

CHINA CLASSIFICATION SOCIETY

RULES FOR MATERIALS AND WELDING

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PART ONE METALLIC MATERIALS

CHAPTER 1 GENERAL

Section 1 GENERAL PROVISIONS

1.1.1 Application

1.1.1.1 Materials or products used for the construction of hull, machinery, boilers and pressure vessels of ships and offshore installations are to be manufactured, tested and inspected in accordance with the relevant requirements of this PART, and are to be furnished with complete certificates of conformity.

1.1.1.2 Where it is proposed to use materials or products, which are not covered by this PART, for the construction of hull, machinery, boilers and pressure vessels of ships and offshore installations, the chemical composition, mechanical properties and heat treatment procedures may be accepted in accordance with other recognized standards.

Newly developed products and materials are to be approved by CCS before being adopted for use on board ships.

1.1.2 Markings

1.1.2.1 All materials or products which have been approved or satisfactorily inspected by CCS are to be marked with CCS stamp as appropriate.

1.1.3 Manufacture

1.1.3.1 Manufacturers are to order materials or products from the works which have been approved by CCS.

1.1.3.2 Manufacturers making marine materials or products are to be provided with necessary manufacturing and testing facilities, and with a complete quality control department for conducting a strict inspection system and maintaining good quality of products.

1.1.4 Approval and inspection

1.1.4.1 Works manufacturing materials, components, products and equipment used for ships or offshore installations are to be subjected to type approval or works approval in accordance with the appropriate procedures established by CCS.

1.1.4.2 Examination of plans and documents: For materials and marine products such as components and equipment intended to be used for ships or offshore installations classed with CCS, manufacturers are in general to submit plans and documents required to be approved, as specified in the Rules, in triplicate to the plan approval unit designated by CCS, prior to manufacturing. When the submitted plans and documents are approved, one set of them is to be kept in the plan approval unit, one delivered to the survey unit carrying out the inspection, and one returned to the manufacturer. Where the plan approval location and the inspection location are the same one, plans and documents are to be submitted in duplicate only. In special cases and subject to agreement of CCS, the manufacturer may submit plans and documents directly to the survey unit carrying out the inspection for review. Where plans of components and fittings are included in the plans of ships and have been approved, re-submission of such plans is not necessary.

1.1.4.3 Materials or products used for ships or offshore installations are to be subjected to surveys by CCS. The Surveyors are:

(1) to carry out inspections in accordance with the approved plans;

(2) to attend the testing of specified items;

(3) to prepare a marine product certificate based on the technical documents provided by the manufacturer when it is confirmed on completion of inspection and testing that the products are in compliance with the requirements of the Rules and the approved plans;

(4) to indicate on the certificate, in addition to listing names of the products and the manufacturer, the other limiting conditions and/or the tests to be required after installation on board ships, if any;

(5) to carry out confirmation testing and/or dismantling inspection, if necessary, for products manufactured not under the supervision of CCS and require one set of the plans and documents and related test reports to be submitted for examination.

Section 2 TESTING AND SURVEY

1.2.1 General requirements

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

1.2.1.2 The manufacturer is to provide the Surveyor with necessary facilities for access to all relevant parts of the works and information so as to enable him to select the test materials, verify the calibration of inspection equipment, the accuracy of the testing and traceability of materials as required by the Rule and verify that manufacture is being carried out in accordance with the approved procedure specification and the quality of the products is maintained.

1.2.1.3 In the event of any material to be found and proved unsatisfactory during subsequent working, machining, fabrication or testing, such material is to be rejected, notwithstanding any previous certification.

1.2.2 Chemical composition

1.2.2.1 Manufacturers producing ship materials or marine products are to be provided with an adequately equipped and competently staffed laboratory for determining the chemical composition of test samples.

1.2.2.2 The method of sampling chemical composition is to follow that carried out for the initial approval tests, normally from the ladle, the tundish or the mould in the case of continuous casting. When multiple heats are tapped into a common ladle, the ladle analysis is to apply. The chemical composition is to be reported in percentage by weight.

1.2.2.3 The manufacturer's analysis may be accepted by CCS subject to occasional independent checks if required by the Surveyor. In case of doubt, the Surveyor may require to check the chemical composition of suitable samples from materials or products. For product samples, the permissible limits of deviation from the specified ladle analysis are to be in accordance with recognized standards.

1.2.3 Heat treatment

1.2.3.1 Materials are to be supplied in the condition as specified in relevant Chapters of this PART. Important forgings or castings are to be subjected to heat treatment. The heat treatment procedures are to be developed by the manufacturers and submitted to CCS for information.

1.2.3.2 Heat treatment is to be carried out in properly constructed furnaces operating satisfactorily and having adequate means for the control and recording of temperature. The furnace dimensions are to be such as to allow the whole item to be uniformly heated to a specified temperature. In the case of very large components which require heat treatment, suitable alternative methods may be adopted. However, such methods are to be proved feasible. Sufficient thermocouples are to be connected to the furnace charge to measure and record the furnace temperature and verify the temperature uniformity of the furnace in addition that the inspection of the temperature uniformity of the furnace is carried out at regular intervals.

1.2.3.3 Manufactories are 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.

1.2.4 Mechanical tests

1.2.4.1 The dimensions, number as well as location and direction of the mechanical test specimens are to comply with the requirements of Chapter 2 and subsequent Chapters of this PART.

1.2.4.2 Where Charpy impact tests are required, a set of three test specimens is to be prepared and the average energy value is to comply with the relevant 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% of that value.

1.2.5 Non-destructive testing

1.2.5.1 Non-destructive testing personnel are to pass the tests specified in CCS Rules for Qualification and Certification of Non-destructive Testing Personnel or corresponding standards, and hold a valid "Qualification Certificate of Non-destructive Testing Operator" issued or accepted by CCS.

1.2.5.2 Non-destructive testing personnel are allowed to engage only in the non-destructive testing appropriate to their qualified range of work.

1.2.5.3 Non-destructive testing instruments are to be periodically calibrated according to relevant standards and relevant equipment are to be in good condition and readily available.

1.2.6 Re-test procedures

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

1.2.6.2 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 taken provided that, of the original set tested, 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, 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.

1.2.6.3 The additional tests detailed in 1.2.6.1 and 1.2.6.2 of this Section are to be made on material adjacent to the original samples.

For castings, where insufficient material remains in the original test samples, the additional tests may be made on other test samples representative of the castings.

1.2.6.4 When unsatisfactory results are obtained from the additional tests detailed in 1.2.6.1 and 1.2.6.2 of this Section, the item or piece from which the specimens were taken is to be rejected. The remainder of the material in the batch may be accepted provided that two further items or pieces are selected and completely tested with satisfactory results. If the tests from one of these additional items or pieces give unsatisfactory results, the batch is to be rejected.

1.2.6.5 When a batch of material is rejected, the remaining items or pieces in the batch may be re-submitted individually for test, and those which give satisfactory results may be accepted.

At the discretion of the manufacturer, the rejected batch may be re-submitted for complete re-tests after a heat treatment in accordance with the requirements of 1.2.3.2 of this Section and may then be accepted, provided that the test results are satisfactory. When unsatisfactory results are obtained from such tests, additional tests may be carried out in accordance with 1.2.6.1 and 1.2.6.2 of this Section. Where such re-tests again fail, the batch is not permitted to be re-submitted for acceptance.

1.2.7 Rectification of defects

1.2.7.1 The material is to be free from harmful internal and external defects which will impair its future use. The defects are to be determined in accordance with other recognized standards.

1.2.7.2 Small surface imperfections may be removed by mechanical means. Under appropriate conditions, repairs by welding may also be accepted provided that the relevant requirements in subsequent Chapters of this PART are complied with. In addition, the extent and method of repair are to be agreed by the Surveyor.

1.2.8 Identification of materials

1.2.8.1 The manufacturer is to adopt a system of identification which will enable the manufacturing processes of the products to be traced effectively, and the system is to be applied to products and certificates.

1.2.8.2 Accepted materials and products are to be marked with CCS stamp. For certain materials where hard stamping is impracticable, stenciling, painting or electric etching may be used. Paints used to identify alloy steels are to be free from harmful elements such as lead, copper, zinc or tin, etc. Coating used to identify austenitic stainless steels and austenitic/ferritic duplex stainless steels is to contain chloride content as low as possible. Small identical items of same type and dimensions that are packed in cases, casks or similar packages as well as steel bars and sections securely fastened together in bundles may be branded on the top of each bundle or package. Alternatively, a durable label giving the required particulars may be attached thereto.

