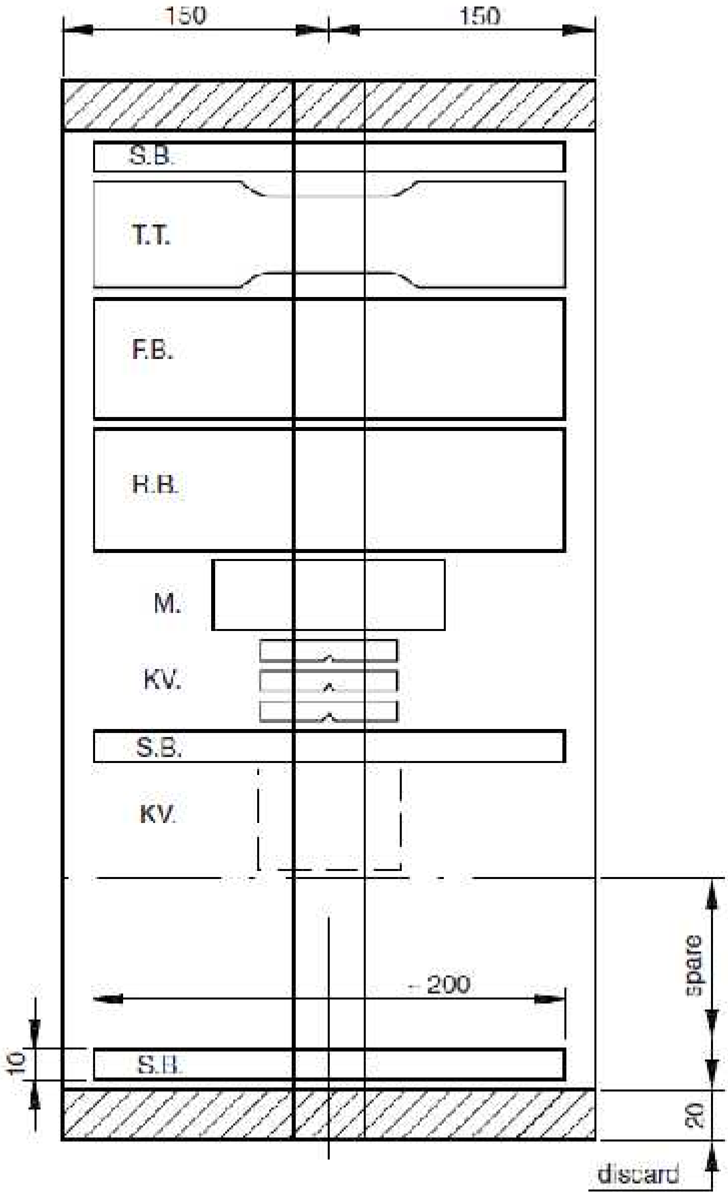


Figure 7.1: Butt weld test assembly (All the dimensions are in mm.)

7.6.4 Test requirements

The required results of tensile and impact tests on deposited metal and butt weld tests are indicated in Table 7.1.

Bend tests are to be performed on a mandrel having a diameter equal to three times the thickness of the specimen; the results are to comply with the requirements in 1.5.3.

7.6.5 Approval in the stress relieved condition

The requirements set forth in 2.3.5 apply.

7.6.6 Tests for checking the hydrogen content

When the additional symbols HH (or H10) or HHH (or H5) are required, the provisions under 2.4 apply.

7.6.7 Fillet weld test assemblies

Fillet weld test assemblies are generally required in addition to the butt weld test and are to be welded in each of the positions applied for approval (horizontal-vertical, vertical, overhead). The requirements set forth in 2.5 apply, as appropriate.

7.7 Annual control tests

7.7.1 The annual tests are to include at least the following assemblies and tests:

a) One deposited metal test assembly is to be welded in accordance with 7.6.2 with wire having minimum or maximum diameter, and the required tests (one longitudinal tensile test and three Charpy V-notch impact tests) are to be conducted.

b) At the discretion of the Society, a butt weld test, to be welded in vertical position, may also be required and three side bend tests and three Charpy V-notch impact tests are to be performed.

c) For flux cored wire electrodes approved with symbol HH (or H10) or HHH (or H5), the hydrogen content may be required to be checked with the same procedure used in the approval tests.

d) The chemical composition may be required to be checked under conditions corresponding to those of the approval tests.

The weld and test procedures, the type of current, the materials, the test results and the re-test procedures, where applicable, are regulated by the requirements relative to the approval tests.

Table 7.1: Mechanical properties

Grade	Tensile test on deposited metal			Tensile test on butt weld	Charpy V-notch impact test Minimum average energy (J)		
	Yield stress R_{eH}(N/mm^2) min.	Tensile strength R_m (N/mm^2)	Elong A5 (%) min.	Tensile strength R_m (N/mm^2) min.	Test temp (°C)	Flat, Horizontal, Overhead	Vertical
1	305	400 – 560	22	400	+20	47	34
2					0		
3					-20		
4					-40		
1Y	375	490 – 660	22	490	+20	47	34
2Y					0		
3Y					-20		
4Y					-40		
5Y					-60		
2Y40	400	510 - 690	22	510	0	47	39
3Y40					-20		
4Y40					-40		
5Y40					-60		

8 Wires and wire-gas combinations for automatic welding of C and C-Mn steels

8.1 Scope

8.1.1 General

The requirements of this Sub-section apply to bare wire-gas combinations and flux cored or flux coated wires with or without shielding gases to be used for automatic welding processes with multi-run technique (M) and two-run technique (T).

As regards preliminary information and requirements not expressly stated in this Sub-section, reference may be made as far as applicable to the corresponding requirements of Sub-section 7.

8.2 Designation

8.2.1 Wire gas combinations are divided, for the various strength levels, into the following grades as defined in 1.2.2:

a) 1, 2, 3, 4 for normal strength grades

b) 1Y, 2Y, 3Y, 4Y, 5Y for high strength grades with specified minimum yield strength up to 355 N/mm^2

c) 2Y40, 3Y40, 4Y40, 5Y40 for high strength grades with specified minimum yield strength up to 390 N/mm^2.

The prefix A is added to indicate automatic welding technique.

8.3 Approval tests

8.3.1 General

Test samples for the approval are to be carried out using the welding technique for which approval is requested (multi run M or two-run T technique).

In the case of the multi-run welding technique using wire diameters approved with the semiautomatic process, the tests are not to be repeated with the automatic process.

8.3.2 Multi-run technique

Where approval for use with the multi-run technique (M) is requested, deposited weld metal and butt weld tests are to be carried out as indicated in 8.3.3 and 8.3.4, respectively.

8.3.3 Deposited metal test

One deposited metal test is to be welded as shown in Fig 5.1; The base metal, the preparation of the test assembly welding, the checks and the number of tests required are to be as indicated in 5.2.3, except that the thickness of each layer is to be not less than 3 mm.

The wire diameter, type of current and welding parameters are to be in accordance with the recommendation of the Manufacturer.

The results of the tests are to comply with the requirements of Table 8.1.

Table 8.1: Mechanical properties

Grade	Tensile test on deposited metal			Tensile test on butt weld	Charpy V-notch impact test	
	Yield stress ReH (N/mm^2) min.	Tensile strength Rm (N/mm^2)	Elong A5 (%) min.	Tensile strength Rm (N/mm^2) min.	Test temp (°C)	Minimum average energy (J)
1	305	400 – 560	22	400	+20	34
2					0	
3					-20	
2Y	375	490 – 660	22	490	0	34
3Y					-20	
4Y					-40	
5Y					-60	
2Y40	400	510 - 690	22	510	0	39
3Y40					-20	
4Y40					-40	
5Y40					-60	

8.3.4 Butt weld tests for multi-run technique

One butt weld assembly is to be welded as shown in Fig 5.2 for each position to be approved; the base metal, the preparation of the test assembly welding, the checks and the number of test specimens required are to be as indicated in 5.2.4.

The diameter of the wire, type of current and welding parameters are to be in accordance with the recommendation of the Manufacturer. The results of the tests are to comply with the requirements of Table 8.1.

8.3.5 Two-run technique

Where approval for use with the two-run technique only (T) is requested, two butt weld test assemblies are to be carried out and no deposited metal test is requested. The indications in 5.2.5 generally apply if not modified below, except that one test assembly is to be 12-15 mm thick and the other is to be 20 mm thick.

The bevel preparation of the test assemblies is to be as shown in Fig 8.1. Small deviations in the edge preparation may be allowed according to the Manufacturer's recommendations.

If approval is requested for welding plates thicker than 20 mm, one assembly is to be prepared with plates 20 mm thick and the other with the maximum thickness for which the approval is requested. For assemblies using plates over 25 mm in thickness, the edge preparation used is to be reported for information. The base metal, checks and number of test specimens required are to be as indicated in 5.2.5.

The diameter of the wire, type of current and welding parameters are to be in accordance with the recommendation of the Manufacturer. The results of the tests are to comply with the requirements of Table 8.1.

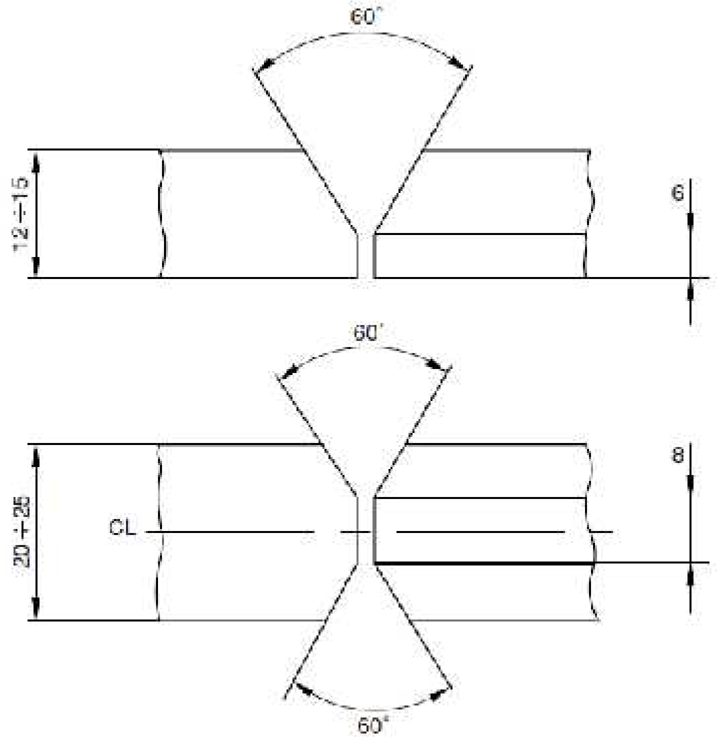


Figure 8.1: Recommended edge preparation for two-run butt weld test assemblies

8.4 Annual control tests

8.4.1 Multi-run technique

The annual tests are to include at least the following:

a) One deposited metal test assembly is to be welded in accordance with 3.3 with wires having minimum or maximum diameter, and the required tests (one longitudinal tensile test and three Charpy-V notch impact tests) are to be conducted.

b) The chemical composition may be required to be checked under conditions corresponding to those of the approval tests.

8.4.2 Two-run technique

The annual tests are to include at least the following:

a) One butt weld test assembly is to be welded in accordance with 8.3.5 with wires having minimum or maximum diameter, and the required tests (one longitudinal tensile test, three Charpy V-notch impact tests and two bend tests) are to be performed. One longitudinal tensile test is also required when the wire is approved for the two-run technique only.

b) The chemical composition may be required to be checked under conditions corresponding to those of the approval tests.

8.4.3 Test requirements

The weld and test procedures, the type of current, the materials, the test results and the re-test procedures, where applicable, are regulated by the requirements relative to the approval tests. For flux cored wire electrodes approved with symbol HH (or H10) or HHH (or H5), the hydrogen content may be required to be checked with the same procedure used in the approval tests.

9 Consumables for welding C and C-Mn steels with electrogas or electroslag process

9.1 Scope

9.1.1 General

The requirements of this Sub-section apply to wire gas combinations and flux cored or flux coated wires for electrogas (EG) and electroslag (ES) vertical welding with or without consumable nozzles of hull structural steels, of the corresponding grades of steel forgings and castings and of comparable steels intended for other structural applications.

9.1.2 Type of wires

The wires are to be of the type recommended by the Manufacturer, obtained from original packages and of known chemical composition. For electrogas processes, wires having the chemical composition specified in Tab 6.1 may be used. Other wires of different chemical composition are to be submitted for consideration.

9.1.3 Shielding gases

The requirements specified in 7.3.1 apply.

9.1.4 Designation

The consumables are divided, for the various strength levels, into the following grades as defined in 1.2.2:

a) 1, 2, 3 for normal strength grades

b) 2Y, 3Y, 4Y for high strength grades with specified minimum yield strength up to 355 N/mm^2

c) 2Y40, 3Y40, 4Y40 for high strength grades with specified minimum yield strength up to 390 N/mm^2.

The prefix AV is added to the grade to indicate electrogas or electroslag welding technique.

For high strength grades, the approval may be restricted for use with steels of specific composition. This applies, in particular, in relation to the content of grain refining elements, and if general approval is required, a Niobium treated steel is to be used for approval tests.

9.2 Information and documentation to be submitted

9.2.1 Information and documentation to be submitted

The following information and supporting documentation are to be submitted together with the request for approval:

a) commercial name, type of wire, limits of chemical composition in the case of bare wires
b) type of process and grading under which the approval is requested
c) type of shielding gas or gas mixture; commercial brand and Manufacturer, in the case of gas mixtures of special types
d) type of flux, consumable insert when used
e) type of current, range of current for which the approval is requested
f) main characteristics of the welding equipment
g) typical chemical composition of the deposited metal
h) main operating characteristics and welding techniques, associated recommendations and limitations in general and in particular as regards edge preparation and welding parameters
i) previous approvals already granted to the proposed consumables.

9.3 Approval tests

9.3.1 Two butt weld test assemblies are to be prepared: one with plates 20/25 mm thick, the other with plates 35/40 mm thick or more. The grade of steel to be used for each of these assemblies is to be selected according to the requirements given in Table 5.4 for two-run submerged arc welding.

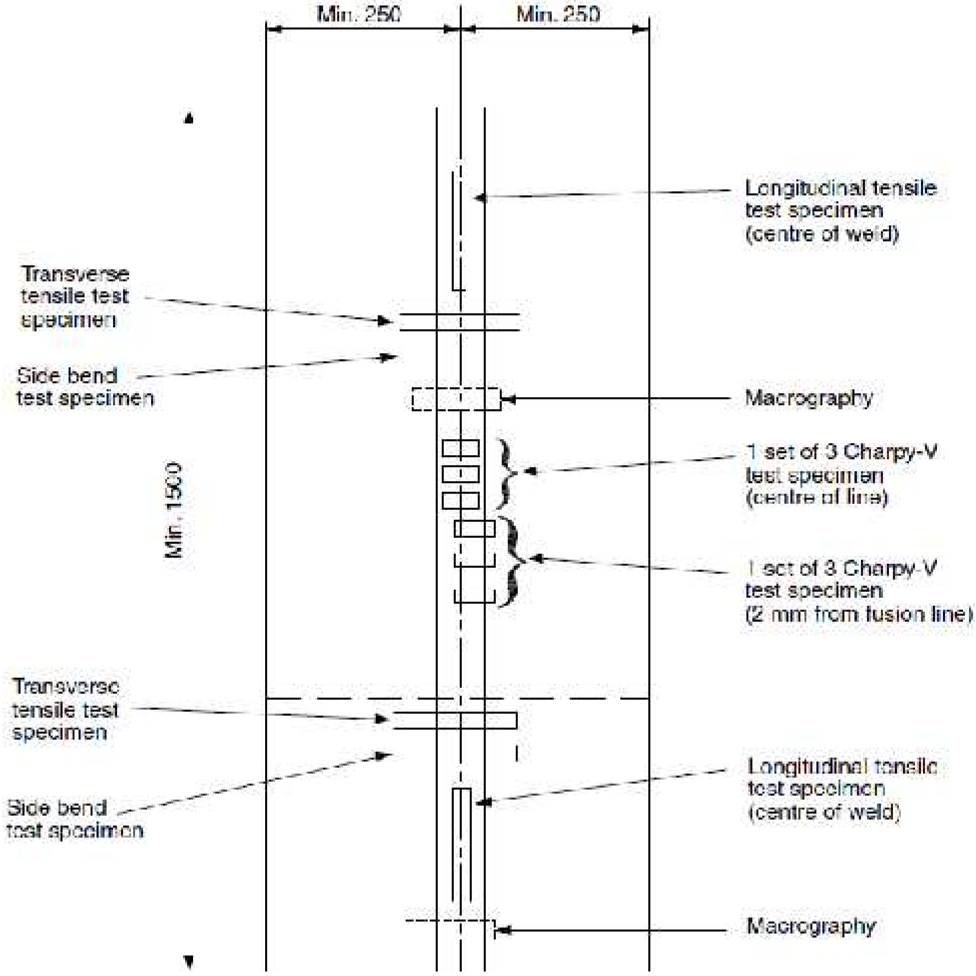


Figure 9.1: Butt weld test assembly for electro-gas and electro-slag welding

The chemical composition of the plate, including the content of grain refining elements, is to be reported. The welding conditions and the edge preparation adopted are to be in accordance with the recommendation of the Manufacturer and are to be reported. The Manufacturer's maximum recommended gap between plates is to be used in making the test assemblies. The test assemblies are to be submitted to radiographic and or ultrasonic examination to ascertain the absence of defects prior to the preparation of test specimens.

The specimens shown in Fig 9.1 are to be taken for the following tests:

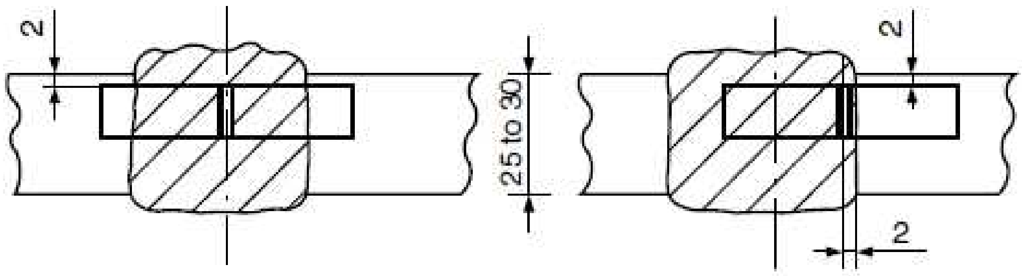
a) two longitudinal tensile tests

b) two transverse tensile tests

c) two side bend tests

d) two sets of three Charpy V-notch impact tests with notch located as shown in Fig 9.2 (i.e. one set with the notch located in the centre of the weld and one set with the notch located at 2 mm from the fusion line in the weld metal)

e) two macro sections (in the middle of the sample and towards the end) and, if required, Vickers hardness checks.



1. Notch in centre of weld 2. Notch 2 mm from the fusion line, weld metal side

Figure 9.2: Position of Charpy V-notch impact test specimens (All the dimensions are in mm.)

The chemical analysis of the deposited weld metal is to be supplied by the Manufacturer and is to include the content of all significant alloying elements, if any.