1.2.8.3 Materials and products found satisfactory at survey are, in addition to the CCS stamp, to be furnished with the Certificate of Marine Products issued by CCS, or alternatively, to be furnished with the manufacturer's certificate of conformity endorsed by the Surveyor (or his deputy), so as to show that the materials or products concerned comply with the requirements of the Rules, manufacturing procedure specification and survey procedure.

1.2.8.4 Manufacturers are required to check whether the original materials or components bear CCS stamp of approval. Manufacturers are to submit to the Surveyor the certificates and stamps of the original materials or components if so required.

CHAPTER 2 MATERIAL TESTS

Section 1 GENERAL PROVISIONS

2.1.1 Application

2.1.1.1 This Chapter covers the requirements for general mechanical tests and technological tests of marine metallic materials and corrosion resistance tests of stainless steel. Tests other than those specified in this Chapter may be carried out in accordance with the relevant requirements of subsequent Chapters of this PART or relevant recognized standards.

2.1.2 Test material

2.1.2.1 Test material is the material used for the preparation of specimens for tests. Unless otherwise specified, all test materials are to be selected by the Surveyor (or his deputy).

The test material is to be so selected as to be representative of the quality of the item or batch as far as possible.

2.1.2.2 Where a certain treatment (for instance heat treatment) might affect the property of the material, the test material is to be subjected to the same treatment as the original material.

2.1.3 Preparation of test specimens

2.1.3.1 The requirements for specimens are to comply with the provisions of each Chapter of this PART. Alternative specimens, such as those complying with national or international standards, may be accepted subject to agreement of CCS.

2.1.3.2 Test samples from which test specimens are taken are to be cut in the final state of the material. Where separate samples are adopted, the samples are to undergo the same treatment as the material which they represent simultaneously. Test specimens are to be prepared in such a manner that the properties of the original material are not affected.

2.1.3.3 Where test material is cut from products by shearing or heat cutting (e.g. plasma, laser and flame cutting, etc.), a reasonable margin is required to allow sufficient material to be removed from the cut edges during machining of the test specimens.

2.1.3.4 Test specimens are not to be subjected to any significant cold straining or heating during straightening or machining. And unless otherwise specified, the test specimens are not to be separately heat treated in any way.

2.1.3.5 Identification of all test specimens is to be made by the laboratory using appropriate numbering system to enable the tracing of specimen to its represented material. The identifying method is not to affect the test results.

2.1.4 Testing machines

2.1.4.1 All tests are to be carried out by competent personnel in accordance with specified procedures.

2.1.4.2 Testing machines are to be maintained in a satisfactory and accurate condition and are to be recalibrated at least once a year by a nationally recognized metrology authority. Testing machines are to be calibrated in accordance with the specified standards. The metric measures of the testing machines being calibrated are to be traced to national standards.

2.1.4.3 Tension testing machines are to be calibrated in accordance with ISO 7500-1 or equivalent national standards. The accuracy of testing machines is to be within ±1%.

2.1.4.4 The calibration of Charpy pendulum-type impact testing machines is to be in compliance with the requirements of ISO 148-2 or equivalent national standards.

2.1.4.5 The calibration of hardness testing machines is to be carried out based on applicable testing methods according to relevant international or national standards.

2.1.5 Testing procedures

2.1.5.1 The testing procedures of different tests may follow established practice as laid down in international or national standards except those given in this Chapter.

2.1.6 Discarding of test specimens

2.1.6.1 If a test specimen fails because of faulty preparation or incorrect operation of the testing machine, it may be discarded and replaced by a new test specimen prepared from material adjacent to the original test material.

2.1.6.2 A tensile test specimen may be discarded and a new specimen is to be prepared for re-test when the specified minimum elongation is not obtained and the distance between the fracture and the nearest gauge mark is less than 1/3 of the original gauge length.

2.1.7 Test temperature

2.1.7.1 Except for impact tests, the mechanical and technological tests are generally carried out at the room temperature (10℃ to 35℃), if it is not specified otherwise in the subsequent Chapters.

Section 2 TENSILE TESTS

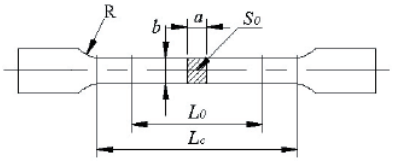
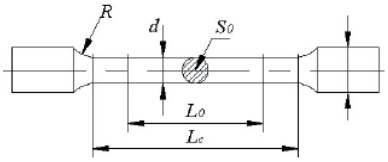
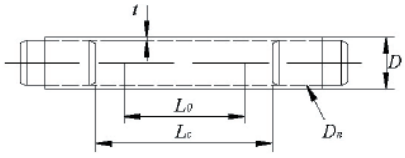
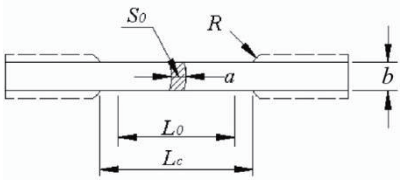
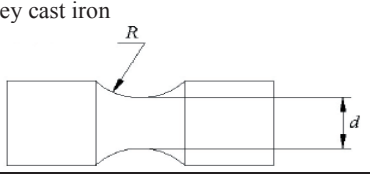
2.2.1 General requirements

2.2.1.1 The mechanical properties of marine metallic materials such as tensile strength, yield strength, elongation and reduction in area are to be determined by a tensile test.

2.2.2 Specimens

2.2.2.1 Tensile specimens are to be of the type and dimensions as given in Table 2.2.2.1. Both ends of the test specimen may be machined to suit the grips of the testing machine used.

Type and Dimensions of Tensile Specimens **Table 2.2.2.1**

Item	Type of specimen	Dimensions of specimen (mm)①	Applicable materials
1	Flat 	Proportional test specimen: $a = t$, $b = 25$, $R = 25$ $L_0 = 5.65\sqrt{S_0}$ $L_c = L_0 + 2\sqrt{S_0}$	Steel plates, strips and sections②
		Non-proportional test specimen: 1: $a = t$, $b = 25$, $R = 25$ $L_0 = 200$, $L_c \geq 212.5$	
		2: $a = t$, $b = 12.5$, $R = 25$, $L_0 = 50$, $L_c \geq 55$	Aluminium alloy plates and sections of $t \leq 12.5$ mm
2	Round 	Proportional test specimen: $d = 10 \sim 20$ (preferably 14), $L_0 = 5d$, $L_C \geq L_0 + 0.5d$, $R = 10$	Thick steel plates and sections; Aluminium alloy plates and sections of $t > 12.5$ mm; Metallic forgings; Wires③, bars④; Castings (excluding grey cast iron)
3	Round tube 	Proportional test specimen: $L_0 = 5.65\sqrt{S_0}$ $L_C \geq L_0 + 0.5D$⑤	Tubes of thin wall and small diameter
4	Tube longitudinally cut 	Proportional test specimen: $a = t$, $b \geq 12$, $R \geq 10$ $L_0 = 5.65\sqrt{S_0}$ $L_C \geq L_0 + 2b$	Tubes of large diameter⑥
5	Grey cast iron 	Non-proportional test specimen: $d = 20$, $R = 25$	Grey cast iron

Notes: ① a, b and d respectively means thickness, width and diameter, D means external tube diameter, L_0 means original gauge length, L_c means parallel length, R means transition radius, S_0 means original cross-sectional area and t means plate thickness.

② For test specimen of full thickness of rolled products, the original rolled surfaces are to be kept. When the capacity of the available testing machine is insufficient, this may be reduced to 25 mm by machining one of the rolled surfaces. Alternatively, for materials over about 40 mm thick, round test specimens as specified in Item 2 may be used.

③ Thin wires may be directly taken as test specimens, with L_0 being 200 mm and L_c between grips being 250 mm.

④ For small-size forging and casting bars or similar products, the test specimens may consist of a suitable length of bar or other product tested in the full cross-section.

⑤ L_c is not to be greater than the distance between the grips or the plugs, whichever is the smallest.

⑥ The test specimen is to be cut longitudinally. The parallel test length is not to be flattened, but the enlarged ends may be flattened for gripping in the testing machine. When the wall thickness is sufficient, round test specimens as specified in Item 2 may be used, with their axes located at the mid-wall thickness.