9.3.2 The results of tensile and impact tests on deposited metal and butt weld tests are to comply with the requirements specified in Table 7.1, as appropriate. Side bend tests 1.5.4 are to be performed on a mandrel having a diameter equal to three times the thickness of the specimen; the results are to comply with requirements in 1.5.3.

The Vickers hardness values, when verification is required, are to be HV ≤ 270.

9.4 Annual control tests

9.4.1 The annual tests are to include at least a butt weld test assembly having thickness 20/25 mm. The non- destructive examinations required for the approval are to be carried out on this sample and the following test specimens are to be taken:

a) one longitudinal tensile test specimen

b) one transverse tensile test specimen

c) two side bend test specimens

d) one set of three Charpy V-notch impact tests with the notch in the weld at 2 mm from the fusion line

e) one set of three Charpy V-notch impact tests with the notch in the centre of the weld

f) one section for macrographic examination.

The chemical composition may be required to be checked under conditions corresponding to those of the approval tests.

The weld and test procedures, the type of current, the materials, the test results and the re-test procedures, where applicable, are regulated by the requirements relative to the approval tests.

10 Consumables for welding high strength quenched and tempered steels

10.1 Scope

10.1.1 General

The requirements of this Sub-section apply to consumables used for weldable high strength quenched and tempered steels with minimum specified yield strength from 420 N/mm^2 to 690 N/mm^2.

Unless otherwise stated in this Sub-section, the requirements relevant to the procedure, tests samples and welding conditions are generally to be in accordance with those of the previous Sub-sections relevant to the approval of consumables for welding carbon and carbon-manganese steels, as follows:

- Sub-section 2: Covered electrodes for manual metal arc welding
- Sub-section 5: Flux-wire combination for submerged arc welding
- Sub-section 7: Wires and wire-gas combination for semiautomatic welding processes employing continuous wire
- Sub-section 8: Wires and wire-gas combination for automatic welding processes employing continuous wire.

10.1.2 Designation

The designation is given by the appropriate grade as defined in 1.2.2 with the relevant prefix and/or suffix.

10.2 Approval tests

10.2.1 The same samples are required as for C and C-Mn steel welding consumables approval.

The deposited metal and the butt weld test samples are to be prepared using high strength steel having mechanical properties corresponding, as appropriate, to those of the welding consumable to be approved. However, at the request of the Manufacturer, the all deposited metal samples may be allowed to be prepared using any C or C-Mn steels, provided that the bevels are duly buttered with the welding consumable to be approved.

10.2.2 The checking of the chemical composition is to be carried out on shavings taken from the deposited material samples.

The checking of C, Mn, Si, S, P, Cr, Cu, Ni, Mo, N and of other alloying elements stated by the Manufacturer is to be carried out on all the samples.

10.2.3 Welding consumables other than solid wire-gas combinations are to be subjected to a hydrogen test in accordance with 2.4 or recognized standards, as applicable. The above consumables are to satisfy the hydrogen test requirement at least for the symbol HH (or H10) or HHH (or H5) for steels having specified yield strength levels, respectively, not higher or higher than 500 N/mm^2.

10.2.4 Unless special requests are made by the Manufacturer, the samples are not to be post-weld heat treated.

10.3 Test requirements

10.3.1 In the tests for checking the operating conditions, the requirements specified under Sub-sections 2, 5 and 7 for electrodes, submerged arc fluxes and wires for continuous wire processes, respectively, are to be met.

In the tests for checking the chemical composition, the limits in percentage specified and guaranteed by the Manufacturer are to be satisfied. In the tests for checking the mechanical properties, the requirements specified in Table 10.1 are to be met. The results of the bend tests are to comply with the requirements in 1.5.3.

Where the required bending angle is not achieved, the specimen may be considered as fulfilling the requirements if the bending elongation LO on a gauge length equal to LS+t (LO being the width of the weld and t the specimen thickness) fulfils the minimum elongation requirements specified for the deposited metal tensile test.

10.4 Annual control tests

10.4.1 For the periodical control tests, the samples and tests for checking the mechanical properties are to be carried out as required for C and C-Mn steel welding consumables.

Table 10.1: Mechanical properties

Grade	Tensile test on deposited metal			Tensile test on butt weld	Charpy V-notch impact test		
	Yield stress R_{eH} (N/mm^2) min.	Tensile strength R_m (N/mm^2)	Elong A5 (%) min.	Tensile strength R_m (N/mm^2) min.	Test temp.(°C)	Minimum average energy (J)	
3	Y42	530 – 680	20	530	-20	47	4
4					-40		
5					-60		
3	Y46	570 – 720	20	570	-20	47	4
4					-40		
5					-60		
3	Y50	610 – 770	18	610	-20	50	5
4					-40		
5					-60		
3	Y55	670 – 830	18	670	-20	55	5
4	375	490 – 660	22	490	-40		
5					-60		
3	Y62	720 – 890	18	720	-20	62	5
4					-40		
5	375	490 – 660	22	490	-60		
3	Y69	770 - 940	17	770	-20	69	5
4					-40		
5					-60		

The tensile strength of the weld metal may be up to 10% below the requirements, provided the results obtained with the transverse tensile tests on the butt weld are satisfactory.

(1) D = mandrel diameter, t = specimen thickness

11 Consumables for welding Mo and Cr-Mo steels

11.1 Scope

11.1.1 General

The requirements of this Sub-section apply to consumables used for welding Mo and Cr-Mo steels.

Unless otherwise stated in this Sub-section, the requirements relevant to the procedure, tests samples and welding conditions are generally to be in accordance with those of the previous Sub-sections relevant to the approval of consumables for welding carbon and carbon-manganese steels, as follows:

- Sub-section 2: Covered electrodes for manual metal arc welding
- Sub-section 5: Flux-wire combination for submerged arc welding
- Sub-section 7: Wires and wire-gas combination for semiautomatic welding processes employing continuous wire
- Sub-section 8: Wires and wire-gas combination for automatic welding processes employing continuous wire.

11.1.2 Designation

Consumables are divided into the following grades, designated by a symbol indicating the nominal percentage Mo and Cr content of the deposited weld metal, as follows:

a) M for Mo = 0,5

b) C1M for Cr = 1,25 and Mo = 0,5

c) C2M1 for Cr = 2,25 and Mo = 1

The relevant prefix and/or suffix are to be added to the grade.

11.2 Approval tests

11.2.1 The same samples as for the C and C-Mn steel welding consumables approval are required. The butt weld test Samples are to be prepared using the corresponding grade of Mo or Cr-Mo steels.

Instead of the above-mentioned Mo and Cr-Mo steels, at the request of the Manufacturer, grades 460 and 510 C-Mn steels for boilers and pressure vessels may be used.

11.2.2 When the approval is required for two types of the same consumable, one with normal C content and the other with "low C" content, i.e. with C content not higher than 0,05%, and if the Manufacturer certifies that the only difference is the C content, for the approval of “low C" welding consumables the tests for checking the mechanical properties of the deposited material and the chemical composition only are to be carried out.

Table 11.1: Pre- and post-weld heating

Consumable grade	M	C1M	C2M1
Preheating:			
Temperature (°C)	-	100 - 150	200 - 280
Post-weld heat treatment:			
Temperature T (°C)	620 ± 10	660 ± 10	710 ± 10
Soaking time at T (minutes)	30	30	60
Cooling rate down to 500°C (°C/h) in furnace (1)	150 - 250	150 - 250	100 - 200

(1) When 500°C is reached, the cooling may be continued either in the furnace or in still air.

Table 11.2: Mechanical properties

Grade	Tensile test on deposited metal (1)		Bend ratio and angle (2)
	Tensile strength R_m (N/mm^2)	Elong. A5 (%) min.	D/ t, α ≥ 120°
M	490 - 640	20	3
C1M	490 – 690	20	3
C2M1	540 - 785	18	4

(1) The values of the minimum yield strength ReH and reduction of area are also to be recorded, for information purposes.

(2) D = mandrel diameter, t = specimen thickness.

Table 11.3: Chemical composition

Grade	Chemical Composition (%)								
	C	Cr	Mo	Mn	Si Max.	S Max.	P Max.	Cu Max.	Ni
M	0.12 (1)	0.15	0.40-0.65	0.50-0,90(2)	0.60(2)	0.040	0.040	0.20	0.30
C1M	0.12 (1)	1.0 -1.5	0.40-0.65						
C2M1	0.12 (1)	2.0-2.5	0.90-1.20						

(1) In the case of electrodes to be certified as “low carbon “ the carbon content is not to exceed 0,05%.

(2) The actual values of Mn and Si contents, guaranteed by the Manufacturer, within the limits specified in the table, are to be stated at the time of the approval of single electrodes.

11.2.3 With the exception of those for the hydrogen content checking, the test samples are to be welded in the preheating condition and are to be post-weld heat treated, as indicated in Table 11.1, depending on the grade of the consumable.

11.2.4 In the case of covered electrodes for manual welding, the checking of the chemical composition is to be carried out, as a rule, on samples of deposited metal described in 1.6.

Two samples are required with two different electrode diameters. In the case of other types of welding consumables, the checking is to be carried out on shavings taken from the deposited metal samples.

The checking of C, Cr and Mo contents is to be carried out on all the samples and, additionally, the checking of Mn, Si, Cu, Ni, S and P contents and that of other alloy elements is to be carried out on one sample.

11.2.5 Consumables may be submitted, at the Manufacturer's request, to hydrogen tests and have the additional symbol H10 (or HH) or H5 (or HHH) added to the grade designation according to the hydrogen content.

11.3 Test requirements

11.3.1 In the tests for checking the operating characteristics, the requirements specified in Sub-sections 2, 5, 7 for electrodes, submerged arc fluxes and wires for continuous wire processes, respectively, are to be met.

In the tests for checking the mechanical properties, the requirements specified in Table 11.2 are to be met. As a rule, transverse tensile tests on the welded joint are not required.

11.3.2 In the tests for checking the chemical composition, the limits in percentage of chemical composition specified in Table 11.3 are to be met.

11.4 Periodical control tests

11.4.1 For the periodical control tests, to be carried out as a rule every two years, in addition to the samples and tests for checking the mechanical properties, as required for the consumables for welding C and C-Mn steels, the samples for checking the chemical composition, requested for the approval, are to be effected.

11.4.2 For the "low C" welding consumables described in 11.2.2, the control tests are limited to one sample of deposited metal 1.6 and to the checking of the chemical composition.

12 Consumables for welding Ni steels for low temperature applications

12.1 Scope

12.1.1 General

The requirements of this Sub-section apply to consumables used for welding Ni steels for low temperature applications.

Unless otherwise stated in this Sub-section, the requirements relevant to the procedure, tests samples and welding conditions are generally to be in accordance with those in the previous Sub-sections relevant to the approval of consumables for welding carbon and carbon-manganese steels, as follows:

- Sub-section 2: Covered electrodes for manual metal arc welding
- Sub-section 5: Flux-wire combination for submerged arc welding

- Sub-section 7: Wires and wire-gas combination for semiautomatic welding processes employing continuous wire
- Sub-section 8: Wires and wire-gas combination for automatic welding processes employing continuous wire.

12.1.2 Designation

Consumables are divided into the following grades designated by a symbol indicating the type of nickel steel for which the consumables are intended, as follows:

a) N15 for steels with Ni = 1,30 - 1,70 (%)

b) N35 for steels with Ni = 3,25 - 3,75 (%)

c) N50 for steels with Ni = 4,75 - 5,25 (%)

d) N90 for steels with Ni = 8,50 - 10 (%).

The relevant prefix and/or suffix are to be added to the grade.

12.2 Approval tests

12.2.1 The same samples as for the C and C-Mn steel welding consumables approval are required.

The butt weld test samples are to be prepared using the corresponding grade of Ni steel.

Instead of the above-mentioned Ni steel, at the request of the Manufacturer, steels with lower Ni content but having suitable mechanical properties for the tests to be carried out may be used. In such case, if deemed necessary by the Manufacturer, the bevels may be duly buttered with the welding consumable to be approved. In the case of use of plates with buttered bevels and where the mechanical properties of the welding consumable are significantly lower than those of the base material, longitudinal instead of transverse specimens may be allowed to be taken for face and root bend tests. In this case the length of the sample is to be such as to allow the taking of these specimens.

12.2.2 In the case of covered electrodes for manual welding, the checking of the chemical composition is to be carried out, as a rule, on samples of deposited metal described in 1.6.

Two samples are required with two different electrode diameters.

In the case of other types of welding consumables, the checking is to be carried out on shavings taken from the deposited metal samples.

The checking of C, Ni, Mn and Si contents is to be carried out on all the samples and, additionally, the checking of Cu,Cr, S, P and other alloy elements is to be carried out on one sample.

12.2.3 Consumables may be submitted, at the Manufacturer’s request, to hydrogen tests and have the additional symbol H10 (or HH) or H5 (or HHH) added to the grade designation according to the hydrogen content.

12.2.4 Unless special requests are made by the Manufacturer, the samples are not to be post-weld heat treated.

12.3 Tests requirements

12.3.1 In the tests for checking the operating characteristics, the requirements specified in Sub-section 2, 5, 7, 8 for electrodes, submerged arc fluxes and wires for continuous wire processes, respectively, are to be met.

In the tests for checking the mechanical properties, the requirements specified in Table 12.1 are to be met.

As a rule, transverse tensile tests on the welded joint are not required.

12.3.2 In the tests for checking the chemical composition, the limits in percentage of chemical composition specified and guaranteed by the Manufacturer are to be met.

12.4 Annual control tests

12.4.1 For the periodical control tests, in addition to the samples and tests for checking the mechanical properties as required for the consumables for welding C and C-Mn steels, the samples for checking the chemical composition, requested for the approval, are to be effected.

Table 12.1: Mechanical properties

Grade	Tensile test on deposited metal			Tensile test on butt weld	Charpy V-notch impact test		Bend ratio and angle
	Yield stress R_{eH} (N/mm^2) min.	Tensile trength R_m (N/mm^2) min.	Elong. A5 (%) min.	Tensile strength R_m (N/mm^2) min.	Test temp. (°C)	Minimum average energy (J)	D/ t (1) $\alpha \geq 120°$
N 15	355	470	22	490	-80	34	3
N 35	355	470	22	490	-100	34	3
N 50	380	520	22	540	-120	34	4
N 90	480	670	22	690	-196	34	4

(1) D = mandrel diameter, t = specimen thickness

13 Consumables for welding Cr-Ni austenitic and austenitic-ferritic stainless steels

13.1 Scope

13.1.1 General

The requirements of this Sub-section apply to consumables used for welding Cr-Ni austenitic and austenitic-ferritic stainless steels.

Unless otherwise stated in this Sub-section, the requirements relevant to the procedure, tests samples and welding conditions are, in general, to be in accordance with those in the previous Sub-sections relevant to the approval of consumables for welding carbon and carbon-manganese steels, as follows:

- Sub-section 2: Covered electrodes for manual metal arc welding
- Sub-section 5: Flux-wire combination for submerged arc welding

- Sub-section 7: Wires and wire-gas combination for semiautomatic welding processes employing continuous wire
- Sub-section 8: Wires and wire-gas combination for automatic welding processes employing continuous wire.

13.1.2 Designation

Consumables intended for welding austenitic steels are divided into the following grades designated by a symbol corresponding to the AWS designation of the weld metal, as follows: 308, 308L, 316, 316L, 316LN, 317, 317L, 309, 309L, 309Mo, 310, 310Mo, 347.

The additional symbol BT is added when the requirements on impact test energy are satisfied at the temperature of -196°C.

Consumables intended for welding austenitic-ferritic steels are designated by a symbol indicating the nominal percentage content of Cr and Ni in the deposited metal (e.g. 2205 means 22% Cr and 5% Ni).

The relevant prefix and/or suffix are to be added to the grade.

13.2 Approval tests

13.2.1 The same samples as for the C and C-Mn steel welding consumables approval are required, with the exception of samples for hydrogen content checking. The all deposited metal and the butt weld test samples are to be prepared using the corresponding grade of stainless steel. However, at the request of the Manufacturer, the all deposited metal may be allowed to be prepared using C and C-Mn steels, provided that the bevels are duly buttered with the welding consumable to be approved.

13.2.2 When the approval is required for two types of the same welding consumable, one with normal C content and one with "low C" content, for the approval of "low C" welding consumables the tests for checking the mechanical properties of the deposited material and the chemical composition only are to be carried out.

13.2.3 In the case of covered electrodes for manual welding, the checking of the chemical composition is to be carried out, as a rule, on samples of deposited metal and described in 1.6. One sample is required for each electrode diameter to be approved. In the case of other types of welding consumables, the checking is to be carried out on shavings taken from the deposited metal samples.

The checking of C, Cr, Ni contents is to be carried out on all the samples, in addition to Mo, Nb and N contents where such elements characterise the welding consumable being tested. For only one of the diameters tested, the chemical analysis of the remaining elements listed in Table 13.2 is also to be carried out.

13.2.4 For consumables for welding austenitic-ferritic steels, the ratio ferrite/austenite is also to be determined in the all deposited material.

13.2.5 Corrosion tests according to ASTM A262 Practice E, ASTM G48 Method A or equivalent recognized standards may be required, on a case-by-case basis, for austenitic and duplex stainless steel consumables.

13.2.6 Unless special requests are made by the Manufacturer, the samples are not to be post-weld heat treated.

13.3 Test requirements

13.3.1 In the tests for checking the operating characteristics, the requirements specified in Sub-section 2, 5, 7, 8 for electrodes, submerged arc fluxes and wires for continuous wire processes, respectively, are to be met.

In the tests for checking the mechanical properties, the requirements specified in Table 13.1 are to be met. For consumables intended for welding Cr-Ni austenitic steels for which the approval is required with the additional symbol BT, the requirements on adsorbed energy in the impact test specified in the table are to be satisfied at the temperature of −196°C.

13.3.2 In the tests for checking the chemical composition of welding consumables intended for Cr-Ni austenitic steels, the limits in percentage specified in Table13.1 are to be satisfied. In the tests for checking the chemical composition of welding consumables intended for austenitic-ferritic steels, the limits in percentage specified and guaranteed by the Manufacturer are to be satisfied.

Table 13.1: Required mechanical properties

Grade	Tensile test on deposited metal			Tensile test on butt weld	Charpy V-notch impact test		Bend ratio and angle
	Yield stress $R_{p0,2}$ (N/mm^2) min.	Tensile strength R_m (N/mm^2) min.	Elong. A5 (%) min.	Tensile strength R_m (N/mm^2) min.	Test temp. (°C)	Minimum average energy (J)	D/ t (1) $\alpha \geq 120°$
Austenitic							
308	290	540	25	515	–20 (2)	27	3
308L	275	490	25	485			
316	290	540	25	515			
316L	275	490	25	485			
316LN	290	540	25	515			
317	290	540	25	515			
317L	275	490	25	515			
309	290	540	22	515			
309L	275	490	22	515			
309Mo	290	540	22	515			
310	290	540	25	515			
310Mo	290	540	25	515			
347	290	540	25	515			
Austenitic-ferrritic							
2205	480	680	25	680	-20	27	

(1) D = mandrel diameter, t = specimen thickness

(2) The impact test temperature is −20°C, except when the additional symbol BT is required, in which case the test is to be carried out at -196°C.

Table 13.2: Chemical composition

Grade	Chemical composition (%)					
	C	Mn	Cr	Ni	Mo	Others
308	≤ 0.08	0.5 – 2.5	18 – 21	8 - 11	≤ 0.75	
308L	≤ 0.04	0.5 – 2.5	18 – 21	8 - 11	≤ 0.75	
316	≤ 0.08	0.5 – 2.5	17 – 20	11 – 14	2 – 3	
316L	≤ 0.04	0.5 – 2.5	17 - 20	11 – 14	2 – 3	
316LN	≤ 0.04	0.5 – 2.5	17 - 20	10 - 14	2 – 3	0.15≤ N≤ 0.75
317	≤ 0.08	0.5 – 2.5	17 - 21	11 – 14	2.5 – 4	
317L	≤ 0.04	0.5 – 2.5	17 - 21	11 – 14	2.5 – 4	
309	≤ 0.15	0.5 – 2.5	22 – 26	11 – 15	≤ 0.75	
309L	≤ 0.04	0.5 – 2.5	22 – 26	11 – 15	≤ 0.75	
309Mo	≤ 0.12	0.5 – 2.5	22 – 26	11 – 15	2 – 3	
310	0.08 – 0.20	1.0 – 2.5	25 – 28	20 – 22.5	≤ 0.75	
310Mo	≤ 0.12	1.0 – 2.5	25 – 28	20 – 22	2 - 3	
347	≤ 0.08	0.5 – 2.5	18 - 21	9 - 11	≤ 0.75	8 C≤Nb+Ta≤1

13.4 Annual control tests

13.4.1 For the periodical control tests, in addition to the samples and tests for checking the mechanical properties as required for the consumables for welding C and C-Mn steels, the samples for checking the chemical composition are also to be effected.

13.4.2 For the "low C" welding consumables described in 13.2.2, the control tests are limited to one sample of deposited metal and to the checking of the chemical composition.

14 Consumables for welding Aluminium alloys

14.1 Scope

14.1.1 General

The requirements of this Sub-section apply to wire or rod-gas combinations to be used for welding the Al-Mg and Al-Si Aluminium alloys specified in Ch 3. (Unless otherwise stated in this Sub-section, the requirements relevant to the procedure, tests samples and welding conditions are generally to be in accordance with those in Sub-sections 2.7 and 2.8 relevant to the approval of consumables for welding with continuous wire process).

The welding consumables preferably to be used for the Aluminium alloys concerned are divided into two categories, as follows:

a) W = wire electrode and wire gas combination for metalarc inert gas welding (MIG), tungsten inert gas welding (TIG) or plasma arc welding (PAW)

b) R = rod-gas combinations for tungsten inert gas welding (TIG) or plasma arc welding (PAW).

Note 1: For Aluminium welding consumables, there is no unique relationship between the products (wire electrode, wire or rod) and the welding process used (TIG, MIG, PAW). Therefore the wire electrodes, wire or rods, in combination with the relevant shielding gas, will be approved on the basis of the above products form W and R and may be used, as appropriate, for one or more of the above processes.

14.1.2 Grading

The consumables are graded as specified in Table 14.1 in accordance with the alloy type and strength level of the base materials used for the approval tests.

Table 14.1: Consumable grades and base materials for the approval tests

Consumable quality grade (symbol)	Base material for the tests	
	Alloy designation	
	Numerical	Chemical symbol
RA/ WA	5754	AlMg3
RB/ WB	5086	AlMg4
RC/ WC	5083	AlMg4,5Mn0,7
	5083	AlMg4,5Mn0,9
	5456	AlMg5
	5059	-
RD/ WD	6005A	AlSiMg(A)
	6061	AlMg1SiCu
	6082	AlSi1MgMn

Note 1: Approval on higher strength AlMg base materials covers also the lower strength AlMg grades and their combination with AlSi grades.

Table 14.2: Composition of shielding gases

Group symbol	Gas composition in volume (%) (1)	
	Argon	Helium
I-1	100	-
I-2	-	100
I-3 (2)	Balance	> 0 to 33
I-4 (2)	Balance	> 33 to 66
I-5 (2)	Balance	> 66 to 95
S	Special gas composition to be specified	

(1) Gases of other chemical composition (mixed gases) may be considered as special gases and are to be covered by separate tests

(2) Gas mixture to be used for the tests is as follows:

- Group I-3: approx. 15% He
- Group I-4: approx. 50% He
- Group I-5: approx. 75% He

14.1.3 Shielding gases

For the purpose of the approval, the type of gas and mixture of gas are grouped as indicated in Table 14.2.

Unless otherwise required for specific applications, gas mixtures in the same group are considered equivalent for approval purposes. Special gases in terms of composition or purity are to be designated with the group “S”.

14.2 Approval tests

14.2.1 Deposited weld metal

For the testing of the chemical composition of the deposited weld metal, a test piece according to Fig 14.1 is to be prepared. The size depends on the type of the welding consumable (and on the process used) and is to give a sufficient amount of pure metal for chemical analysis. The base metal is to be compatible with the weld metal in respect of chemical composition.

The chemical analysis of the deposited weld metal is to be supplied by the Manufacturer and is to include the content of all the significant elements. The results of the analysis are not to exceed the limit values specified in the standards or by the Manufacturer.

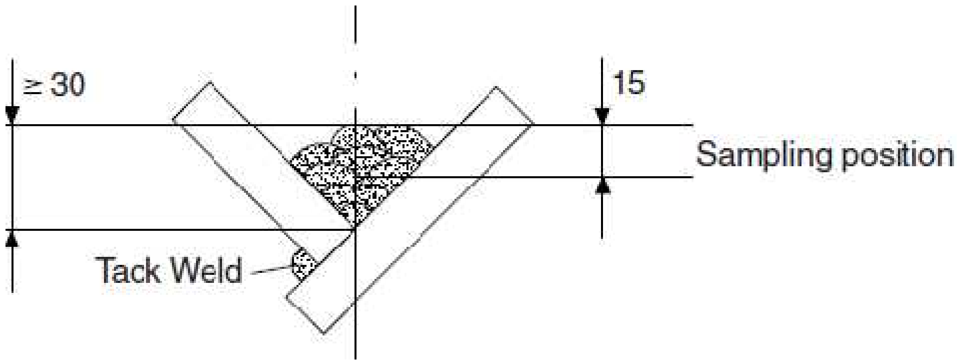


Figure 14.1: Deposited weld metal test assembly

14.2.2 Butt weld test assembly

Butt weld test assemblies, in the material specified in Table 14.3 and having thickness 10-12 mm, are to be prepared for each welding position (downhand, horizontal, verticalupward and overhead) for which the consumable is recommended by the Manufacturer (see Fig 14.2); see also 14.2.3.

Subject to the agreement of the Society, consumables satisfying the requirements for the downhand and verticalupward position will also be considered as complying with the requirements for the horizontal position.

14.2.3 Additional butt weld test assembly

One additional test assembly, having 20-25 mm, is to be welded in the downhand position (see Fig 14.3).

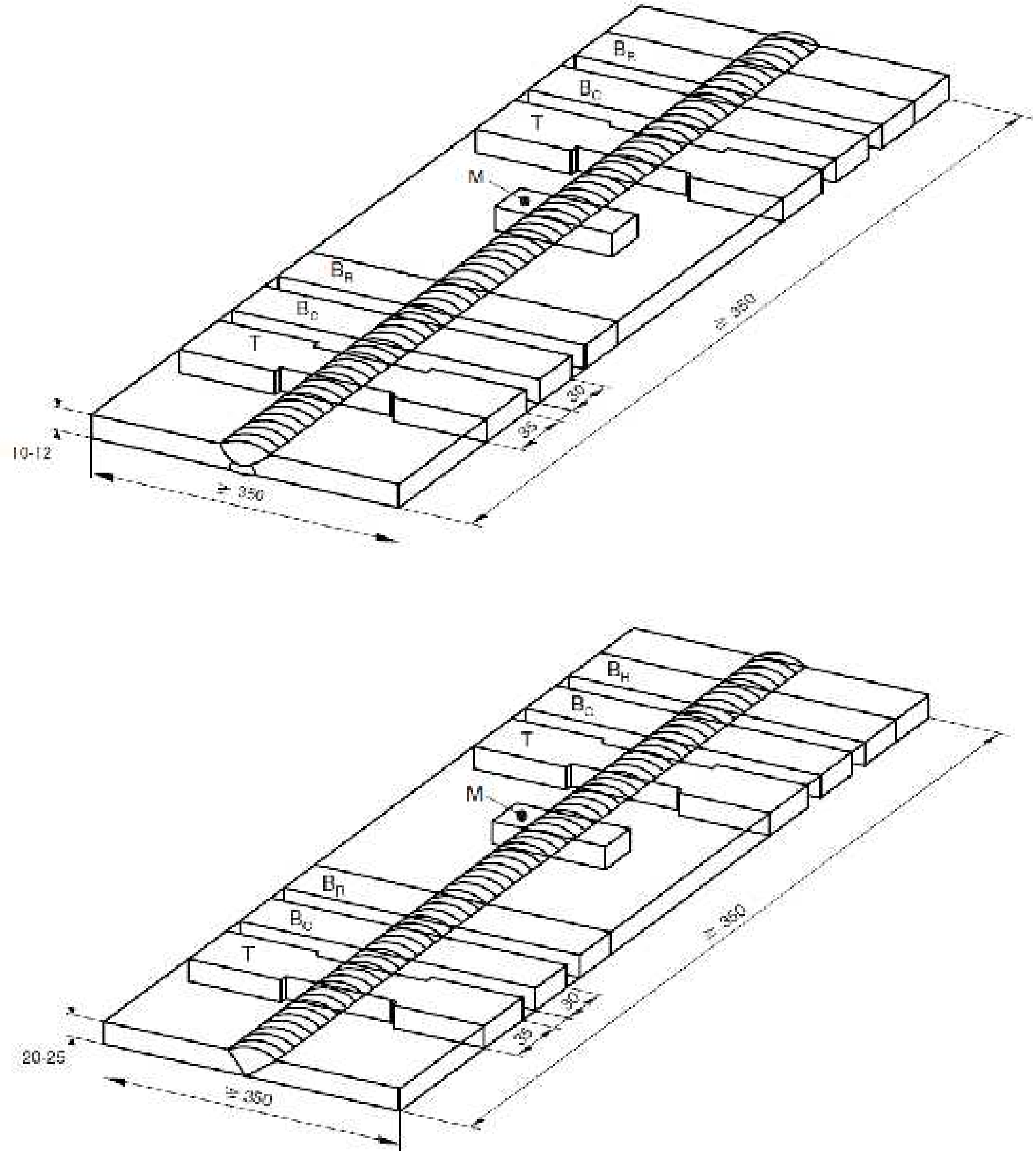


Figure 14.3: Additional butt weld test assembly in downhand position

T = flat tensile test specimen; BC = face bend test specimen; BR = root bend test specimen; M = macrographic section

Note 1: Edge preparation is to be single V with an angle of 70°.

Note 2: Back sealing runs are allowed.

14.2.4 Post-weld condition

On completion of welding, the assemblies are to be allowed to cool naturally to ambient temperature. Welded test assemblies and test specimens are not to be subjected to any heat treatment. Grade D assemblies are to be allowed to artificially age for a minimum period of 72 hours from the completion of the welding and a maximum of one week, before testing is carried out.

14.3 Test requirements

14.3.1 It is recommended that the weld assemblies are subjected to radiographic examination to ascertain if there are any defects in the welds prior to the preparation of the test specimens. In the tests for checking the operating characteristics, the requirements specified in Sub-section 7 for wires for continuous wire processes are to be met.

14.3.2 The test specimens are to be taken from the welded assemblies as shown in Fig 14.2 and Fig 14.3. For each assembly they are to include:

- one specimen for macrographic examination
- two transverse tensile specimens
- two face bend specimens, and
- two root bend specimens.

The macro specimen is to be examined for defects such as cracks, lack of fusion, cavities, inclusions and pores. Cracks, lack of fusion or incomplete penetration are not allowed.

The transverse tensile test results are to meet the requirements stated in Table 14.3.

The bend test parameters are stated in Table 14.3. After bending, no crack or other open defect exceeding 3 mm in length is to be seen on the outer surface. Defects which may appear at the corners of a bend specimen are not to be considered.

It is recommended that the bending test is performed with the “wrap around bending method” instead of the “free bend test” in order to obtain uniform bending of the specimen (see Fig 14.4).

14.4 Annual control tests

14.4.1 For the annual control tests, the deposited weld metal test assembly as per Fig 14.1 and the butt weld test assembly as per Fig 14.2 are to be welded using the wire having the maximum approved diameter. The tests required in 14.2.1 and 14.3 are to be performed.

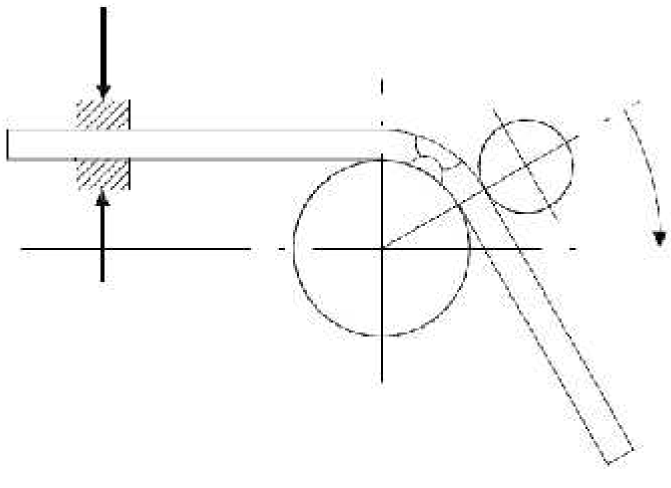


Figure 14.4: Wrap around bend test

The fixed edge of the test specimen is to be clamped to avoid sliding. The whole welded zone (weld and heat affected zone), in the case of transverse bending, is to be entirely positioned in the bent zone.

Table 14.3: Requirements for the transverse tensile and bend tests

Grade	Base material used for the test	Tensile strength R_m (N/mm^2) min.	Former diameter	Bending angle (1) (°) min.
RA/ WA	5754	190	3 t	180
RB/ WB	5086	240	6 t	
RC/ WC	5083	275	6 t	
	5383 or 5456	290	6 t	
	5059	330	6 t	
RD/ WD	6061, 6005A or 6082	170	6 t	

(1) During testing, the test specimen is not to reveal any one single flaw greater than 3 mm in any direction. Flaws appearing at the corners of a test specimen is to be ignored in the evaluation unless there is evidence that they result from lack of fusion.

Section 3 Approval of Over Weldable Shop Primers

1 Scope

1.1 General

1.1.1 Shop primers applied on plates and sections to be welded without being removed are to be approved by the Society in accordance with the procedure detailed in this section.

1.1.2 The approval is limited to the following welding processes:

- manual metal arc welding with covered electrode
- flux-cored wire metal arc welding
- solid wire metal arc welding.

The acceptance of shop primers for use with welding processes other than those above will be specially considered in connection with the approval of the welding procedure at the user’s works.

2 Information and documentation to be submitted

2.1 General

2.1.1 The application for approval is to be submitted to the Society by the shop primer Manufacturer or authorized supplier.

2.1.2 The following information and supporting documentation, as applicable, are to be submitted:

- type designation, product name
- product description including components of the primer, type of diluent and mixture ratio
- product specification, data sheet giving characteristics of the shop primer and application instruction (surface preparation, method of application, drying time, recommended dry coat thicknesses, etc.)
- documentation relevant to previous tests and approvals.
- welding procedure specifications used
- approval test results (see 3).

3 Approval tests

3.1 Base material

3.1.1 Normal strength hull steels or equivalent grades are to be used for the test samples.

3.2 Filler metal

3.2.1 Approved filler metals are to be used.

3.2.2 Basic covered electrodes are to be used for manual metal arc welding.

3.3 Type and dimension of test samples

3.3.1 Test samples consist of double fillet welded T-joints formed by plates of the following dimensions:

- 300mm x 120mm x 15mm for manual welding and semiautomatic bare wire and flux cored arc welding with gas shielding

3.4 Number of samples required

3.4.1 Two samples for each process are to be welded:

a) manual metal arc welding with covered electrode of diameter 4 mm

b) flux-cored wire metal arc welding with wire of diameter 1.2 mm

c) solid wire metal arc welding with wire of diameter 1.2 mm

3.5 Preparation of test samples

3.5.1 The shop primer is to be applied in compliance with the manufacturer's specifications. The shop primer thickness (measure made on dry coat) of the test samples is to be at least 30% greater than the maximum foreseen in normal use.

3.5.2 The pieces are to be tack welded such as to form a T with adherent contact between the surfaces, without gap.

For each test a), b) and c) described in 3.4.1, one sample is to be welded in horizontal-vertical position (PB), and the other in vertical upwards position (PF), using electrodes of diameter 4 mm and wire of diameter 1.2 mm. Welding is to be made in accordance with Welding Procedure Specification (WPS).

The fillet weld is to be deposited in one bead having dimensions not exceeding 7x7 mm as shown in Fig 3.1.

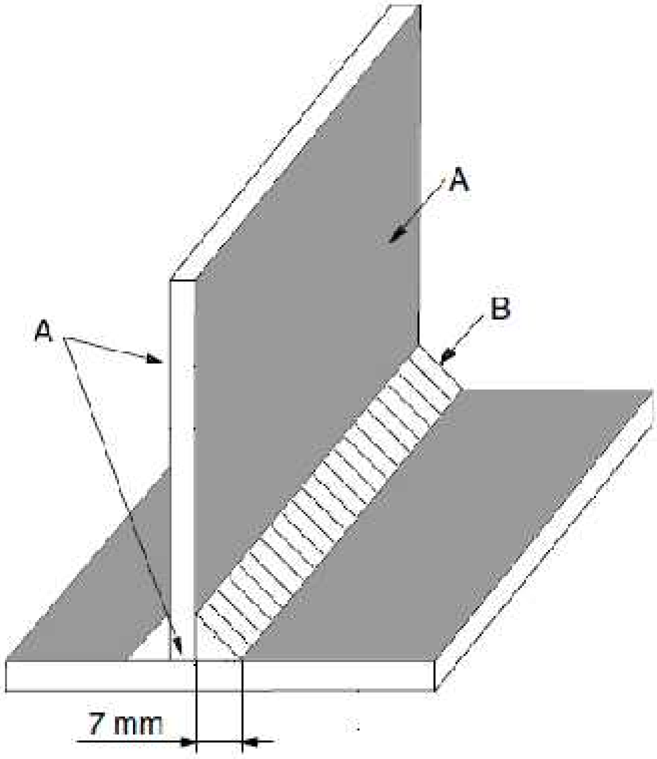


Figure 3.1: Typical T welded sample

A: Surfaces coated with the shop primer

B: Weld bead

3.6 Test requirements

3.6.1 The test sample is to be fractured by suitable means in order to locate the fracture in the throat of the fillet weld.

3.6.2 Visual examination is to be carried out consisting of checking the external and fractured surface to determine weld penetration and presence of worm-holes, pores and other defects. Possible defects located within 10 mm from the ends of the weld are disregarded. Lack of penetration having total length not exceeding 1/4 of the weld length is accepted.