2.2.2.2 Proportional test specimens with a gauge length $5.65\sqrt{S_0}$ or $5d$ are preferably to be used, and L_0 is preferably to be not less than 20 mm. When the cross-section of a test specimen is too small, a proportional test specimen with a gauge length $11.3\sqrt{S_0}$ or $10d$ or a non-proportional test specimen may be used. The actual gauge length may be rounded off to the nearest 5 mm provided that the difference between this length and L_0 is less than ±10% of L_0.

2.2.2.3 The surface roughness, dimensions and geometric tolerances of test specimens are to be in accordance with recognized standards.

2.2.3 Yield strength and elongation of materials

2.2.3.1 The yield phenomenon is not exhibited by all the metallic materials detailed in this PART. For metallic materials showing a yield phenomenon, the upper yield strength R_{eH} is to be determined. For metallic materials showing no yield phenomenon, the proof strength R_p under test force is to be taken as yield strength.

2.2.3.2 The yield strength for different types of metallic materials is defined as follows:

(1) For carbon, carbon-manganese and alloy steel products and welding consumables, either the upper yield strength R_{eH}, or strength $R_{p0.2}$ at the non-proportional elongation being 0.2% of the original gauge length is to be determined.

(2) For austenitic and duplex stainless steel products and welding consumables, strength $R_{p0.2}$ or strength $R_{p1.0}$ at the non-proportional elongation respectively being 0.2% or 1.0% of the original gauge length is to be determined.

(3) For aluminium alloy and copper alloy products and welding consumables, strength $R_{p0.2}$ at the non-proportional elongation being 0.2% of the original gauge length is to be determined.

2.2.3.3 The elongation A is usually determined on the proportional test specimens as specified in Table 2.2.2.1. Except thin aluminium alloy plates detailed in Chapter 8 of this PART, the elongation specified in other Chapters means elongation A_5 determined on a proportional gauge length $5.65\sqrt{S_0}$ or $5d$.

2.2.3.4 When a non-proportional test specimen which is made of ferritic steel of low or medium strength and not cold worked is used, in order to check whether the elongation of the material complies with the Rules, the required minimum elongation may be converted to the minimum equivalent elongation A_0 from the following formula:

$$A_0 = 2A_5\left(\frac{\sqrt{S_0}}{L_0}\right)^{0.40}$$

where: A_5 — the minimum elongation value as specified in relevant Chapters of this PART when L_0 is $5.65\sqrt{S_0}$ or $5d$, in %;

S_0 — original cross-sectional area in parallel length of test specimen, in mm^2;

L_0 — gauge length of test specimen, in mm.

During testing, the elongation actually measured is not to be less than the specified minimum equivalent elongation.

2.2.3.5 The above conversion is applicable only to carbon, carbon-manganese and low alloy steels with a tensile strength not exceeding 700 N/mm^2 in the hot rolled, annealed, normalized, or normalized and tempered conditions. For carbon, carbon-manganese and low alloy steels with a tensile strength exceeding 700 N/mm^2 in other delivery conditions as well as for other materials, the minimum equivalent elongation is to be additionally calculated in accordance with recognized methods.

2.2.4 Testing

2.2.4.1 Testing at room temperature is to comply with the following requirements:
(1) During plastic deformation at yield, the stress rate is to be within the limits specified in Table 2.2.4.1(1) for the determination of the yield strength or the proof strength of metallic materials.

Rate of Stressing under Load during Tensile Test Table 2.2.4.1(1)

Modulus of elasticity of the material, E N/mm^2	Stress rate (N/mm^2/s)	
	Min.	Max.
<150 000	2	20
≥150 000	6	60

(2) After reaching the yield or proof load, in order to measure the tensile strength of materials, for ductile material, the strain rate is not to exceed 0.008/s. For brittle materials, such as cast iron, the elastic stress rate is not to exceed 10 N/mm^2 per second.
(3) For steel, the upper yield strength is to be calculated from the following measured load values:
① the load immediately prior to a distinct fallback in the movement of the pointer of the testing machine or the load at a marked hesitation of this pointer;
② the value of load measured either at the commencement of plastic deformation at yield or at the first peak obtained during yielding even when that peak is equal to or less than any subsequent peaks observed during plastic deformation at yield, as shown in a load/extension diagram.
(4) The 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 an amount representing 0.2% or 1.0% of the extensometer gauge length. The point of intersection of this line with the plastic portion of the diagram represents the load for calculation of the proof strength ($R_{p0.2}$ or $R_{p1.0}$).
2.2.4.2 Testing at elevated temperatures (≥ 50℃) is to comply with the following requirements:
(1) The test specimens used for determination of lower yield strength or the 0.2% non-proportional elongation strength at elevated temperatures are to have an gauge length L_0 of not less than 50 mm and a cross-sectional area S_0 of not less than 65 mm^2. Where this is precluded by the dimensions of the product or by the capacity of the test equipment available, the test specimen is to be of the largest practicable dimensions.
(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℃.
(3) The straining rate when approaching the yield strength or non-proportional elongation strength is to be controlled within the range of 0.1% to 0.3% of the original gauge length per minute.
(4) The time intervals used for estimation of straining rate from measurements of strain are not to exceed 6s.

Section 3 IMPACT TESTS

2.3.1 Impact test specimens

2.3.1.1 Impact test specimens are to be of the Charpy V-notch type, as shown in Figure 2.3.1.1. The dimensions and tolerances of the specimens are to comply with the requirements of Table 2.3.1.1.

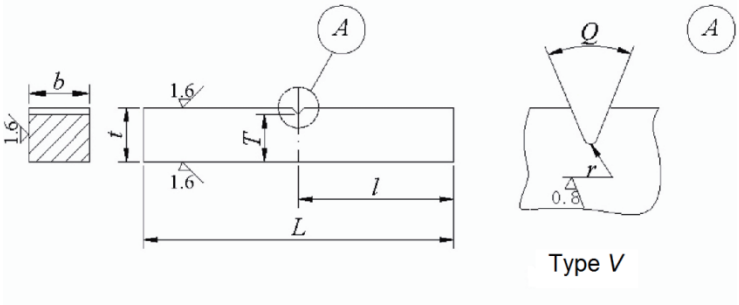


Figure 2.3.1.1

Dimensions of Impact Test Specimens **Table 2.3.1.1**

Item		Designation	V-notch specimen	
			Nominal dimensions	Tolerance
Length (mm)		*L*	55	±0.60
Width (mm)	Standard specimen	*b*	10	±0.11
	Standard subsidiary specimen	*b* *b*	7.5 5	±0.11 ±0.06
Thickness (mm)		*t*	10	0.075
Angle of notch (°)		*Q*	45	±2
Width of notch (mm)		*U*	-	-
Depth below notch (mm)		*T*	8	0.075
Root radius (mm)		*r*	0.25	±0.025
Distance of notch from end of test specimen (mm)		*l*	27.5	±0.42
Angle between plane of symmetry of notch and longitudinal axis of test specimen (°)		–	90	±2

2.3.1.2 The position and direction of cutting of the impact specimens are to comply with the relevant requirements of this PART. The notch of the test specimen is generally to be perpendicular to the original surface of the piece, and the position of the notch is not to be nearer than 25 mm to a flame-cut or sheared edge.

2.3.1.3 In all cases, specimens with maximum thickness are to be taken as far as possible. The width of the standard subsidiary test specimen and the conversion with the impact energy of the standard specimen is given in Table 2.3.1.3. For specimens smaller than 5 mm in size, the impact test is generally not required.

Conversion **Table 2.3.1.3**

Width of standard subsidiary specimen (mm)	Conversion ratio with impact energy of standard specimen
7.5	5/6
5	2/3

2.3.2 Testing

2.3.2.1 All the impact tests are to be carried out on pendulum-type impact testing machines, and the specifications of the testing machines are to comply with the requirements of Table 2.3.2.1.

Specifications of Testing Machines **Table 2.3.2.1**

Maximum impact energy of testing machine (J)	≥ 150
Distance between supports (mm)	$40^{+0.5}_{-0}$
Radius of curvature of supports (mm)	1.0 ~ 1.5
Taper of supports	1:5
Angle of the tip of hammer (°)	30 ±1
Radius of curvature of the tip of hammer (mm)	1.0 ~ 2.5
Speed of hammer at the moment of striking (m/s)	4.5 ~ 7.0

2.3.2.2 Impact tests are to be carried out at specified test temperatures. Where the test temperature is not room temperature, the temperature of the test specimen is to be strictly controlled. Test specimens are to be kept at the specified test temperature for at least 5 min (for liquid medium) or 30 min (for gas medium), and to be hammered within 5 s after being taken out so that the temperature of the test specimen at the moment of fracture is within the range of ±2℃ of the specified test temperature.