Wormholes and pores having diameter not exceeding 3mm are generally acceptable where the total area of porosity is not higher than 5% of the fracture section area.

3.7 Re-tests

3.7.1 Where tests on one sample fails, re-tests on two samples for the same welding process are admitted. Both test samples are to provide satisfactory results. Failing this, the shop primer is not approved.

4 Certification and Validity

4.1 Certification

4.1.1 Subject to the satisfactory outcome of the required checks and tests, the Society will issue to the Manufacturer or supplier concerned the approval certificate for the shop primer.

4.2 Validity

4.2.1 The approval certificate has five-year validity. For another five-year period, renewal survey is to be carried out by the Society. The manufacturer has to declare that no changes have been made to the production.

Section 4 Approval of Welding Procedures

1 General

1.1 Scope

1.1.1 General

This Section specifies in Sub-section 2, 4 and 5 the requirements for the approval of arc welding procedures for steel materials, and in Sub-section 6 those for Aluminium alloys. The requirements relevant to materials not covered herein are agreed on a case-by-case basis following, as far as applicable, the criteria specified in this Section.

1.1.2 Other standards and specifications

Procedures considered equivalent by the Society may be accepted.

1.1.3 Special requirements

In the case of applications involving the storage and transport of liquefied gases, the appropriate requirements of the Society's Rules for the Classification of Steel Ships also apply.

1.2 Welding procedure

1.2.1 Welding processes

Qualification tests are, as a rule, required for the automatic or semiautomatic processes indicated below together with their relevant numbering according to ISO 4063:

- submerged arc welding with wire electrode: 121
- flux-cored wire metal arc welding without gas shield: 114
- metal arc inert gas welding (MIG welding): 131
- metal arc active gas welding (MAG welding): 135
- flux-cored wire metal arc welding with active gas shied: 136
- flux-cored wire metal arc welding with inert gas shield: 137
- tungsten inert gas arc welding (TIG welding): 141
- plasma arc welding: 15

1.2.2 Manual metal arc welding

In the case of manual metal arc welding, where the joint is welded with approved covered electrodes and by certified welders, qualification tests are generally not required; the results of tests performed by the shipyard on joints welded under similar conditions may be required, to the Surveyor's satisfaction.

Qualification tests may be required for one side manual metal arc welding on ceramic backing. Qualification tests are required in the case of welding higher strength steels having minimum yield stress equal to or higher than 390 N/mm^2, steels intended for low temperature applications (see 1.1.3) and steels not approved or not complying with recognised standards.

1.2.3 Welding consumables

Consumables approved in accordance with the requirements of Sec 2 are to be used within the limits of their approval.

When non-approved welding consumables are used, the requirements relevant to the qualification of the welding procedures are established on a case-by-case basis and tests on a deposited metal sample are required.

Requirements relevant to the grade of welding consumables to be used are given in the relevant Society's Rules.

1.2.4 Preliminary welding procedure specification

A welding procedure specification is to be prepared by the Manufacturer or Shipyard which intends to perform the qualification tests. This document is also referred to as a preliminary welding procedure specification (pWPS) and is to be submitted to the Society for review prior to the tests.

This pWPS may be modified and amended during the procedure tests as deemed necessary however it shall define all relevant variables as mentioned in the welding procedure specification, see 1.2.5.

In case that the test pieces welded according to the pWPS show unacceptable results the pWPS shall be adjusted by the Shipyard or Manufacturer. The new pWPS shall be prepared and the test pieces welded in accordance with the new pWPS.

In general, the qualification tests shall reflect fabrication conditions in respect to welding equipment, inside or outside fabrication, weld preparation, preheating and any postweld heat treatment. It shall be the manufacturer's responsibility to establish and document whether a procedure is suitable for the particular application. The test pieces are to be chosen so as to cover all the production welds in accordance with the approval range of parameters given in 2.5.

1.2.5 Approval of welding procedure specification

The qualification tests when required, welding of test pieces according to the proposed pWPS and testing of test specimens, are to be witnessed by the Surveyor.

Upon satisfactory completion of the tests, the Society may approve the pWPS as a welding procedure specification.

In its final version, the welding procedure specification (WPS) is to include all the parameters characterising the welding process; in particular, as applicable:

a) type of welding process and equipment, as appropriate

b) type of joint, preparation and backing material, if any

c) base metal and thickness range

d) filler metal

e) welding position

f) minimum preheat, minimum and maximum interpass temperature

g) post-weld heat treatment if applicable

h) shielding gas as applicable

i) welding parameters

j) other information relevant to the welding techniques as applicable.

The actual parameters used for welding the approval test pieces and the results of the inspections and tests carried out are to be recorded in the welding procedure qualification record (WPQR) also referred to as welding procedure approval record (WPAR).

The WPQR is generally prepared by the shipyard or welding shops and endorsed by the attending Surveyor.

1.2.6 Inspections

Inspections and control tests may be periodically and randomly required as deemed necessary by the Society and are to yield satisfactory results in order to maintain the validity of the approval.

The results of any suitable control performed during production may be accepted, to the Surveyor's satisfaction.

1.2.7 Responsibilities of the users

The qualification tests are intended to verify that a manufacturer is adequately qualified to perform welding operations using a particular procedure. Irrespective of the inspections carried out by the Surveyor, the user is responsible for the use of the approved procedures, within the limits of the range qualified and the conditions stated at the time of the approval.

Compliance with the above is essential for the validity of the approval.

2 Welding procedure qualification tests for C and C-Mn steels for ship hull and other welded structures in general

2.1 Plates butt weld with full penetration

2.1.1 Assembly of test pieces

Preparation and welding are to be in accordance with the pWPS and under the general condition of production welding which it represents. If tack welds and / or start and stop points are a condition of the weld process they are to be fused into the joint and are to be included in the test pieces. The test assembly is to be of a size sufficient to ensure a reasonable heat distribution and is to have the minimum following dimensions (see Fig 2.1):

a) manual or semiautomatic welding:

length L=6t,	min. 350mm;
width W with W/2=3t,	min. 150mm.

b) automatic welding:

length L=	min.1000 mm;
width W with W/2=4t,	min. 200 mm.

In the case of steel plates impact tested in the longitudinal direction (CVN-L), the butt weld of the test piece is perpendicular to the rolling direction of the two plates. In the case of steel plates impact tested in the transversal direction (CVN-T), the butt weld of the test piece is parallel to the rolling direction of the two plates.

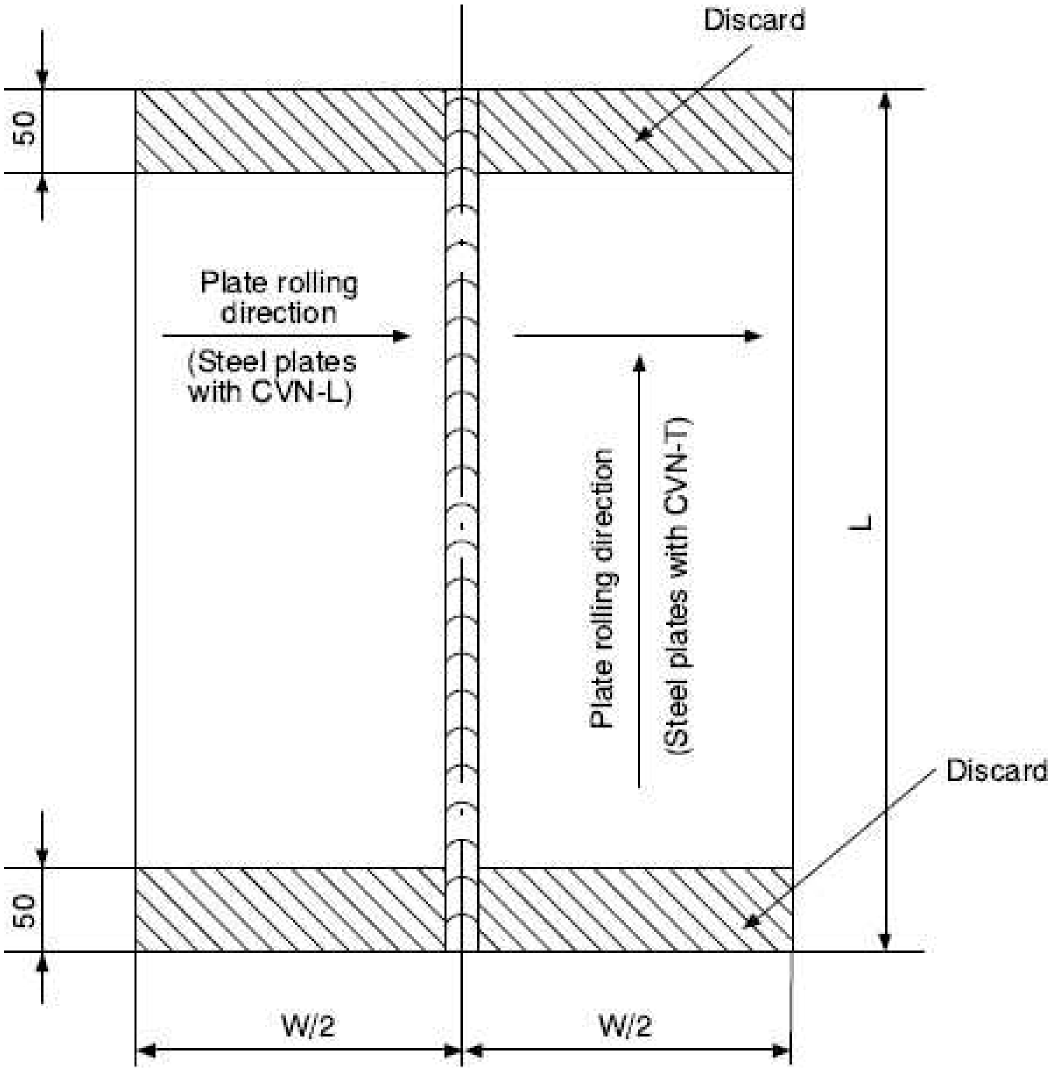


Figure 2.1: Test assembly for plate butt weld

2.1.2 Examinations and tests

Non-destructive examinations and destructive tests required according to Table 2.1 are to be carried out, while the location of the test specimens is to be in accordance with Fig 2.2.

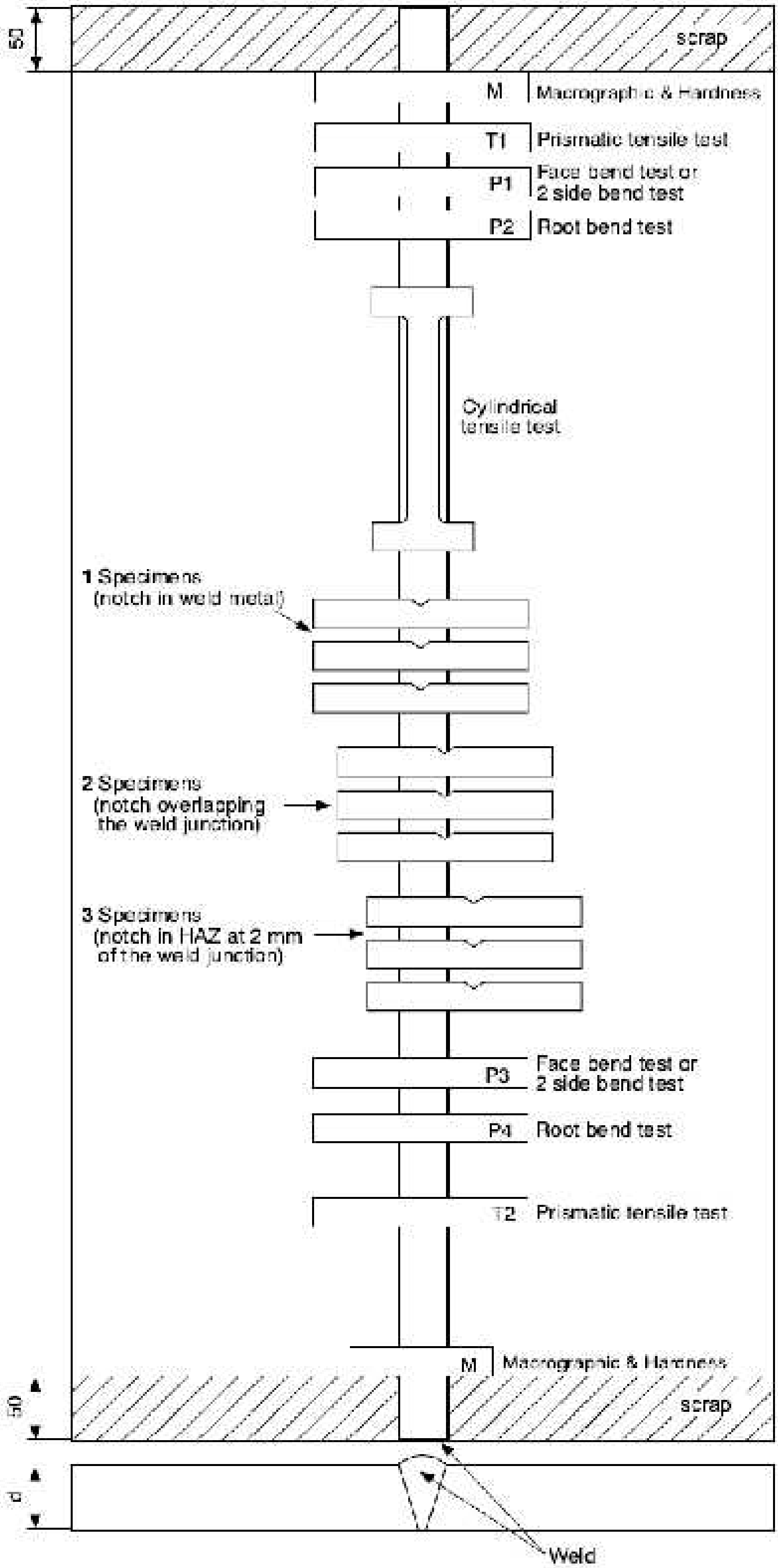


Figure 2.2: Location of test specimens

2.1.3 Non-destructive examinations

Non-destructive examinations are to be carried out after any required or specified post-weld heat treatment and prior to the cutting of test specimens. Imperfections detected by visual or non-destructive testing shall be assessed in accordance with ISO 5817 class B, except for the following imperfections for which the level C applies:

- excess weld metal or convexity,
- excess throat thickness, and
- excess of penetration.

Table 2.1: Examinations and tests

Type of examination or test	Extent of examination or test
Visual examination	100%
Surface crack detection (1)	100%
Radiographic or ultrasonic examination	100%
Transverse tensile test	2 specimens
Transverse bend tests (2)	2 root and 2 face specimens
Charpy V-notch impact tests (3)	3 sets
Macro examination	on 1 section
Hardness test (4)	on 1 section
Longitudinal tensile test (5)	1 specimen

(1) Dye penetrant according to ISO 3452 (or equivalent accepted standard) or magnetic particle testing; for non-magnetic materials, dye penetrant only.

(2) For $t \geq 12$mm, the face and root bends are preferably to be replaced by 4 side bends.

(3) 3 sets each of 3 specimens as per 2.1.7.

(4) Only required for high strength steels with minimum specified yield strength equal to or greater than 355N/mm^2.

(5) Required only when the use of non-approved filler metal has been accepted (see 1.2.3).

2.1.4 Transverse tensile tests

Specimens for transverse tensile tests are to be in accordance with Chapter 2.

The tensile strength recorded for each specimen is to be not less than the minimum required for the parent metal; the location of the fracture is to be reported. When butt welds are made between plates of different grades, the tensile strength to be obtained on the welded assembly is to be in accordance with the requirement of the grade having lower strength.

2.1.5 Tensile tests on cylindrical specimens

When required (see Table 2.1), a round tensile specimen is to be cut along the weld axis to the dimension given in Chapter 2 in the all weld metal. Where the size of the deposited metal is too small, a 6 mm diameter specimen may be taken or a deposited weld metal test is to be carried out in accordance with the requirements of Sec 2.

The tensile properties recorded (yield stress ReH, tensile strength Rm and elongation A5) are to be not less than the minimum required for the approval of the appropriate grade of consumables.

When more than one welding process or type of consumable has been used to make the test weld, test specimens are to be removed from the area of the weld where each was used with the exception of those processes or consumables used to make the first weld run or root deposit.

2.1.6 Bend tests

Transverse root bend, face bend and side bend specimens are to be machined to the dimensions given in Chapter 2.

For dissimilar or heterogeneous butt-joints, one longitudinal bend test may be used instead of transverse bend tests.

The test specimens are to be bent on a mandrel having a diameter equal to 4 times the thickness of the specimen; the bending angle is to be 180°. After testing, the test specimens are not to reveal any open defect, in any direction, greater than 3 mm. Defects appearing at the corners of the test specimen during testing are to be investigated case-by-case.

When butt welds are made between plates of different grades, face and root longitudinal bend test specimens may be used instead of the transverse bend test specimens.

2.1.7 Impact tests

Dimensions and testing of Charpy V-notch impact test specimens are to be in accordance with Chapter 2.

Charpy V-notch impact test specimens in accordance with Chapter 2 are to be sampled from 1 to 2 mm below the surface of the parent material, transverse to the weld and on the side containing the last run. The Charpy V-notch specimens are located in the buttwelded joint as indicated in Fig 2.3 and Fig 2.4, and the Vnotch is to be cut perpendicular to the surface of the weld.

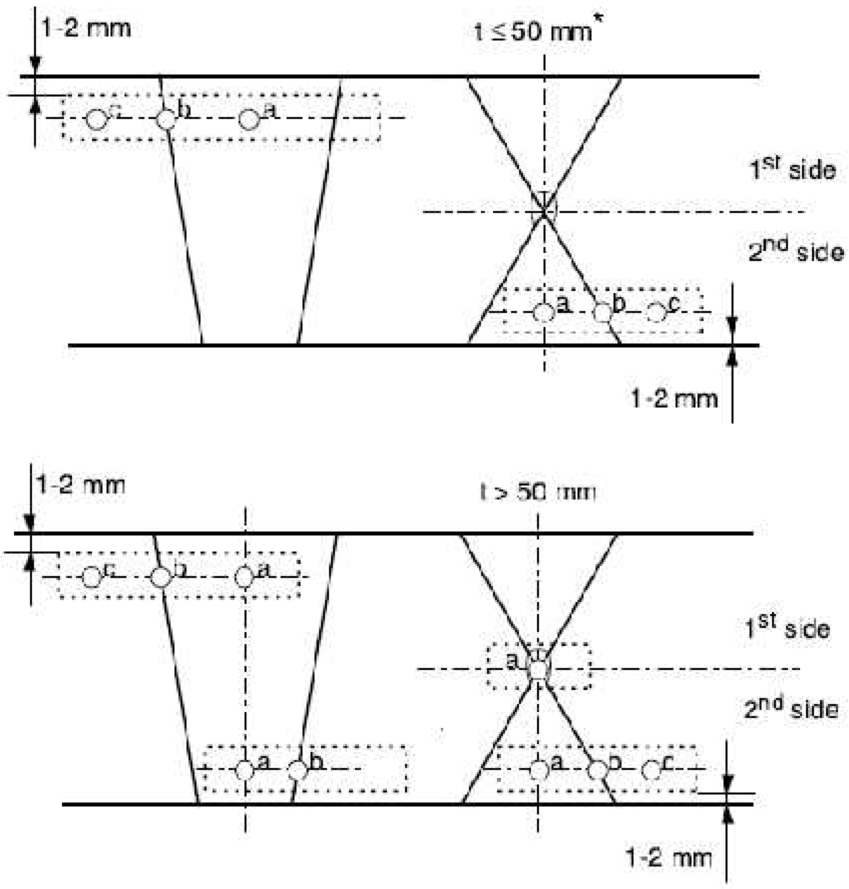


Figure 2.3: Location of V-notch for normal heat input ≤50 kJ/cm

a: Centre of weld “WM”

b: On fusion line “FL”

c: In HAZ, 2 mm from fusion line

*: For one side pass welding over 20 mm “WM” FL and HAZ, 2mm from fusion line to be added on root side.