Section 4 BEND TESTS

2.4.1 General requirements

2.4.1.1 The bend test is normally used for the examination of the bend deformation property and metallurgical defects of metallic materials.

2.4.1.2 The bend test is to bend slowly a test specimen on a press machine at room temperature with an angle α using a former having a diameter D as required by the relevant Sections of this Chapter. After bending, the test specimens are to be examined by naked eye or by the aid of a five-fold magnifying glass

for surface defects on the outside of the bend portion, such as cracks or laminations.

2.4.2 Test specimens

2.4.2.1 Bend test specimens are to be of the dimensions given in Table 2.4.2.1 in accordance with the type of materials.

2.4.2.2 The original surfaces of the bend test specimens are to be retained as far as possible. Where the capacity of the test machine is restricted, the thickness of plate specimens may be reduced to 25 mm by machining on the compression side while the side in tension is to be the original surface, and round bar specimens may be machined to a diameter of 35 mm.

Dimensions of Bend Test Specimens **Table 2.4.2.1**

Item	Dimensions of test specimen (mm)				Applicable materials
	Thickness a	width b	length L	Edge rounded	
1	$a = t$ ①	b = 30 mm ②	$11a \sim 9a + D$	Edges on tension side to be rounded to a radius of 1 to 2 mm	Plates and structural sections
2	a = 20 mm	b = 25 mm	$11a \sim 9a + D$		Castings, forgings and semi-finished products
3	$a = d$ ③		$11a \sim 9a + D$		Bars or wires

Notes: ① t means thickness and may be reduced according to paragraph 2.4.2.2.
② When t is less than 6 mm, b is to be taken as 5 times the thickness.
③ d means diameter of round materials, and D means the diameter of the mandrel.

Section 5 Z-DIRECTION TENSILE TESTS

2.5.1 General requirements

2.5.1.1 The Z-direction tensile test is used for the evaluation and examination of the property of lamellar tearing and metallurgical defects by measuring the reduction of area through a tensile test in through-thickness direction of the plate.

2.5.2 Preparation of specimens

2.5.2.1 The position and number of test specimens of Z-direction steel plates in the through-thickness direction are to be as follows:

(1) A test sample of 200 mm × 300 mm is to be taken from one end of the plate near the middle of its width B, from which six test specimens are to be prepared, of which three are for the specified testing and the others for the possible re-testing, as shown in Figure 2.5.2.1(1).

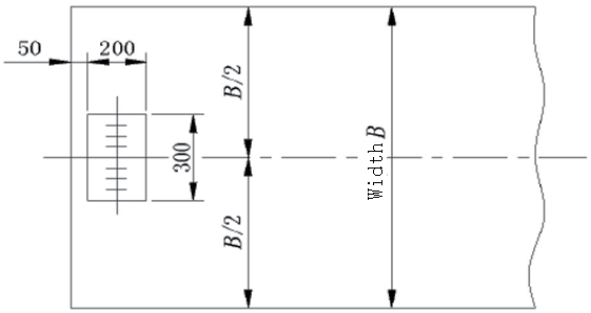


Figure 2.5.2.1(1)

(2) For plates having a weight exceeding 20t, another six specimens are to be prepared from the opposite end for the same testing.

2.5.2.2 Tensile test specimens in through-thickness direction are to be prepared as follows:

(1) Where the plate thickness t is less than 40 mm, tabs of adequate thickness and a tensile strength not less than that of the plate are to be welded on both sides of the plate to provide gripping heads so as to provide sufficient gauge length for the specimen. Welding of the plate and tabs is to be carried out by manual arc welding or contact welding so as to reduce the influence on the test plate, as shown in Figure 2.5.2.2(1). Where manual arc welding is used, suitable small diameter low hydrogen electrodes are to be used, with the welding current being as low as possible and weld runs skipped symmetrically. Between each run, the test

plate is to be left in still air until it has cooled to below 250℃.

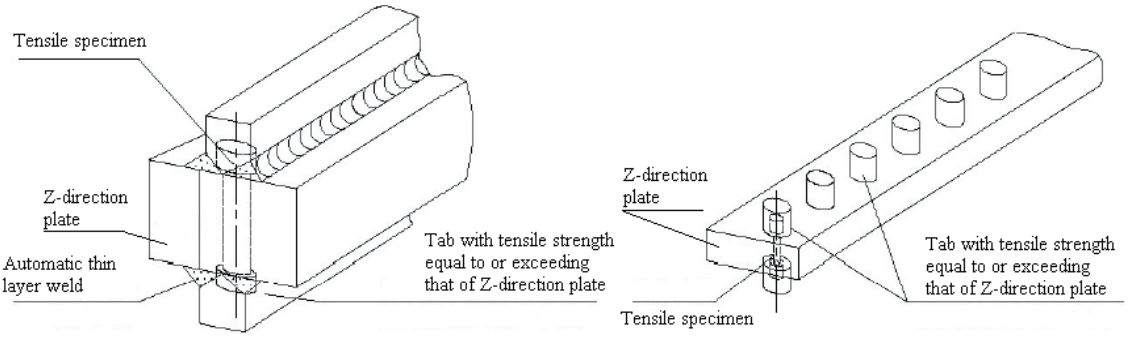


Figure 2.5.2.2(1)

(2) Where the plate thickness t is equal to or more than 40 mm, the specimens may be prepared in the full thickness of the plate without welded-on tabs.
(3) The shape, dimensions and machining of specimens are to comply with the requirements shown in Figure 2.5.2.2(3).

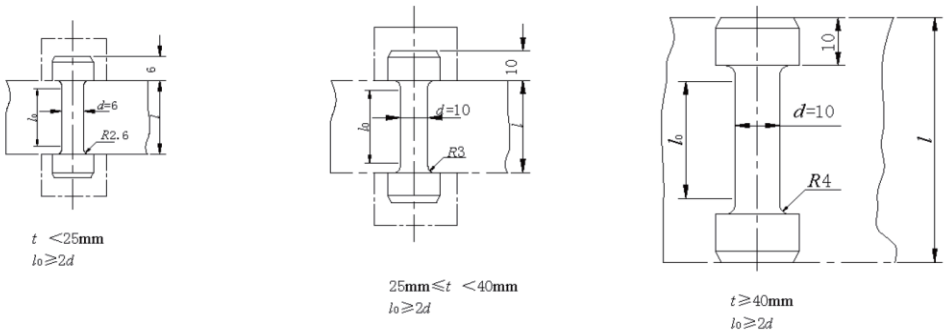


Figure 2.5.2.2(3)

2.5.3 Testing

2.5.3.1 The tensile test in through-thickness direction is to be carried out as required by the conventional method. The reduction of area (Z_Z) is defined as the ratio (in percentage) of the ultimate variation in the cross-sectional areas, obtained from the test, with respect to the original cross-sectional area:

$$Z_Z = \frac{S_0 - S}{S_0} \times 100\%$$

where: S_0 — original cross-sectional area of the specimen;
S — cross-sectional area at fracture which is normally elliptical in shape, where D_1 and D_2 are the major and minor axes of the "ellipse" respectively. Area S is to be calculated by the following formula:

$$S = \frac{\pi}{4}\left(\frac{D_1 + D_2}{2}\right)^2$$

Section 6 DUCTILITY TESTS FOR PIPES AND TUBES

2.6.1 General requirements

2.6.1.1 Ductility tests for pipes and tubes are generally used for inspecting the ductility and metallurgical defects of metal pipes and tubes.
2.6.1.2 In addition to ductility tests specified in this Section, where ring expanding tests or ring tensile tests are required, such tests are to be carried out in accordance with ISO 8495 or ISO 8496 respectively.

2.6.2 Flattening tests

2.6.2.1 The test specimens are to be cut with the ends perpendicular to the axis of the pipe or tube. The

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

2.6.2.2 Testing is to be carried out at room temperature and is to consist of flattening the specimen in a direction perpendicular to the longitudinal axis of the pipe. Flattening is to be carried out between two parallel plain rigid platens which extend over both the full length and the full width after flattening of the test specimen.
Flattening is to be continued until the distance H between the platens, measured under load, is not greater than the value given by the formula:

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

where: t — thickness of the pipe, mm;
D — external diameter of the pipe, mm;
C — constant dependent on the steel type and detailed in the specific requirements (see Chapter 4 of this PART).
After flattening, the specimens are to be free from cracks or other flaws. Small cracks at the ends of the test specimens may be disregarded.
2.6.2.3 For welded pipes or tubes, the weld is to be placed at 90° to the direction of flattening.

2.6.3 Drift expanding tests

2.6.3.1 The test specimens are to be cut with the ends neat and perpendicular to the axis of the tube. The end to be tested is to be free of notches and the edges of the end are to be rounded properly.
2.6.3.2 The length of test specimens is to be selected from Table 2.6.3.2 according to the angle of the drift. The test piece may be shorter provided that after testing the remaining cylindrical portion is not less than 0.5 external diameter of the tube.

Length of Test Piece **Table 2.6.3.2**

Angle of drift (°)	30	45	60
Length of test piece (mm)	2D	1.5D	1.5D

Note: D is external diameter of tube.

2.6.3.3 Testing is to be carried out at room temperature by forcing a hardened conical steel mandrel having a suitable angle as specified in Table 2.6.3.2 into the end in alignment with the axis of the tube (as shown in Figure 2.6.3.3), thus expanding the end of the tube to an external diameter as required in relevant Chapters of this PART.

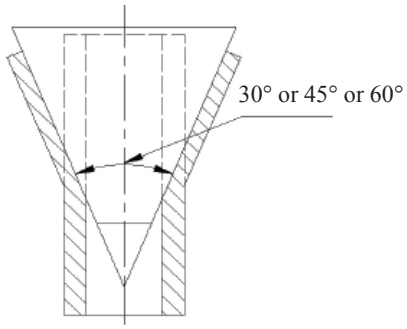


Figure 2.6.3.3 Drift Expanding Test of Tube

2.6.3.4 The mandrel is to be lubricated, but there is to be no rotation of the tube or mandrel during the test. The rate of penetration of the mandrel is not to exceed 50 mm/min.
2.6.3.5 The expanded portion of the tube is to be free from cracks or visible flaws after testing.

2.6.4 Flanging tests

2.6.4.1 The test specimens are to be cut with the ends perpendicular to the axis of the tube. The edges of the end to be tested are to be rounded properly.
2.6.4.2 The length of test specimens is to be equal to approximately 1.5 times the external diameter of the

tube. The test piece may be shorter, provided that the remaining cylindrical portion as calculated is not less than 0.5 external diameter of the tube.

2.6.4.3 Testing is to be carried out at room temperature and is to consist of flanging the end of the tube by means of a hardened conical steel mandrel (as the two ones shown in Figure 2.6.4.3). The percentage increase in the external diameter of the end of the specimens is to be as required in relevant Chapters of this PART.

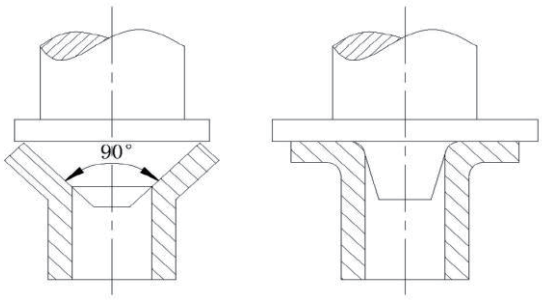


Figure 2.6.4.3 Flanging Tests

2.6.4.4 The mandrel is to be lubricated, but there is to be no rotation of the tube or mandrel during the test. The rate of penetration of the mandrel is not to exceed 50 mm/min.

2.6.4.5 The cylindrical and flanged portion of the tube is to be free from cracks or visible flaws after testing.

2.6.5 Bend tests

2.6.5.1 The test specimens are to be cut as circumferential strips of full wall thickness and with a width of not less than 40 mm. For thick walled pipes, the thickness of the test specimens may be reduced to 20 mm by machining. The edges of the specimens may be rounded to a radius of 1.6 mm.

2.6.5.2 Testing is to be carried out at room temperature. During testing, the diameter of the former is to be selected in accordance with the provisions of Chapter 4 of this PART. The specimen is to be bent to an angle of 180°, in the direction of the original curvature. After bending, the specimens are to be free from cracks or laminations.

Section 7 INTERGRANULAR CORROSION TESTS OF STAINLESS STEEL

2.7.1 General requirements

2.7.1.1 Intergranular corrosion tests of stainless steel are mainly used to evaluate basic corrosion-resisting properties of austenitic stainless steels and austenitic/ferritic duplex stainless steels.

2.7.2 Preparation of test specimens

2.7.2.1 The material for the intergranular corrosion test of stainless steel is to be taken adjacent to that for the tensile test.

2.7.2.2 The total surface area of test specimens of intergranular corrosion tests is to be between 12 cm^2 and 35 cm^2. For rolled plates and tubes with external diameter over 56 mm, bend specimen with thickness not more than 6 mm and width not less than 10 mm is to be used. For steel bars with diameter not more than 12 mm, bend specimens may be taken directly from the round section. Where the thickness or diameter of the product is more than 6 mm or 12 mm respectively, one side of the product may be machined so that the thickness is reduced to 6 mm. The rolled side of the specimen is to be stretched during bending.

For small-diameter tubes with external diameter not greater than 60 mm, test pieces may be cut directly as the specimen for flattening test.

2.7.2.3 For butt weld joint, test piece is to be cut from a test specimen of the same base material, welding material and welding procedures as the weld joint under investigation. Longitudinal bending test piece with thickness not more than 6 mm is to be used. Where the thickness of the test piece is more than 6 mm, the test piece is to be machined down to 6 mm from one side. The retained surface is in contact with corroding media and is to be stretched during bending test. The requirements for the sizes of test pieces of plate joint and tube joint are as follows:

(1) For flat plates with welded butt joint, longitudinal bending test pieces of 50 mm wide and 100 mm long are to be selected.

(2) For welded tubes with outer diameter over 60 mm and with welded butt joint, test pieces are to be selected in a boat shape in parallel with the weld bead. The size of the test pieces is shown in the above (1).
(3) For welded tubes with outer diameter over 60 mm and with longitudinal weld bead, longitudinal bending test pieces in parallel with the weld bead are to be selected, with width of at least 20 mm and length of at least 50 mm.
(4) For welded tubes up to 60 mm outside diameter, test pieces can be subject to a flattening test.

2.7.3 Testing

2.7.3.1 The corroding media solution used for the test is to be prepared as follows:
(1) put 100 g copper sulphate ($CuSO_4 \cdot 5H_2O$) into 700 ml~800 ml distilled water;
(2) add 100 ml sulphuric acid (relative density 1.84 g/ml) slowly into the solution mentioned in (1);
(3) dilute the solution mentioned in (2) up to 1 L with distilled water.

2.7.3.2 Fine copper turnings are to be put into a test vessel to form a bed of copper turnings, and the ratio of the copper turnings to the solution is at least 50 g/L. 2.7.3.3 Cleaned specimens are to be subject to sensitization heat treatment (except for weld joint specimen): heated to a temperature of 700 ±10℃ for 30 min, followed by rapid cooling in water. They are then to be positioned on the bed of copper turnings in the test vessel. Add the corroding media solution to immerse the entire specimen and the solution is to be at least 20 mm higher than the surface of the specimen. Heat the test vessel till the solution boils, so that the specimen is immersed in the boiling solution for 16 h, unless for a longer time agreed between the supplier and the user. Precautions are to be taken to prevent concentration of the solution by evaporation. Where multiple specimens are positioned in the vessel, the ratio between total volume of the solution and total surface area of the specimens is not to be less than 10 ml/cm^2, and there is to be no contact between specimens.
Weld joint specimens that are solution annealed after welding are to be subject to sensitization heat treatment before the test.

2.7.3.4 After immersion, each test specimen is to be bent under the conditions specified in Table 2.7.3.4 at ambient temperature.

Bending Radius and Angle of Test Specimens of Intergranular Corrosion Tests Table 2.7.3.4

Product type	Radius of former	Bending angle
Rolled product	Diameter or thickness of the specimen	90°
Forged product	Twice the thickness of the specimen	90°
Weld joint	Twice the thickness of the specimen①	90°

Note: ① For duplex stainless steel, radius of former may be determined according to the agreement, and its maximum value is not to be more than twice the thickness of the specimen.

Test specimens of small-diameter tubes may be subject to flattening tests as required by Section 6 of this Chapter.
2.7.3.5 After bending or flattening, magnifying glass with not more than 10 times magnification is to be used to observe the stretched surfaces of the test specimens, which are to be free from cracks due to intergranular corrosion (cracking at edges, and the appearance of deformation lines, wrinkles, or “orange peel” on the surface are all disregarded).
2.7.3.6 When the above test results are questionable, a metallographic examination of a longitudinal cross section of the test piece may be carried out.