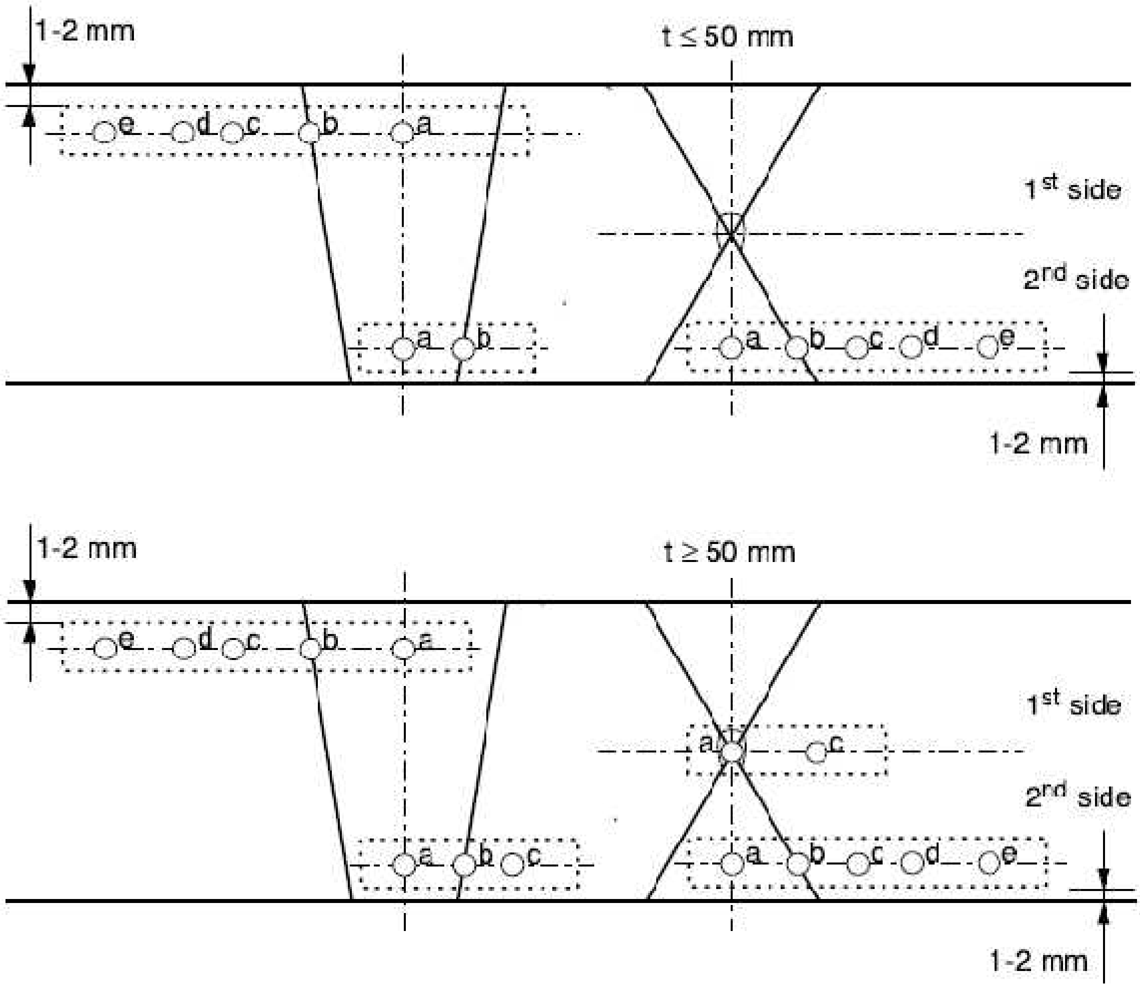
The test temperature and absorbed energy are to be in accordance with Table 2.2.

When butt welds are made between different steel grades / types, the test specimens are to be taken from the side of the joint with steel of lower toughness level. Temperature and absorbed energy results are to be in accordance with the minimum value required for the steel of lower toughness level.

Where more than one welding process or consumable has been used to make the test weld, impact test specimens are to be removed from the respective areas where each was employed. This should not apply to the process or consumables used solely to make the first weld run or root deposit.

When cast or forged material with specified impact values is to be welded, test temperature and absorbed energy are to be in accordance with the requirements of the base material.

Figure 2.4: Location of V-notch for high heat input ≤ 50 kJ/cm



a: Centre of weld “WM”

b: On fusion line “FL”

c: In HAZ, 2 mm from fusion line

d: In HAZ, 5 mm from fusion line

e: In HAZ, 10 mm from fusion line in case of heat input > 200 kJ/cm

Table 2.2: Impact test requirements for butt joints (t ≤50 mm)

<table>
<tr><th rowspan="3">Grade of steel</th><th rowspan="3">Testing temperature (°C)</th><th colspan="3">Value of minimum average absorbed energy (J) (1)</th></tr>
<tr><th colspan="2">For manually or semi-automatically welded joints</th><th rowspan="2">For automatically welded joints</th></tr>
<tr><th>Downhand,Horizontal, Overhead</th><th>Vertical upward, Vertical downward</th></tr>
<tr><td>A (2)</td><td>20</td><td rowspan="11">47</td><td rowspan="6">34</td><td rowspan="6">34</td></tr>
<tr><td>B (2), D</td><td>0</td></tr>
<tr><td>E</td><td>-20</td></tr>
<tr><td>AH32, AH36</td><td>20</td></tr>
<tr><td>DH32, DH36</td><td>0</td></tr>
<tr><td>EH32, EH36</td><td>-20</td></tr>
<tr><td>FH32, FH36</td><td>-40</td><td rowspan="5">39</td><td rowspan="5">39</td></tr>
<tr><td>AH40</td><td>20</td></tr>
<tr><td>DH40</td><td>0</td></tr>
<tr><td>FH40</td><td>-20</td></tr>
<tr><td>FH40</td><td>-40</td></tr>
</table>

(1) For thickness above 50 mm, impact test requirements are to be agreed by the Society.

(2) For grade A and grade B steels, average absorbed energy in fusion line and heat affected zone is to be minimum 27 J.

Unless otherwise agreed with the Society, the test temperature and absorbed energy of steels not covered by these

requirements are to be in accordance with the specification of the parent metal.

2.1.8 Macro examinations

The test specimens are to be prepared and etched on one side to clearly reveal the weld metal, fusion line, the heat affected zone (HAZ) and about 10mm of unaffected parent metal.

The examination shall reveal a regular weld profile, through fusion between adjacent layers of weld and base metal and the absence of defects such as cracks, lack of fusion etc.

2.1.9 Hardness tests

Hardness testing is required for steels with minimum specified yield strength equal to or greater than 355N/mm^2.

Unless otherwise agreed, the Vickers method HV10 is to be used.

The indentations are to be made in the weld, heat affected zones, and the parent metals measuring and recording the hardness values. Two rows of indentations are to be carried out in accordance with Fig 2.5.

For each row of indentations, there is to be a minimum of 3 individual indentations in the weld, the heat affected zones (both sides) and the parent metals (both sides). The distance between the indentations may vary from 0,5 to 2 mm depending on the zone tested. Typical example of hardness indentations are given in Fig 2.5.

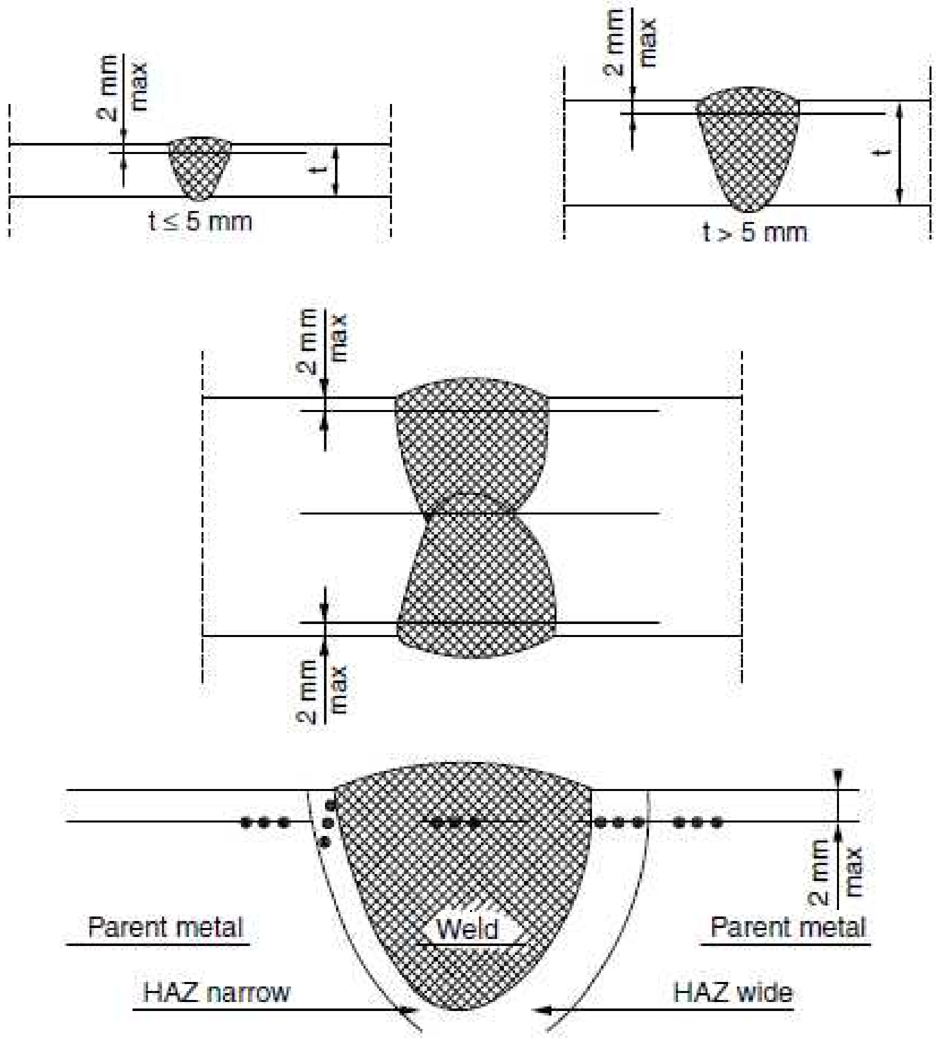


Figure 2.5: Examples of hardness indentations

The results of hardness tests are not to exceed 350 HV for steels with a specified minimum yield strength less than or equal to 420N/mm^2.

2.2 Plates fillet weld

2.2.1 Assembly and welding

Preparation and welding are to be in accordance with the pWPS and under the general condition of production welding which it represents. If tack welds are a condition of the weld process they are to be fused into the joint and are to be included in the test pieces. The test assembly is welded on one side only. For single pass manual and semi-automatic welding, a stop/restart is to be included in the test length and its position is to be clearly marked for subsequent examination. The test assembly is to be of a size sufficient to ensure a reasonable heat distribution and is to have the minimum following dimensions (see Fig 2.6):

a) manual or semiautomatic welding:

length L=6t, min. 350mm;

width W=3t, min. 150mm.

b) automatic welding:

length L= min.1000 mm;

width W=3t, min. 150 mm.

2.2.2 Examinations and tests

Non-destructive examinations and destructive tests required according to Table 2.3; a discard of 50 mm from both edges is permitted.

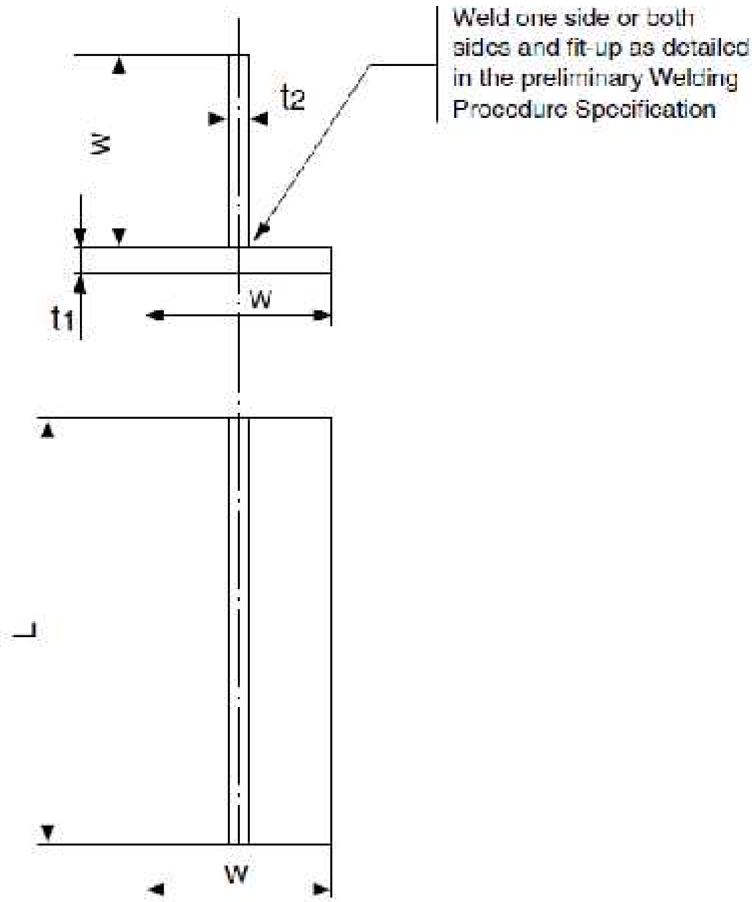


Figure 2.6: T fillet joint on plates

Table 2.3: Examinations and tests

Type of examination or test	Extent of examination or test
Visual examination	100%
Surface crack detection (1)	100%
Macro examination (2)	2 sections
Hardness test (3)	on 1section
Fracture test	1 test

(1) Dye penetrant according to ISO 3452 (or equivalent accepted standard) or magnetic particle testing; for non-magnetic materials, dye penetrant only.

(2) One of the macro sections is to be taken at the position of the stop/restart; see 2.2.1.

(3) Only required for high strength steels having: ReH ≥ 355 N/mm^2

2.2.3 Visual examination and surface crack detection

Non-destructive examinations are to be carried out after any required or specified post-weld heat treatment and prior to the cutting of test specimens. Imperfections detected are to be assessed in accordance with 2.1.3.

2.2.4 Macro examination

The test specimen is to be prepared and etched on one side to clearly reveal the weld metal, fusion line, root penetration, the heat affected zone and about 10mm of unaffected base material.

The examination shall reveal a regular weld profile, through fusion between adjacent layers of weld and base metal and the absence of defects such as cracks, lack of fusion etc. The dimensions of leg size, throat and penetration are to be reported.

2.2.5 Fracture test

The fracture test is to be performed by folding the upright plate onto the through plate. Evaluation is to be concentrated on cracks, porosity and pores, inclusions, lack of fusion and incomplete penetration. Imperfections that are detected shall be assessed in accordance with ISO 5817 Class B.

2.2.6 Hardness test

Hardness testing is required for steels with minimum specified yield strength equal to or greater than 355N/mm^2.

Unless otherwise agreed, the Vickers method HV10 is to be used.

The indentations are to be made in the weld, heat affected zones, and the parent metals measuring and recording the

hardness values. Two rows of indentations are to be carried out in accordance with Fig 2.7.

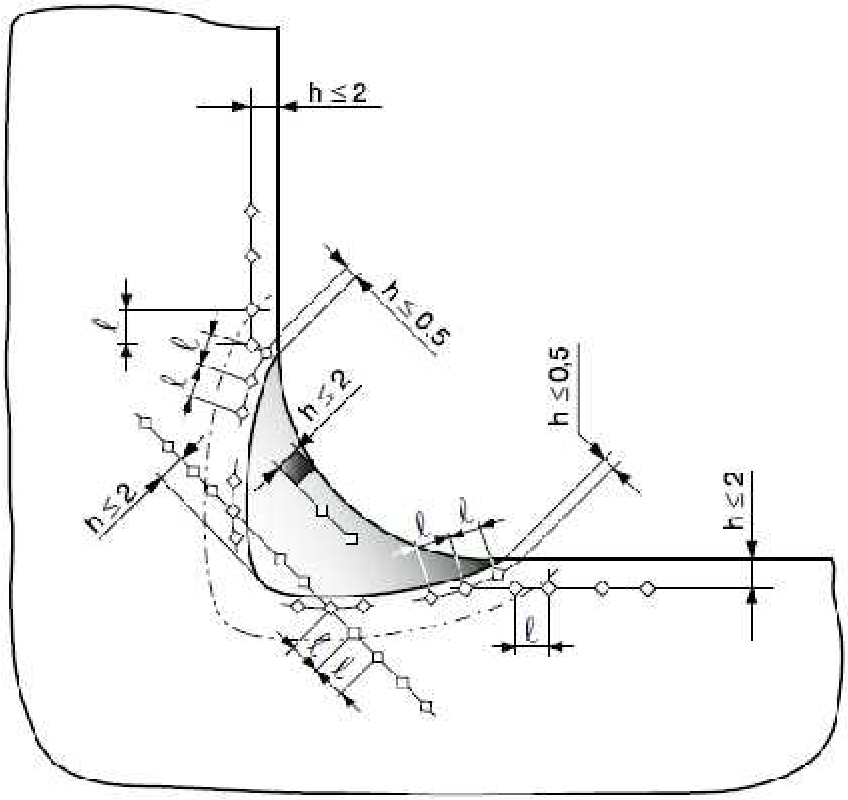


Figure 2.7: Macro and hardness indentations

For each row of indentations, there is to be a minimum of 3 individual indentations in the weld, the heat affected zones (both sides) and the parent metals (both sides).

The results of hardness tests are not to exceed 350 HV for steels with a specified minimum yield strength less than or equal to 420N/mm^2.

2.3 Pipes butt weld with full penetration

2.3.1 Assembly and welding

Preparation and welding are to be in accordance with the pWPS and under the general condition of production welding which it represents. If tack welds are a condition of the weld process they are to be fused into the joint and are to be included in the test pieces. The test assembly is to be in accordance with Fig 2.8.

Edge preparation and fit-up as detailed in the preliminary Welding Procedure Specification

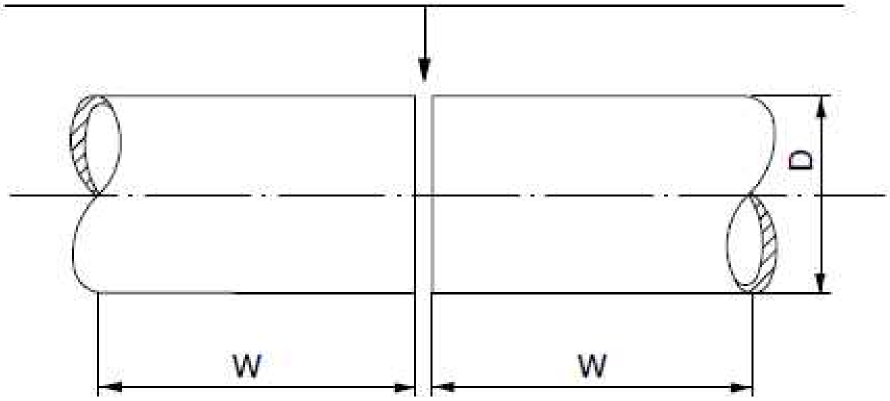


Figure 2.8: Pipe weld test assembly

W: minimum value = 150 mm; D = outside diameter

2.3.2 Examinations and tests

Non-destructive examinations and destructive tests required according to Table 2.1. The location of the test specimens is to be in accordance with Fig 2.9.

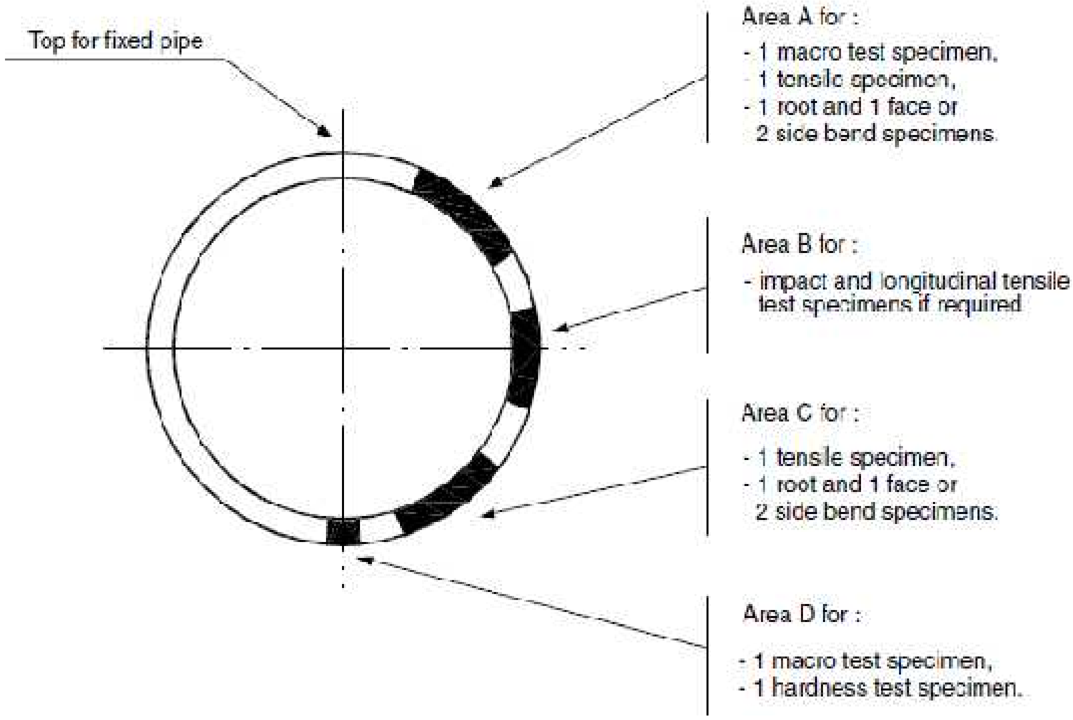


Figure 2.9:

2.3.3 Results

The results are to comply with the requirements for plate butt weld in 2.1.

2.4 Re-testing

2.4.1 If the test piece fails to comply with any of the requirements for visual or non-destructive testing, one further test piece is to be welded and subjected to the same examination.

If this additional test piece does not comply with the relevant requirements, the pWPS is to be regarded as not capable of complying with the requirements without modification.

2.4.2 If any test specimens fails to comply with the relevant requirements for destructive testing due to weld imperfection only, two further test specimens shall be obtained for each one that failed. These specimens can be taken from the same test piece if there is sufficient material available or from a new test piece, and is to be subjected to the same test. If either of these additional test specimens does not comply with the relevant requirements, the pWPS is to be regarded as not capable of complying with the requirements without modification.

2.4.3 If a tensile test specimen fails to meet the requirements, the re-testing is to be in accordance with Chapter 2.

2.4.4 If there is a single hardness value above the maximum values allowed, additional hardness tests shall be carried out (on the reverse of the specimen or after sufficient grinding of the tested surface). None of the additional hardness values is to exceed the maximum hardness values required.

2.4.5 The re-testing of Charpy V-notch impact test specimens are to be carried out in accordance with Chapter 2.

2.4.6 Where there is not sufficient material remaining in the test piece to provide the additional test specimens, a further assembly shall be welded using the same procedure to provide the additional specimens.

2.5 Range of approval

2.5.1 General

The approval of a WPS obtained by a yard or Manufacturer is valid for welding in workshops under the same technical and quality management, to the Society's satisfaction. The welding procedure is to be used within the range of the parameters indicated below; changes outside the range specified of one or more of these parameters require a new qualification test.

2.5.2 Parent metal

For hull structural steel grades A to FH40 as defined in Chapter 3, the following applies:

a) For each strength level, welding procedures are considered applicable to the same and lower toughness grades as that tested;

b) For each toughness grade, welding procedures are considered applicable to the same and two lower strength levels as that tested;

c) For applying the above a) and b) to high heat input processes above 50kJ/cm, e.g. the two-run technique with either submerged arc or gas shielded metal arc welding, electroslag and electrogas welding, welding procedure is applicable that toughness grade tested and one strength level below.

Where steels used for construction are supplied from different delivery conditions from those tested, the Society may require additional tests.

For weldable C and C-Mn hull steel forgings as defined in Chapter 3, the following applies:

a) Welding procedures are considered applicable to the same and lower strength level as that tested;

b) Qualification tests on quenched and tempered hull structural steel forgings do not qualify other delivery condition and vice-versa.

For weldable C and C-Mn hull steel castings as defined in Chapter 3, the following applies:

a) Welding procedures are considered applicable to the same and lower strength level as that tested;

b) Qualification tests on quenched and tempered hull structural steel castings do not qualify other delivery condition and vice-versa.

2.5.3 Thickness

The qualification of a WPS carried out on a welded assembly of thickness t is valid for the thickness range given in Table 2.4.

In addition to the requirements of Table 2.4, the range of approval for fillet welds shall be as follows;

a) Single pass fillet welds; for throat thickness "a" the range of approval is "0.75 a" to "1.5 a".

b) Multipass fillet welds; for throat thickness "a" the range of approval is as for multipass butt welds (i.e. a=t).

For the vertical-down welding, the test piece thickness t is always taken as the upper limit of the range of application.

For unequal plate thickness of butt welds the lesser thickness is the ruling dimension.

Notwithstanding the above, the approval of maximum base material thickness for any technique is restricted to the test assembly thickness if three of the hardness values in the heat affected zone are found to be within 25 HV of the maximum permitted, as stated in 2.1.9 and 2.2.6.

Table 2.4: Approved thickness range

Thickness t of test piece (mm) (1)	Range of approval	
	Single run or single run from both sides, Butt and T -joints	Multi-run welding, Butt, T-joint and fillet welds (2)
$3 < t \leq 12$	0,7 t to 1,1t	3 mm to 2 t (2)
$12 < t \leq 100$	0,7 t to 1,1 t (3)	0,5 t to 2 t (max.150)

(1) For multi process procedures, the recorded thickness contribution of each process is to be used as a basis for the range of approval for the individual welding process.

(2) For fillet welds, the range of approval is to be applied to both parent materials.

(3) For high heat input process over 50 kJ/cm, the upper limit of range of approval is to be 1,0 t.

2.5.4 Pipe diameter

Qualification tests on an assembly of pipes of diameter D is valid for diameters in the range given in Table 2.5.

Table 2.5: Approved diameter range

Diameter of the test piece (mm)	Range of approval (1)
D ≤ 25	0,5 D to 2 D
D > 25	≥ 0,5 D (25 mm min.)

(1) Qualification for plates also covers pipes with outside diameter > 500 mm.

2.5.5 Welding position

Standard positions are given in Fig 2.10 for plates and pipes.

Approval for a test made in any position is restricted to that position. To qualify all positions, test assemblies are to be welded for highest and lowest heat input position and all applicable tests are to be made on those assemblies.

For plates butt welds with full penetration, the highest heat input position is normally the vertical upwards position and the lowest heat input position is normally the horizontalvertical position.

2.5.6 Welding process

The approval is only valid for the welding process(es) used in the qualification tests. It is not permitted to change from a multi-run to a single run.

For multi-process procedures the welding procedure approval may be carried out with separate qualification tests for each welding process. It is also accepted to make the qualification test as a multi-process procedure test. The approval of such a test is only valid for the process sequence carried out during the multi-process procedure test.

For the manual metal arc welding process (111) and semiautomatic welding process with flux cored wire without shielding gas (114), the approval obtained is valid for the diameter of the electrode used in the welding procedure test plus or minus one electrode diameter size for each run, except for the root run of the one side welded assembly without backing strip, for which no size change is allowed.

For the gas metal arc welding processes (131, 135, 136), the approval obtained for face and/or back shielding gas is restricted to the type of gas (nominal composition) used during the procedure test. The approval is restricted to the wire system used in the approval test (e.g. single wire or multi-wire) and, in the case of automatic welding, to the relevant welding technique.

For the submerged arc processes (12), the approval obtained is restricted to the wire system used in the approval test (e.g. single wire or multi-wire) and relevant welding technique (T, M, U). Change in the flux trade mark requires new welding procedure approval tests.

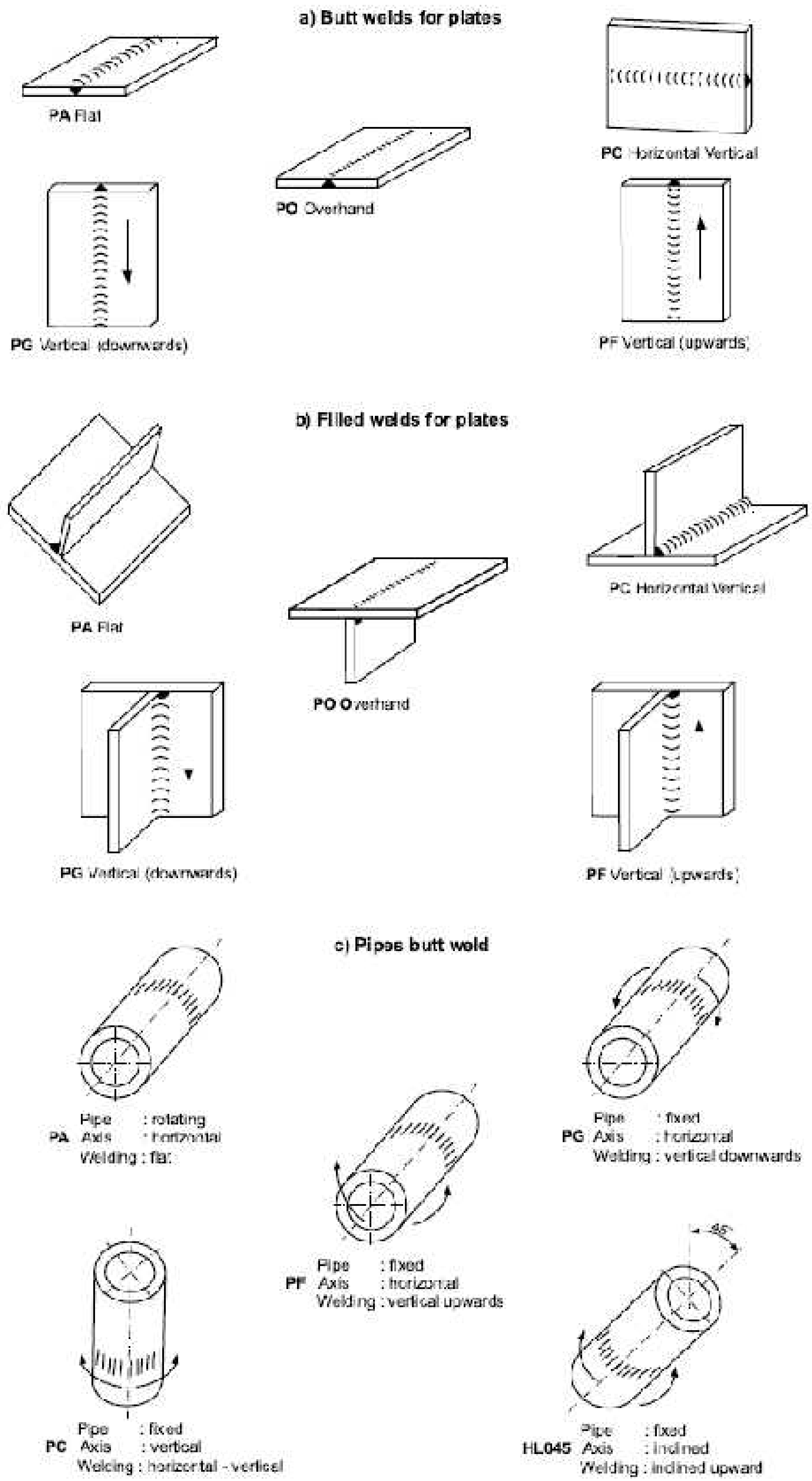


Figure 2.10: Welding positions according to ISO Standard

2.5.7 Welding consumables

Except high heat input process (over 50KJ/cm), welding consumables tested cover other approved welding consumables having the same grade mark including all suffixes specified in Sec 2 with that tested. Change in the trade name of filler metal requires new welding procedure approval tests when Charpy V-notch impact tests are required at temperature strictly below -20°C.

2.5.8 Heat input

The upper limit of heat input approved is 25% greater than that used in welding the test piece or 50KJ/cm whichever is smaller, except that the upper limit is 10% greater than that for high heat input processes over 50KJ/cm. The lower limit of heat input approved is 25% lower than that used in welding the test piece.

2.5.9 Preheat and interpass temperature

The minimum preheat temperature is not to be less than that used in the qualification test.

The minimum interpass temperature is not to be less than the specified preheat temperature.

The maximum interpass temperature is not to be higher than that used in the qualification test.

2.5.10 Post-weld heat treatment

The heat treatment used in the qualification test is to be maintained during manufacture. Holding time may be adjusted as a function of thickness.

2.5.11 Type of joint

The range of approval depending on type of welded joint for test assembly is given in Table 2.6.

New qualification tests may be required by the Surveyor when changes occur in the geometry of the bevel which may significantly affect the penetration or fusion.

3 Welding procedures for Cr-Ni austenitic and austenitic-ferritic stainless steels for application with chemicals

3.1 General

3.1.1 Test pieces, tests and requirements for the approval of the welding procedures are agreed on a case-by-case basis and are as far as applicable in accordance with those specified in 2.1 to 2.5.

3.1.2 Checks of the chemical composition of the weld metal may be required and, in the case of austenitic-ferritic steels, the examination of the metallographic structure of the weld for the determination of the average ferrite content is generally to be performed (value required according to ASTM E 562: min. 25% and max. 65%).

Impact tests are not required in the case of austenitic steels and are required in the case of austenitic-ferritic steels and performed at −20°C; the average value for the absorbed energy is to be not lower than 27 J.

Conventional corrosion tests according to recognised standards may be required depending on the type of steel.

Table 2.6: Range of approval for type of joint

Type of welded joint for test assembly			Range of approval						
			Butt welds for plates with full or partial penetration				T butt joints for plates with full or partial penetration		Fillet welds on plate and pipe
			Welded from one side		Welded from bothsides		Welded from one side	Welded from both sides	
			With backing	No backing	With gouging	No gouging			
Full penetration butt weld for plates	One side (1)	With Backing	◊	-	X	X	-	X	X
		No Backing	X	◊	X	X	X	X	X
	Both sides	With Gouging	-	-	◊	-	-	X	X
		No Gouging	-	-	X	◊	-	X	X
Fillet weld for plates			-	-	-	-	-	-	◊

Note 1:

◊ indicates the type of assembly of qualification test.

x indicates on the same line as the symbol ◊ those welds for which the WPS is also approved.

- indicates on the same line as the symbol ◊ those welds for which the WPS is not approved.

(1) Butt welds on a plate welded from one side approve butt welds on pipes having diameter > 500mm within the limitations of the table.

3.1.3 Typical selection of consumables grades depending on the parent metal to be welded is given in Table 3.1.

Table 3.1: Typical selection of consumable grades for welding Cr-Ni austenitic steels

Consumable Grade	Steel grade to be welded
308	304
308L	304- 304L
316	304-316
316L	304-304L-316-316L
316LN	304-304L-316-316L-316LN-316Ti- 316Nb
317	304-316-317
317L	304-304L-316-316L-317-317L
309	309 (1)
309L	309- 309L (1)
309Mo	309- 309Mo -316 (1)
310	310 (1)
310Mo	310- 310Mo (1)
347	321- 347

(1) Also for joints between ferritic and austenitic steels.

4 Welding procedures for high strength quenched and tempered steels

4.1 General

4.1.1 Test pieces, tests and requirements for the approval of the welding procedures are to be as specified in 2.1 to 2.5, unless otherwise specified in this Sub-section.

4.1.2 The bend specimens are to be bent on a mandrel having a diameter equal to 5 times the specimen thickness in the case of steel types 420 and 460 and equal to 6 times the specimen thickness in the case of steel types 500, 550, 620 and 690.

4.1.3 The results from the hardness test is not to exceed 420 HV10 for steels with a specified minimum yield strength from 420N/mm^2 to 690N/mm^2.

4.1.4 For the range of approval of parent metal the following applies:

a) For each strength level, welding procedures are considered applicable to the same and lower toughness grades as that tested;

b) For each toughness grade, welding procedures are considered applicable to the same and one lower strength levels as that tested;

c) Qualification tests with quenched and tempered steels do not qualify thermo-mechanically rolled steels and vice-versa.

5 Approval of welding procedures for Aluminium alloys

5.1 Plates butt weld

5.1.1 Assembly and welding

The applicable requirements of 2.1.1 apply.

The cleaning of the parts to be welded is to be carried out in accordance with the same procedure as used in the construction.

Welding consumables used are to be approved by the Society in accordance with Sec 2.

5.1.2 Examinations and tests

Non-destructive examinations and destructive tests required according to Table 5.1. The location of the test specimens is to be in accordance with Fig 5.1.

Table 5.1: Examinations and tests

Type of examination or test	Extent of examination or test
Visual examination	100%
Radiographic or ultrasonic examination	100%
Dye penetrant test	100%
Transverse tensile tests	2 specimens
Transverse bend tests (1)	2 root and 2 face specimens
Macro examination	1 section
Check of Mg content	Weld metal

(1) The face and root bends are preferably to be replaced by 4 side bends for t ≥ 12 mm.