Section 8 CRACK TIP OPENING DISPLACEMENT (CTOD) TESTS FOR METALLIC MATERIALS

2.8.1 General requirements

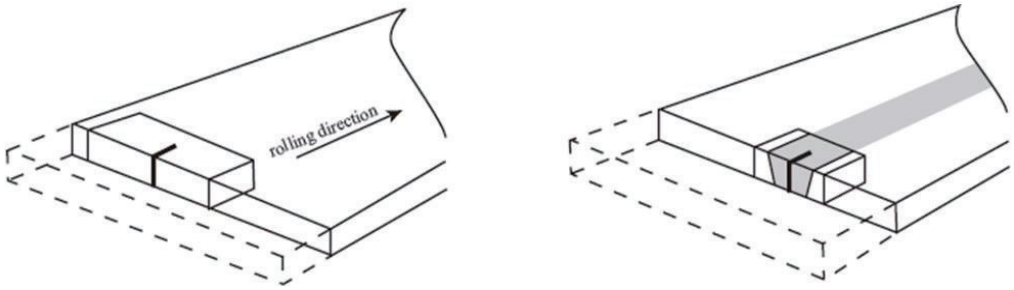
2.8.1.1 This Section applies to crack tip opening displacement (CTOD) tests for metallic materials and welding consumables.
2.8.1.2 This Section applies to CTOD test using specimens in three point bending.
2.8.1.3 CTOD test is to use a testing machine with controllable loading rate and displacement-load

synchronous recording device, and the data of test process are to be recorded automatically.

2.8.1.4 In addition to the provisions in this Section, other test methods may be used to determine CTOD values of metallic materials subject to prior agreement.

2.8.2 Specimen preparation

2.8.2.1 Unless specified in an agreement, the sampling direction for raw metal specimens is usually to be such that the notch is parallel to the rolling direction of the plate and perpendicular to the through-thickness direction of the plate (Figure 2.8.2.1a); the sampling direction for deposited metal specimens is to be such that the notch is parallel to weld direction and perpendicular to the through-thickness direction (Figure 2.8.2.1b).



a Sampling direction of plate　　b Sampling direction of deposited metal

Figure 2.8.2.1 Sampling Direction of Specimens

2.8.2.2 Unless agreed otherwise, tests are to be made on specimens of the full section thickness. Main dimensions of specimens are to comply with the provisions in Figure 2.8.2.2 and Table 2.8.2.2 and other dimensions are to comply with the requirements of recognized standards.

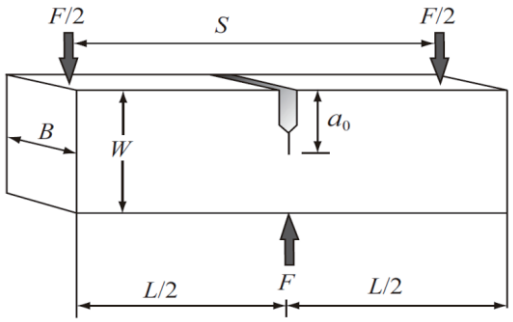


Figure 2.8.2.2

Dimensions of CTOD Specimens **Table 2.8.2.2**

Name	Symbol	Rectangular specimens	Square specimens	Deviation
Specimen thickness	B	B	B	±0.5%B
Specimen width	W	$2B$	B	±0.5%W
Loading span	S	$4W$	$4W$	±0.5%S
Specimen length	L	$\geq 4.5W$	$\geq 4.5W$	
Effective crack length*	a	$0.45W \sim 0.55W$	$0.45W \sim 0.55W$	

Note: For specimens of deposited metal test, the range of effective crack length may be $0.45W \sim 0.70W$.

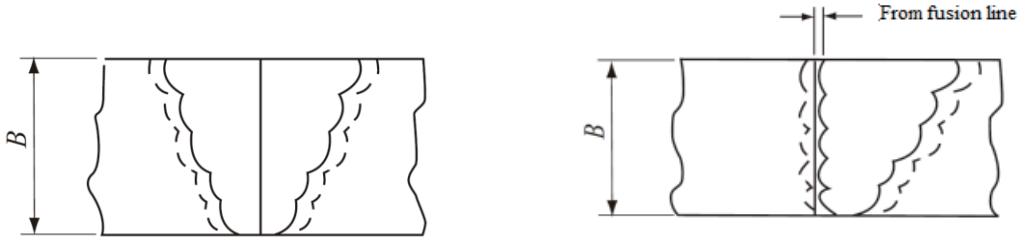
2.8.2.3 Specimens are to be processed by means of machining. The length center of the specimen is to be machined (wire-cutting) with notch, and the radius of notch tip is not to be greater than 0.08 mm. Then fatigue cracks are to be prepared on a fatigue testing machine to specified effective crack length of the specimen. The difference between the two crack length measurements on the surfaces of the specimen, measured to ±0.05 mm, is not to exceed 15% of the average of the two measurements. The minimum fatigue crack extension is not to be below $0.025W$, nor less than 1.3 mm. On preparing fatigue crack, circulating forces applied on the specimen are usually to comply with the following:

$$F_{\max} = kBW\,(R_{p0.2} + R_m) \quad \text{N}$$

where: k — load coefficient, to be not more than 0.016 for steel and between 0.0117 and 0.0145 for weld;
B — specimen width, in mm;
W — specimen height, in mm;
$R_{p0.2}$ — proof strength of test material, in N/mm^2;
R_m — tensile strength of test material, in N/mm^2.

2.8.2.4 When it is necessary to determine the fracture toughness in the heat affected zone of a weld, material of the maximum thickness applicable to the welding method used with K, single V or J type weld preparation is recommended.

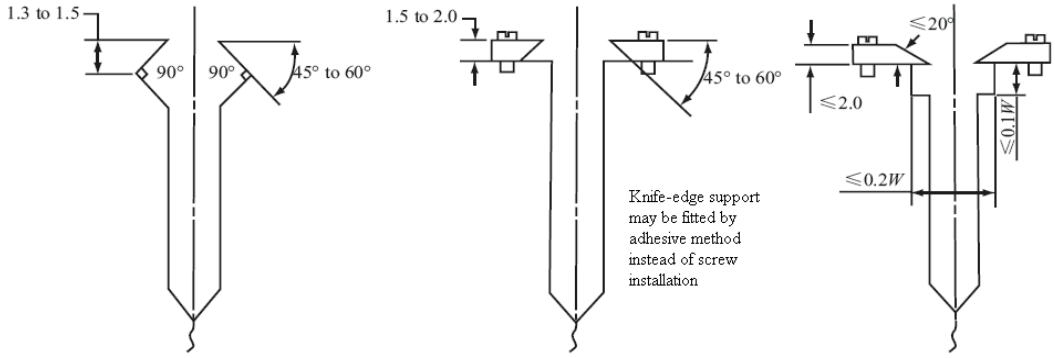
2.8.2.5 The location and orientation of specimen notch may be selected based on test purpose and according to Figure 2.8.2.5.



(a) For evaluating deposited metal (b) For evaluating heat affected zone of parent material

Figure 2.8.2.5 Location and Orientation of Notch of Welded Specimens

2.8.2.6 The specimen notch may be grooved or fitted with a knife-edge support according to Figure 2.8.2.6 to place a displacement gauge (clip-on extensometer). The distance between knife edge and upper surface of the specimen is to be measured and recorded.



(a) Integral knife-edge support (b) Knife-edge support fitted on notch

Figure 2.8.2.6 Measures to Install Displacement Gauge on Specimen

2.8.3 Tests

2.8.3.1 CTOD tests are to be carried out in laboratories acceptable to CCS.

2.8.3.2 During test, specimen temperature is to be controlled to an accuracy of ±2℃ of specified value, and the temperature is to be measured in a region not further than 2 mm from the crack tip.

2.8.3.3 Displacement gauges with good linearity and accuracy are to be used for test, and their full-scale ranges are to satisfy the need of expected crack opening displacement measurement and linear deviation is not to be more than ±1%. The displacement gauge is to be calibrated once every day of testing before the test, and if multiple tests are to be carried out during the day, at intervals of no more than 10 tests. It is to be demonstrated that the calibration is satisfactory for the test conditions.

2.8.3.4 The displacement gauge is to be placed steadily at knife-edge support of the specimen and its design is to allow free rotation of the points of contact between the gauge and knife edges. When test is carried out in temperature medium, the effect of temperature medium on displacement measurement is to be minimized.

2.8.3.5 The test procedure and the evaluation of test results are to be in compliance with recognized standards.

2.8.4 Test requirements

2.8.4.1 After test, the fracture surface of each specimen is to be examined and measured, and the

effectiveness of the specimen is to be evaluated according to the requirements of 2.8.4.2 and 2.8.4.3 below. For each test, there are to be at least 3 effective specimens.

2.8.4.2 The specimen is to satisfy the following requirements, otherwise the specimen is to be regarded as invalid:

(1) the fatigue crack front is in a single plane;

(2) any part of the fatigue crack surface lies in a plane whose angle with the plane of the notch does not exceed 10°;

(3) the length of any part of the fatigue crack is more than $0.025W$ or 1.3 mm, whichever is the greater;

(4) as shown in Figure 2.8.4.2(4), the length of fatigue crack front is measured respectively at 9 locations in the through-thickness direction of the specimen and the weighted average length a_0 is calculated according to the following formula, with the difference between the maximum and minimum lengths of original fatigue crack not exceeding $0.1a_0$:

$$a_0 = \frac{1}{8}\left(\frac{a_{01} + a_{09}}{2} + \sum_{i=2}^{8} a_{0i}\right)$$

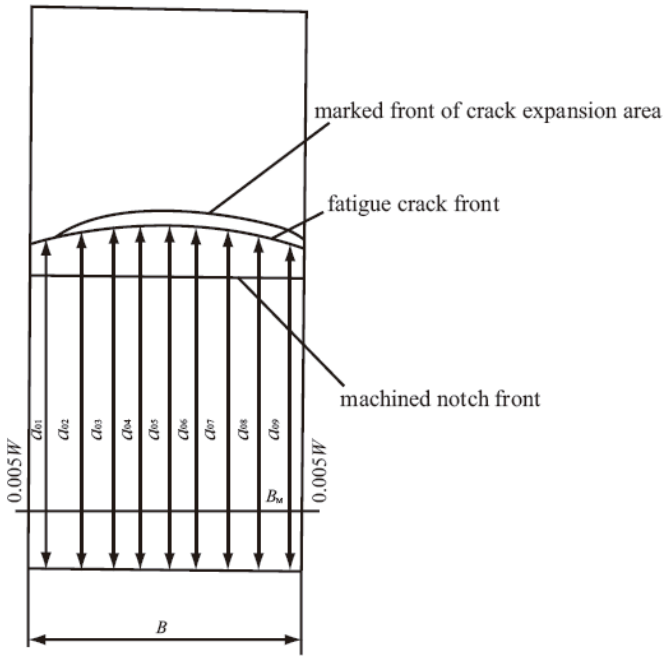


Figure 2.8.4.2(4) Measurement Sketch

2.8.4.3 In addition to 2.8.4.2, tests on deposited metal and heat affected zones (HAZ) are to comply with the following requirements:

(1) for specimens of grain coarsened HAZ, the front of fatigue crack is to be within 0.5 mm of the fusion line and all of the grain coarsened HAZ present is to be sampled. However, if fusion line irregularities prevent this, a sample including as much grain coarsened HAZ as possible may be accepted;

(2) for test specimens of other structures of HAZ, the fatigue crack is to be in the expected region of the HAZ so far as practicable. However, if fusion line irregularities prevent this, a sample including as much relevant microstructure as possible may be accepted.

2.8.5 Test reports

2.8.5.1 CTOD test report is to include:

(1) details of the material, its condition and size;

(2) the thickness and width of the test specimen;

(3) the fatigue pre-cracking conditions;

(4) the test temperature and environment;

(5) the test machine control system and rate of change of displacement or load;

(6) crack length measurements;

(7) force/displacement (F–V curve) records, preferably in the form of an autographic record;
(8) the critical crack opening displacement;
(9) a photograph of the fracture;
(10) any observation on the fracture surface.

Section 9 PITTING CORROSION TEST FOR DUPLEX STAINLESS STEELS

2.9.1 General requirements

2.9.1.1 The pitting corrosion test for duplex stainless steels is mainly used to evaluate the corrosion resistance performance of austenitic/ferritic stainless steel products and weld joints.

2.9.2 Test specimen

2.9.2.1 An original surface of the specimen is to be kept as far as possible. For flat products, a specimen is recommended to be approximately 25 mm by 50 mm by (1.5 mm to 5.0 mm). Other product forms may be cut for test specimens convenient for testing. For weld joints, weld reinforcement is to be removed.
2.9.2.2 Specimens are generally taken by machining. After the specimens are cut, any material that may have been affected by high temperature or deformation associated with the cutting is to be removed by machining or grinding prior to testing.
2.9.2.3 All surfaces of the specimen are to be polished to a uniform finish. Polishing is to be performed slowly to prevent overheating.
2.9.2.4 The dimensions of the specimen are measured, and the total exposed surface area is calculated.
2.9.2.5 The specimen is to be cleaned, dipped in alcohol or acetone, and air dried.
2.9.2.6 The specimen is to be weighed to the nearest 1 mg or better.

2.9.3 Test procedures

2.9.3.1 The test solution is prepared by dissolving 100 g of reagent-grade ferric chloride, $FeCl_3 \cdot 6H_2O$, in 900 ml of distilled water (approximately 6% $FeCl_3$ by weight). The pH of the test solution is to be adjusted to approximately 1.3 prior to beginning the test by the addition of HCl or NaOH, as required.
2.9.3.2 Fill the test container with the required volume of at least 0.2 ml/mm^2 of the specimen surface area, submerge the specimen, transfer it to the constant temperature bath, and allow it to come to equilibrium at the desired test temperature. Test temperatures for different materials are shown in Table 2.9.3.2.

Test temperature for different duplex stainless steel base material and weld Table 2.9.3.2

Grade	Uniform number	Condition	Test temperature (℃)
022Cr22Ni5Mo3N	S22253	Base metal	25
		Weld metal	22
022Cr23Ni5Mo3N	S22053	Base metal	25
		Weld metal	22
03Cr25Ni6Mo3Cu2N	S25554	Base metal/Weld metal	40
022Cr25Ni7Mo4N	S25073	Base metal/Weld metal	40

2.9.3.3 Place the specimen in the glass cradle and immerse it in the test solution for 24 h once the temperature has been established. Cover the test container with a watchglass during the test period. Maintain the test temperature with an accuracy of ±1℃ throughout the test.
2.9.3.4 At the end of the test, remove the specimen from the solution, rinse with water, remove corrosion products, dry and weigh the specimen to 1 mg or better.

2.9.4 Test results

2.9.4.1 No pitting attack is to be visible on the test face(s).
2.9.4.2 Unless otherwise specified, the corrosion rate (i.e. weight loss per unit area after 24-hour immersion) is not to exceed 10 mdd. The corrosion rate is to be calculated as follows:

$$CR = \frac{W_1 - W_2}{S} \times 10^4$$

where: CR — corrosion rate, in mdd;

W_1 — specimen weight prior to test, in mg;
W_2 — specimen weight after test, in mg;
S — total surface area, in mm^2.

Section 10 METAL DROP-WEIGHT TEST

2.10.1 General requirements

2.10.1.1 This Section applies to the determination or verification of the nil-ductility transition (NDT) temperature of ferritic steels (including martensitic, pearlitic, bainite and all other non-austenitic steels) with thicknesses not less than 12 mm.

2.10.1.2 In order to determine the NDT temperature of ferritic steels, drop-weight tests are to be carried out at a sequence of temperature.

2.10.2 Test specimens

2.10.2.1 Specimens for drop-weight tests may generally be taken near sampling positions for normal tests of mechanical properties. For rolled plates, the sampling direction is to be such that the longitudinal direction of specimens is perpendicular to the rolling direction of plates.

2.10.2.2 Dimensions of specimens are shown in Table 2.10.2.2. During sampling, specimens with maximum thickness are to be taken as far as possible. The preparation of specimens (including dimensional deviation, crack-starter weld deposited and notch preparation) is to comply with the requirements of recognized standards (such as GB/T6803) in addition to the following requirements:

(1) the specimen sides are to be saw-cut or machined (minimum 25 mm to flame-cut surface);

(2) where the thickness of the material is greater than the prescribed specimen thickness, the machining of the plate to prescribed specimen thickness is to be on one side only.