(2) In the case of non-approved filler metal, the check of Mg content and other checks, as appropriate, are generally required.

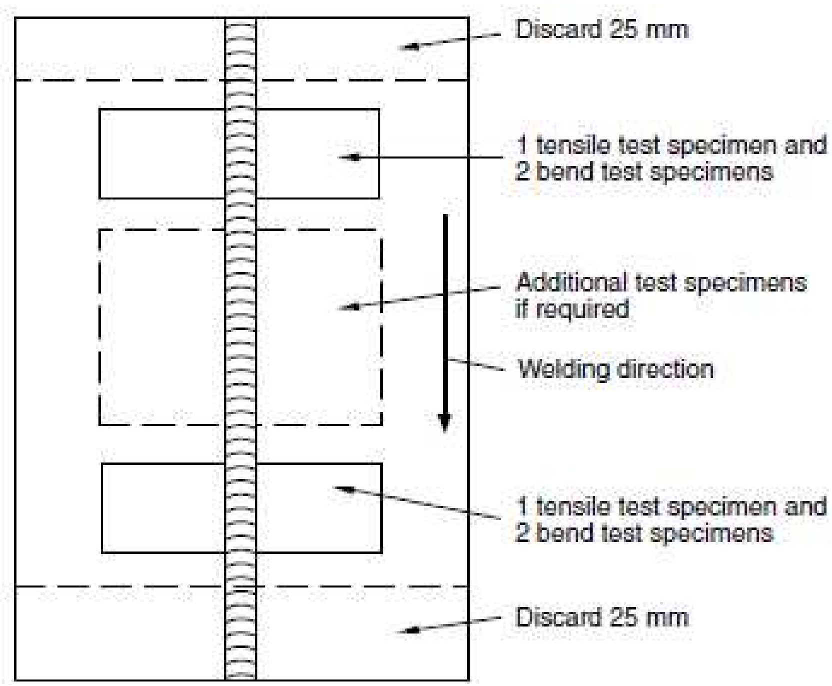


Figure 5.1: Location of test specimens for a butt joint in plate

5.1.3 Non-destructive examinations

Non-destructive examinations should be carried out after any required post-weld heat treatment and natural or artificial ageing, and prior to the cutting of test specimens. Welds should be free from cracks. Imperfections detected by visual or non-destructive testing should be assessed in accordance with ISO 10042, level B, excpet for excess weld metal or convexity, excess throat thickness and excess of penetration for which the level C applies.

5.1.4 Transverse tensile tests

Specimens for transverse tensile tests are to be in accordance with Chapter 2. The weld is to be made flush maintaining the thickness of the assembly. The tensile strength results are to meet the requirements stated in Chapter 2.

Table 5.2: Minimum tensile strength for series 5000 and 6000 alloys

Grade (Alloy designation)	Minimum tensile strength Rm (N/mm^2)
5754	190
5086	240
5083	275
5383	290
5059	330
5456	290
6005 A	170
6061	170
6082	170

5.1.5 Bend tests

Transverse root bend, face bend and side bend specimens are to machined to the dimensions given in Chapter 2.

For dissimilar or heterogeneous butt joints, longitudinal bend test may be used instead of transverse bend tests.

The bend test specimens should be bent on a mandrel with maximum diameter as given in the formula below. The

bending angle shall be 180°.

$$d=\frac{(100\times t_s)}{A}-t_s$$

Where

- d is the maximum former diameter
- ts is the thickness of the bend test specimen (this includes side bends).
- A is the minimum tensile elongation required by the alloy grade, temper condoition and thickness (for combination between different alloys, the lowest individual value should be used).

The “wrap around bending method“, is the recommended bending procedure in lieu of the usual “free” bend test (see Fig 5.2).

After testing, the test specimens are not to reveal any open defect in any direction greater than 3 mm. Defects appearing at the corner of the test specimen may be disregarded unless there is evidence that they result from lack of fusion.

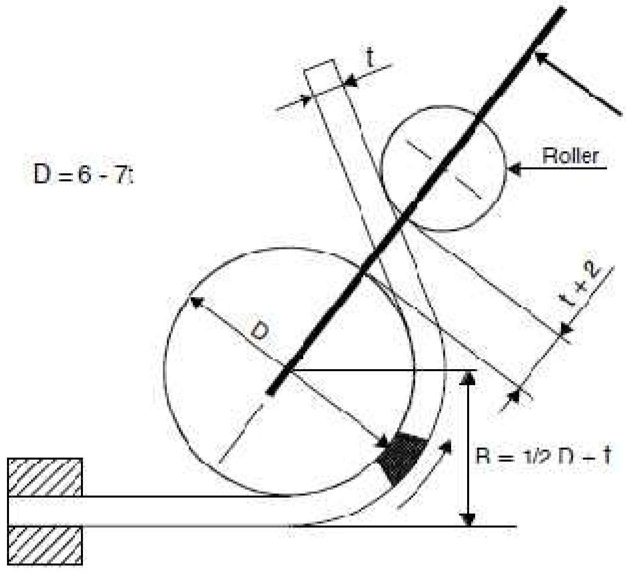


Figure 5.2: Wrap around bend test

The fixed edge of the test specimen is to be clamped to avoid sliding.

The whole welded zone (weld and heat affected zone), in the case of transverse bending, is to be entirely positioned in the bent zone.

5.1.6 Macro examination

The test specimens are to be prepared and etched on one side to clearly reveal the fusion line, the HAZ, the build up of the runs and the unaffected parent metal. The examination is to reveal a regular weld profile, thorough fusion between adjacent layers of weld and base metal, and the absence of defects such as cracks and lack of fusion.

The acceptance levels are given in 5.1.3.

5.2 Plates fillet joint

5.2.1 Assembly and welding

The requirements of 2.2.1 apply except otherwise specified in the following.

The cleaning of the parts to be welded is to be carried out in accordance with the same procedure as used in the construction.

The two plates are to be positioned and tack welded edgewise so as to constitute a T assembly without clearance.

Welding on one or both sides and fit up are to be as detailed in the pWPS. In general for semi-automatic welding a stop/restart position is to be included in the test length and is to be clearly marked for subsequent examination.

5.2.2 Examinations and tests

Non-destructive examinations and destructive tests are to be carried out in accordance with the requirements of Table5.3.

Table 5.3: Examinations and tests

Type of examination or test	Extent of examination or test
Visual examination	100%
Dye penetrant test	100%
Macro examination (1)	2 specimens
Fracture test	1 specimen

(1) One of the macro sections is to be taken at the position of the stop/restart (see 5.1.1).

5.2.3 Visual examination and surface crack detection

The requirements specified in 5.1.3 are to be complied with.

5.2.4 Macro examination and fracture test

The fracture test as well as the macro examination are to show, in general, the absence of defects, in particular lack of root penetration. However in the macro examination, small soundness defects of the weld metal such as blowholes or inclusions may be accepted provided that their total area does not exceed 6% of the weld metal section examined.

The dimensions of leg size, throat and penetration are generally to be reported.

5.3 Re-testing

5.3.1 If the test piece fails to comply with any of the requirements for visual or non-destructive testing, one further test piece is to be welded and subjected to the same examination.

If this additional test piece does not comply with the relevant requirements, the pWPS is to be regarded as not capable of complying with the requirements without modification.

5.3.2 If any test specimens fails to comply with the relevant requirements for destructive testing due to weld imperfection only, two further test specimens shall be obtained for each one that failed. These specimens can be taken from the same test piece if there is sufficient material available or from a new test piece, and is to be subjected to the same test. If either of these additional test specimens does not comply with the relevant requirements, the pWPS is to be regarded as not capable of complying with the requirements without modification.

5.3.3 If a tensile test specimen fails to meet the requirements, the re-testing is to be in accordance with Chapter 2.

5.4 Range of approval

5.4.1 General

Unless otherwise specified in this Sub-section, reference may be made to the requirements in 2.5.

5.4.2 Parent metal

The alloys are grouped into three groups :

a) Group A: Aluminium-magnesium alloys with Mg content ≤ 3,5% (alloy 5754)

b) Group B: Aluminium-magnesium alloys with 4% ≤ Mg ≤ 5,6% (alloys 5059, 5083, 5086, 5383 and 5456)

c) Group C: Aluminium-magnesium-silicon alloys (alloys 6005A, 6061 and 6082)

For each group, qualification tests made on one alloy qualify the procedure for the other alloys of the same group with equal or lower minimum specified tensile strength after welding. Qualification on Group B alloys qualify the procedure for Group A alloys.

5.4.3 Thickness

The qualification of a WPS carried out on a test assembly of thickness t is valid for the thickness range given in Table 5.4.

In case of butt-joints between dissimilar thickness, t is the thickness of the thinner metal.

In case of fillet joints between dissimilar thickness, t is the thickness of the thicker metal.

In addition to the requirements of Table 5.4, the range of qualification of the fillet welds throat thickness a is given in Table 5.5.

Where a fillet weld is qualified by means of a butt weld test, the throat thickness range qualified should be based on the thickness of the deposited weld metal. Where the majority of production work is fillet welding, an additionnal fillet weld test may be required.

Table 5.4: Range of qualification for parent material thickness

Thickness t of the test piece (mm)	Range of qualifications
t ≤3	0,5 to 2 t
3 . t ≤20	3 to 2 t
t ≥20	≥0,8 t

Table 5.5: Range of qualification for the throat thickness of fillet welds

Throat thickness a of the test piece (mm)	Range of qualifications
a . 10	0,75a to 1,5a
a ≥10	≥7,5

5.4.4 Welding positions

The test pieces are to be welded in the position(s) used in the construction taking into account that:

a) Horizontal-vertical position qualifies also for flat and vertical upwards positions

b) Vertical upwards position qualifies also for flat and horizontal- vertical positions

c) Overhead position qualifies also for flat, vertical upwards and horizontal-vertical positions

5.4.5 Welding process

The approval is valid only for the welding process used in the welding procedure test. It is not permitted to change a multi run deposit into a single run (or run on each side) or viceversa for a given process. In the case of a multi-process procedure, the approval is only valid for applying the processes in the order used during the procedure qualification tests.

Note 1: For multi-process procedures each welding process may be approved separately or in combination with other processes. Similarly one or more processes may be deleted from an approved WPS provided the joint thickness is within the approved thickness range of the relevant welding process to be applied.

5.4.6 Welding consumables

The welding consumable used in the qualification tests qualifies:

a) Approved welding consumables of the same strength as the consumable used in the procedure qualification tests.

b) Approved welding consumables of higher strength than the consumable used in the procedure qualification tests.

The qualification given to shielding gas and backing gas is restricted to the gas/gas mixture used in the welding procedure test, see ISO 14175 or other recognised standards for gas designations.

5.4.7 Type of current

Changes in the type of current (AC, DC, pulsed) and polarity require a new welding procedure qualification.

5.4.8 Post-weld heat treatment or ageing

Addition or deletion of post-weld heat treatment or ageing is not permitted. Artificial ageing for 6000 series alloys gives approval for prolonged natural ageing.

5.4.9 Type of joint

The range of approval for the types of joint in relation to the type of joint used in the procedure qualification test is as follows:

a) butt-joint welded from one side with backing qualifies also for welding from both sides with gouging;

b) Butt-joint welded from one side without backing qualifies also for welding from one side with backing, from both sides with gouging and from both sides without gouging;

c) Butt-joint welded from both sides with gouging only qualifies that condition;

d) Butt-joint welded from both sides without gouging qualifies also for welding from both sides with gouging and from one side with backing.

Section 5 Approval of CO_2 Laser Welding Procedures

1 General

1.1 Application

1.1.1 The requirements of this Section apply to the approval of CO_2 laser welding procedures for butt- and T joints in hull construction. Stake welding is not covered by these requirements.

1.2 General requirements

1.2.1 The user's workshop is to demonstrate by means of a weld procedure approval test and examination of the first production welds, that the welds produced under the normal conditions are sound and have the required technical properties.

1.2.2 The approval is granted for a defined range of applications (materials, plate thicknesses, seam preparation, tolerances, etc.) and for specific characteristic welding parameters (laser power, welding speed, welding consumables, etc.), in accordance with the samples welded during the procedure qualification tests. Normally, changes in essential variables outside the approved range (see Sub-section 7) require supplementary tests or new qualification.

1.3 Welding procedure specification

1.3.1 A welding procedure specification is to be prepared by the Manufacturer and proposed for approval; this document is also referred to as preliminary welding procedure specification (pWPS) and is to be modified and amended during the procedure tests as deemed necessary. In its final version, the welding procedure specification (WPS) is to include all the welding parameters and main data affecting the quality of welded joints and is to be used as a basis for the laser production welds.

1.4 Parent metal

1.4.1 In addition to the structural steels defined in Chapter 3, two new grades of steel have been defined with a narrower range of chemical composition. These grades, designated L24 (normal steel) and L36 (higher strength steel), have the chemical composition indicated in Chapter 3. The steels are to comply with the requirements stated in Chapter 3.

1.4.2 Steels having chemical composition different from that indicated in Table 1.1 may be used provided that satisfactory results are obtained in the approval tests and production welds. In particular, the following deviation from the standard composition given in Table 1.1 may be specially considered subject to an adequate limitation of the welding speed, e.g. 0,6m / 1' for a thickness of 12 mm or 2m / 1' for a thickness less than or equal to 6 mm:

- C ≤0,15% subject to a reduction in welding speed and/or increase in applied energy in respect of the values found adequate for the maximum level of C 0,12%,
- S ≤0,010% and P ≤0,015% for a material thickness less than or equal to 12 mm, or
- S ≤0,017% and P ≤0,018% for a material thickness less than or equal to 6 mm.

Table 1.1: L24 and L36 steel chemical composition

Elements	Ladle analysis (%)
C	≤0,12
Mn	0,90 - 1,60 (1)
Si	0,10 - 0,50
S	≤0,005
P	≤0,010
CEQ (2)	≤0,38
Pcm (3)	≤0,22

(1) Manganese may be reduced to 0,70% for L24 grade consistent with the lowest values used in the weld procedure test.

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

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

1.5 Welding consumables

1.5.1 Welding consumables and auxiliary materials are to be approved by the Society and are to be clearly defined in the WPS.

2 Approval of welding procedure

2.1 General

2.1.1 Qualification tests are to be carried out in the presence of the Surveyor at the user’s workshop under fabrication conditions.

2.1.2 Approval of the welding procedure is subject to the acceptance of the first production welds.

2.2 Assembly and welding

2.2.1 Butt-joint test assemblies and/or T-joint test assemblies are to be selected in accordance with the range of application applied for approval.

2.2.2 Test assemblies are to be of a sufficient size to ensure reasonable heat distribution during welding and to provide for the required test specimens, after sufficient discard at the ends. Unless otherwise agreed, the dimensions are to be in accordance with 4.1.2 and 5.1.1 .

2.2.3 Welding is to be carried out in accordance with the pWPS and under the general conditions of production welding which they represent.

2.2.4 The type of joint preparation including tolerances is to be representative of the fabrication welds. Maximum and minimum values of tolerances are to be incorporated in the weld procedure test.

Where gaps are required, the minimum and the maximum values are to be verified on two procedure tests.

2.2.5 The plates are to be held in place by clamps, or other suitable holding devices, or by tack welds as provided for fabrication welding. If tack welds are to be used in the fabrication, they are to be included in the test pieces.

2.2.6 The welding parameters are to be recorded and are to be in accordance with the pWPS. Each test piece is to contain at least one stop/restart of the welding process.

3 Non-destructive examinations

3.1 General

3.1.1 Prior to the cutting of the test specimens, nondestructive examinations are to be carried out over the entire length of the weld.

3.1.2 Where automatic non-destructive examinations are used in fabrication (e.g. ultrasonic), the test piece is to be subjected to such examinations.

3.1.3 Imperfections detected by visual or other nondestructive examination are to be assessed in accordance with EN ISO13919-1 level C.

4 Plates butt welds

4.1 Assembly

4.1.1 The weld direction is to be perpendicular to the rolling direction of the plate and is to be marked on the test piece.

Where impact tests are prescribed for the base metal in the transverse direction, the weld direction is to be parallel to the rolling direction of the plate (see Fig 4.1).

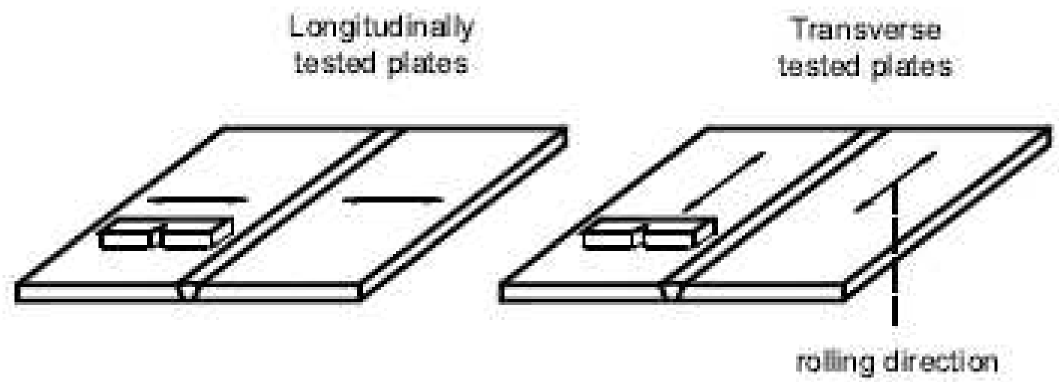


Figure 4.1: Butt weld test assembly with Charpy impact test

4.1.2 The dimension of the butt weld test assembly is to be in accordance with Fig 4.2.

The dimensions in Fig 2 are as follows:

- W min. =300 mm
- L min. = 300 mm
- D max. = 25 mm for thickness below or equal to 25mm
- D max. = 50 mm for thickness above 25mm.

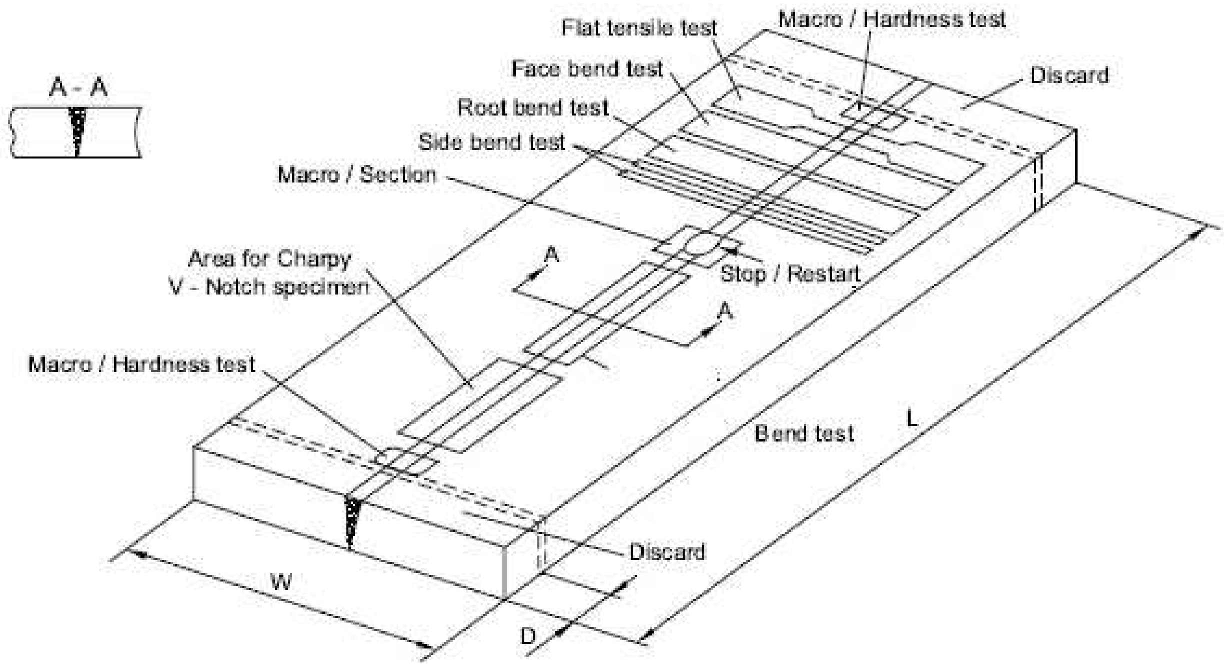


Figure 4.2: Butt weld test assembly

4.2 Examinations and tests

4.2.1 General

Non-destructive examinations and destructive tests are to be in accordance with the requirements of Table 4.1, while the location of the test specimens is to be in accordance with Fig 4.2.

Table 4.1: Examinations and tests

Type of examination or test	Extent of examination or test
Visual examination	100%
Radiographic examination	100%
Magnetic particle examination	100%
Transverse tensile tests	2 specimens
Transverse bend tests (1)	2 root and 2 face specimens
Longitudinal bend test	1 face specimen
Impact tests (2)	3 sets
Macro examination	3 sections
Hardness test	2 sections

(1) The face and root bends are preferably to be replaced by 4 side bends for t ≥12 mm.

(2) 3 sets of 3 specimens as per 4.5.1.

4.2.2 Non-destructive examinations

The requirements in Sub-section 3 are to be complied with. Special attention is to be paid to the stop/restart positions

with respect to profile, proper fusion and absence of cracks and porosity.

4.3 Tensile tests

4.3.1 Transverse tensile test specimen and procedure is to be in accordance with Chapter 2.

4.3.2 The tensile strength is to be not lower than the specified minimum tensile strength of the parent material. The location of the fracture is to be reported, i.e. weld metal, HAZ, parent metal.

4.4 Bend tests

4.4.1 Bend test

Transverse, side and longitudinal bend specimens are to be in accordance with Chapter 2.

The test specimens are to be bent on a mandrel having a diameter 3,5 times the thickness of the specimen; the bending angle is to be 180°.

4.4.2 During the test, the specimens are not to reveal any open imperfection, in any direction, greater than 3 mm.

Defects not initiated by a weld defect appearing at the corner of the test specimen are disregarded.

4.5 Impact tests

4.5.1 Charpy V-notch impact tests are to be taken 1 mm below the surface of the sample transverse to the weld and with the notch perpendicular to the material surface; they are to be machined to the dimensions indicated in Chapter 2.

Three sets of Charpy V-notch specimens, each set including 3 specimens, are to be taken as follows:

- one set with the notch along the weld metal centre line with tolerance ± 0,1mm
- one set with the notch in the heat affected zone (HAZ)
- one set with the notch in the parent metal.

The direction of fracture is to coincide with the weld direction (see Fig 4.3). The parent material specimens are to have the same orientation as the specimens from the weld joint.

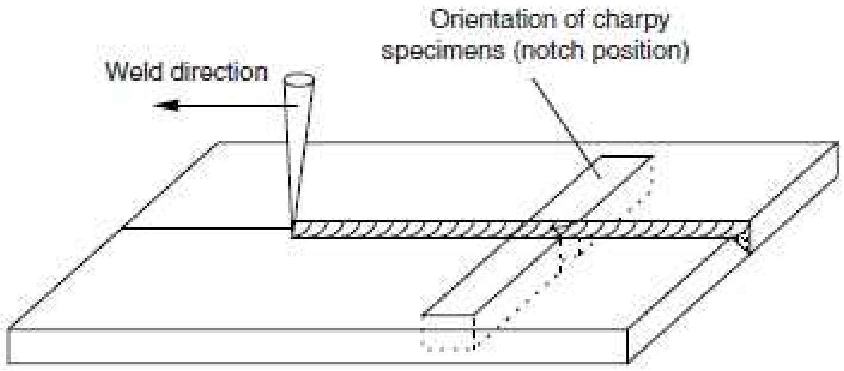


Figure 4.3: Fracture direction of Charpy impact tests

4.5.2 The test temperature and the results are to comply with the requirements specified for the parent metal.

4.5.3 Requirements for reduced Charpy V specimens are given in Chapter 2.

4.5.4 The Society may require additional tests, e.g. Charpy tests with other notch locations, and other or additional temperatures or CTOD tests.

4.6 Hardness measurements

4.6.1 Hardness test

The Vickers method HV10 is generally to be used. The indentations are to be made in the weld, heat affected zones (HAZ) and the parent metal, with the object of measuring and recording the range of values in the weld joint (see Fig 4.4). For butt welds, the upper and lower rows are to transverse 2 mm maximum below the surface, depending on the plate thickness.

For each row of indentations, a minimum of 3 individual indentations is required in the weld, both sides of the HAZ and the parent metal.

For the HAZ, the indentations are to be placed as close as possible to the fusion line.

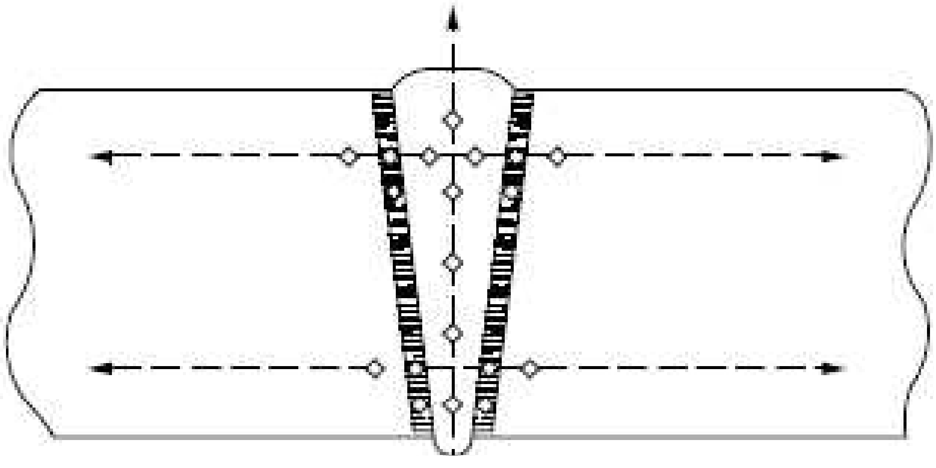


Figure 4.4: Butt weld hardness indentations

4.6.2 Where no filler metal or low hydrogen welding consumables (H5) are used in the procedure, values not higher than 380HV are considered acceptable; one individual value not higher than 400HV is accepted for each section.

Values not higher than 350HV are required in all other cases.

4.7 Metallographic examination

4.7.1 The three macro sections are to be taken as shown in Fig 4.2.

One section is to be a length of weld including a stop/restart position. This longitudinal section is to be cut as shown in Fig 4.5 and examined at the mid-thickness of the plate.

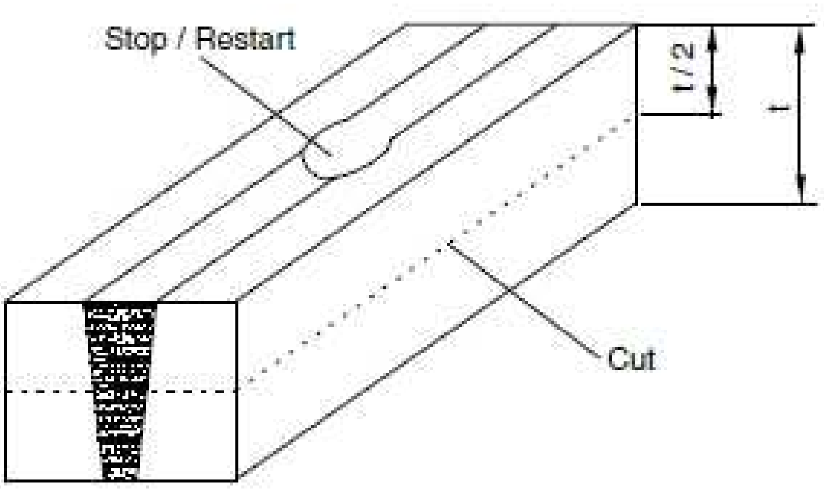


Figure 4.5: Longitudinal mid-thickness macro section

4.7.2 The test specimens are to be prepared and etched on one side only to clearly reveal the fusion line, the HAZ, the solidification structure of the weld metal and the unaffected parent metal.

4.7.3 The sections are to be examined by the naked eye (or by low power hand lens if deemed necessary) for any imperfection present in the weld metal and HAZ and for unsatisfactory profile features. Any imperfections are to be assessed in accordance with Sub-section 3.

4.7.4 The weld shape is to be within the limits specified in Fig 4.6. For thicknesses up to 8 mm, lower values for “d” and “d1“may be accepted at the discretion of the Society.

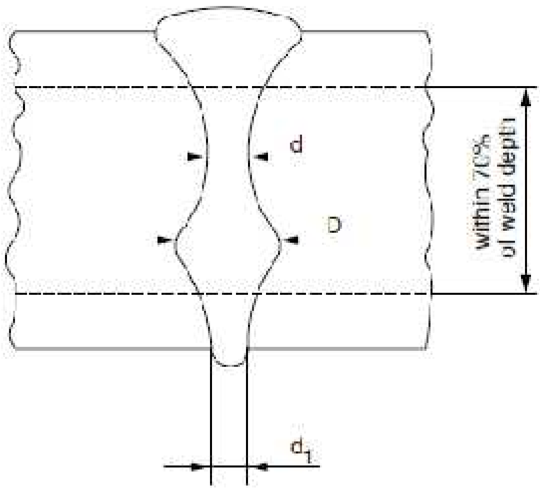


Figure 4.6: Weld shape limitations

d: Minimum weld width, with d ≥1,5 mm

d1: Weld root width, with d1 ≥1,0 mm

D/d: Secondary wide zone “bulge”, if bulging occurs D/d ≤1,2

5 T joint weld procedure test

5.1 Assembly

5.1.1 The dimensions of the T-joint weld test assembly are to be in accordance with Fig 5.1. The dimensions in Fig 5.1 are as follows:

- W min. = 300 mm
- L min. = 1000 mm
- D max. = 50 mm.

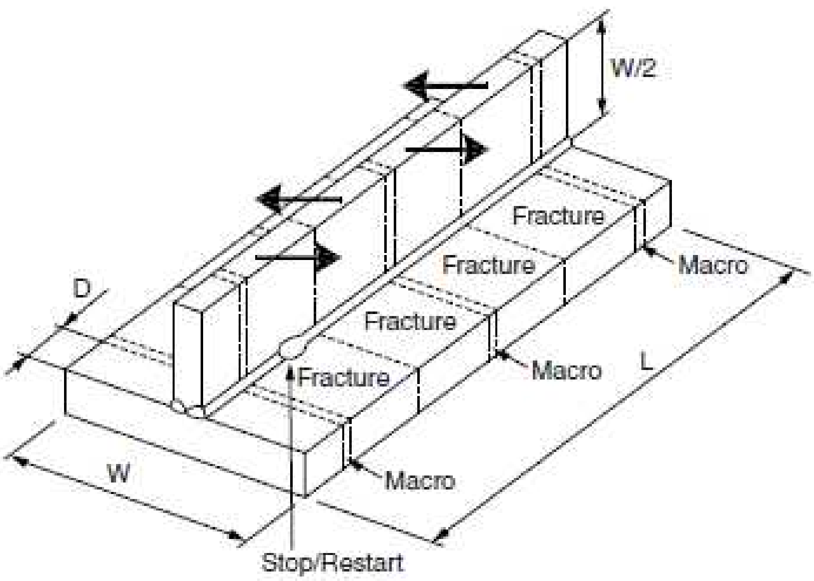


Figure 5.1: T-joint test assembly

5.2 Examinations and tests

5.2.1 General

Non-destructive examinations and destructive tests are to be in accordance with the requirements of Table 5.1, while the

location of the test specimens is to be in accordance with Fig 5.1.

Table 5.1: Examinations and tests

Type of examination or test	Extent of examination or test
Visual examination	100%
Magnetic particle examination	100%
Ultrasonic examination	100%
Macro examination	3 sections
Hardness test	3 sections
Break test	4 specimens (1)

(1) One specimen is to be taken from the stop/restart position.

5.2.2 Non-destructive examination

The requirements in Sub-section 5.3 are to be complied with. Special attention is to be paid to the stop/restart positions with respect to profile, proper fusion and absence of crater defects.

5.2.3 Macro examination

The three macro sections are to be taken as shown in Fig 5.1. Two sections are to be taken from the ends adjacent to the discards, the third from the middle of the length.

5.2.4 Hardness test

Hardness indentations are to be made as shown in Fig 5.2 in accordance with 4.6.1, as appropriate. All hardness values are to be recorded. The values are to comply with the requirements in 4.6.2.

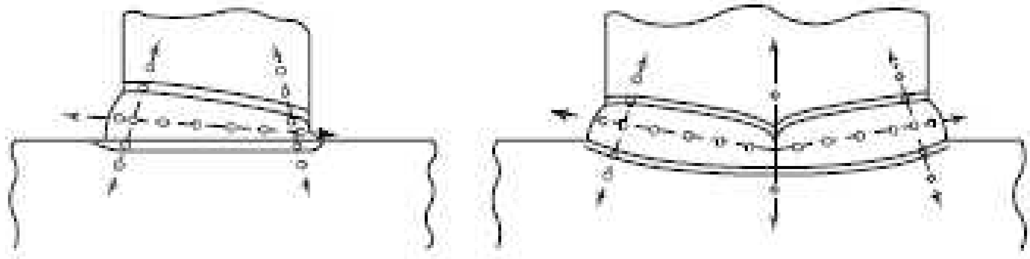


Figure 5.2: T joint weld hardness indentations

5.2.5 Break test

Break test specimens are to be taken from the length of the welded assembly remaining after removal of the macro sections. Four test specimens (not less than 100 mm each in length) are to be taken and fractured by folding the upright plate in alternate directions onto the through plate (see Fig 5.1).

A saw cut may be made to facilitate breaking in accordance with Fig 5.3.The fracture surfaces are to be examined for possible defects which are to be assessed in accordance with Sub-section 3.

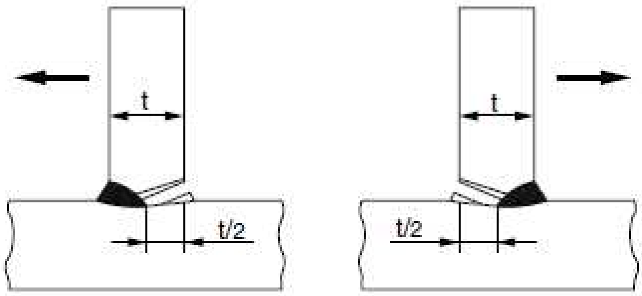


Figure 5.3: Break test

Note 1: If a break in the weld cannot be obtained, an alternative is to machine the base plate flush to the web and to X-ray the weld in the direction of weld centre line.

6 Re-testing

6.1 Non-destructive and destructive tests

6.1.1 If the test piece fails to comply with any of the requirements for visual or non-destructive testing, one further test piece is to be welded and subjected to the same examination.

If this additional test piece does not comply with the relevant requirements, the pWPS is to be regarded as not capable of complying with the requirements without modification.

6.1.2 If any test specimens fails to comply with the relevant requirements for destructive testing due to weld imperfection only, two further test specimens shall be obtained for each one that failed. These specimens can be taken from the same test piece if there is sufficient material available or from a new test piece, and is to be subjected to the same test. If either of these additional test specimens does not comply with the relevant requirements, the pWPS is to be regarded as not capable of complying with the requirements without modification.

6.1.3 If a tensile test specimen fails to meet the requirements, the re-testing is to be in accordance with Chapter 2.

6.1.4 The re-testing of Charpy V-notch impact test specimens are to be carried out in accordance with Chapter 2.

7 Range of approval

7.1 Parent metal

7.1.1 Approval is given to that grade tested.

7.2 Thickness

7.2.1 The approval of a procedure carried out on a welded assembly of thickness t is valid for the range 0,80t to 1,2t. Speed and power may be changed within the limitations in 7.6.2.

7.3 Edge preparation and surface condition

7.3.1 Cutting process

The cutting processes are as follows:

- thermal cut
- thermal cut and sand blasted
- thermal cut and ground
- milled.

Other cutting methods, such as mechanical cutting (shearing), may be considered analogously depending on their

edge geometry and surface condition. A change in the cutting process requires new qualification.

7.3.2 Surface condition

Any major change in surface condition, such as a change from uncoated to shop primer coated surfaces, requires new qualification. In this context, special attention is to be paid to T-joint configurations.

7.4 Joint type, bevel

7.4.1 Butt-joints cannot cover T-joints and vice versa.

7.4.2 Any change in joint geometry with respect to that specified in the welding procedure qualification report (WPQR) requires new qualification.

7.5 Welding machine

7.5.1 Laser machine

A procedure approved for use on one laser machine is valid for that machine and beam shape only. The approval is valid for the focusing system used at the approval tests.

7.5.2 Modification of laser machine

Modifications carried out on an approved laser machine or the use of other laser machines having the same technical specification (from the laser beam technology point of view) only required a reduced re-approval test, if the beam parameters are within the approved range.

7.6 Welding parameters

7.6.1 General

Variations within the limits described below in the welding speed, laser power, focusing parameters and wire feed rate are allowed to accommodate changes in material thickness or fit-up, without need for re-approval. Monitoring of welding parameters within a given procedure setting is to be applied.

7.6.2 Laser power and welding speed

The parameter (laser power / thickness x speed) is to be within the range 90-120% of that originally approved (while also maintaining the welding speed above 0,6m/1’).

For each resetting of parameters, one test sample is to be taken and verified for weld profile shape and freedom from defects by non-destructive examination.

7.6.3 Wire feed speed

The wire feed speed is to be maintained within the limits established by the procedure tests.

7.6.4 Focusing optic and focus position

The focusing parameters are to be kept within the limits specified in accordance with recognised standards.

7.6.5 Number of runs

A change in the number of passes requires a new approval.

7.6.6 Process and shielding gas

Any change in shielding gas or plasma control gas composition requires a new approval. A change in the flow rate up to 10% is admitted.

7.6.7 Welding position

A change of the welding position requires a new approval.

7.6.8 Welding consumables

Any change of welding consumables requires a new approval.

7.6.9 Other variables

The range of approval related to other variables may be taken according to established practice as represented in recognised standards.