Type and Dimension of Specimen **Table 2.10.2.2**

Specimen type	P1	P2	P3	P4	P5	P6
Length *L* (mm)	360	130	130	130	360	360
Breadth *B* (mm)	90	50	50	50	90	90
Thickness *T* (mm)	25	20	16	12	38	50

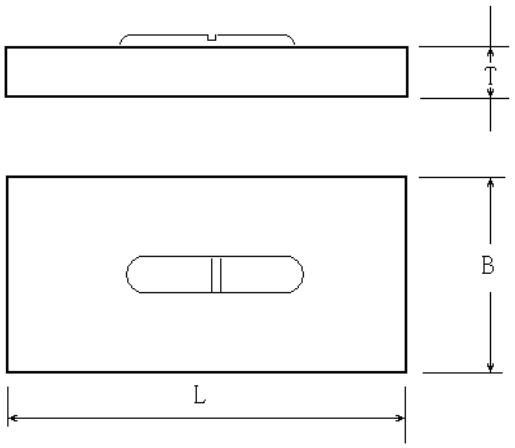


Figure 2.10.2.2 Standard Drop-Weight Specimen

2.10.2.3 The number of specimens taken is to meet the need of tests and retests.

2.10.3 Tests

2.10.3.1 Except for the following provisions, tests are to be carried out according to recognized standards (such as GB/T6803).

2.10.3.2 In order to determine the NDT temperature of metallic materials, tests at a sequence of temperatures are to be carried out. The test temperature is generally to be an integral multiple of 5℃.

2.10.3.3 For tests for product qualification, the drop-weight test is carried out only at specified temperatures.

2.10.3.4 A set of two specimens is to be prepared for test at each test temperature.

2.10.4 Test requirements

2.10.4.1 Tests at a sequence of temperatures for measuring the NDT temperature of material are to be carried out until at least one of a set of specimens breaks (i.e. crack extending to one or both edges of the tension surface of a specimen), and the lowest test temperature in a sequence of temperatures where none of a set of two specimens breaks is to be taken as the NDT temperature of the material tested.

2.10.4.2 For tests for product qualification, if one of a set of two specimens breaks, retest may be carried out; if both specimens break, retest is not permitted. A set of two specimens is to be reprepared for retest in the vicinity of original sampling position at original temperatures and no break is permitted for any one of the two specimens for retest.

CHAPTER 3 STEEL PLATES, FLAT BARS AND SECTIONS

Section 1 GENERAL PROVISIONS

3.1.1 Application

3.1.1.1 This Chapter applies to steel plates, flats, sections and bars intended for use in the construction of hull, machinery, boilers, pressure vessels and offshore installations, etc.

3.1.1.2 Where steels other than those specified in this Chapter are used, the chemical composition, deoxidation method, condition of supply and mechanical properties of the steels are to be submitted to CCS for approval.

3.1.1.3 Normal and higher strength corrosion resistant hull structural steels used as the alternative means of coating for crude oil tanks are to comply with, in addition to the relevant requirements of this Chapter, the relevant requirements of CCS Guidelines for Survey of Corrosion Resistant Steel of Cargo Oil Tanks in Crude Oil Tankers.

3.1.2 Manufacture

3.1.2.1 The steels are to be manufactured at works which have been approved by CCS in accordance with the approved procedures, types and grades of steels. During works approval, testing for cold or hot workability and welding property may be required at the discretion of CCS.

3.1.2.2 Steel is to be manufactured by open hearth, electric, basic oxygen processes or by other processes specially approved by CCS. The deoxidation method used for each grade is to comply with the relevant requirements of subsequent Sections of this Chapter.

3.1.2.3 The steels are to be cast in metal ingot moulds or made by a continuous casting process approved by CCS, and to comply with the following:

(1) The size of the ingot, or of the continuous cast billet or slab, is to be of sufficient proportion to the dimensions of the final product, in order that the amount of mechanical work will be adequate to ensure a satisfactory property in the finished product.

(2) Where mould cast is employed, sufficient discard is to be taken from the top and bottom ends of each ingot to ensure that the finished product is free from internal defects. When necessary, the Surveyor may require the steel works to carry out periodical sulphur prints or other suitable proving tests to demonstrate that the steel has a sound quality.

(3) Where continuous casting is employed, a specified program of tests is to be carried out under the supervision of the Surveyor.

3.1.2.4 Rolling practice and heat treatment method applied for steel is to comply with the appropriate conditions of supply as specified in relevant sections in this Chapter. The definitions of applicable rolling and heat treatment procedures are given as follows.

(1) As Rolled, AR

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

(2) Normalising, N

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

(3) Controlled Rolling, CR (Normalizing Rolling, NR):

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

(4) Quenching and Tempering, QT

Quenching involves a heat treatment process in which steel is heated to an appropriate temperature above the Ac3, held for a specific period of time, and then cooled with an appropriate coolant for the purpose of

hardening the microstructure. Tempering subsequent to quenching is a process in which the steel is reheated to an appropriate temperature not higher than the Ac1, maintained at that temperature for a specific period of time to restore toughness properties by improving the microstructure and reduce the residual stress caused by the quenching process.

(5) Thermo-Mechanical Rolling, TM (Thermo-Mechanical Controlled Processing, TMCP):

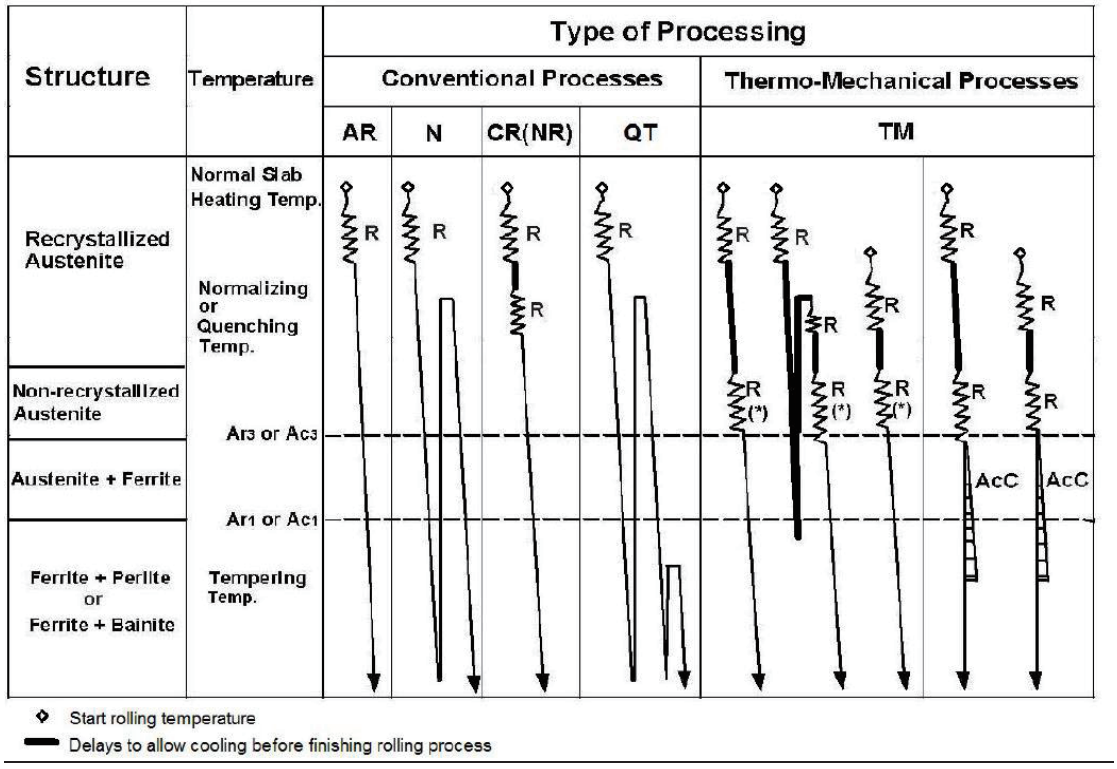
This is a procedure which involves the strict control of both the steel temperature and the rolling reduction. Generally a high proportion of the rolling reduction is carried out close to the Ar3 temperature and may involve the rolling in the dual phase temperature region. Unlike controlled rolled (normalised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

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

(6) Accelerated Cooling, AcC

Accelerated cooling is a process, which aims to improve mechanical properties by controlled cooling with rates higher than air cooling immediately after the final TM-rolling operation. Direct quenching is excluded from accelerated cooling.

The material properties conferred by TM(TMCP) and AcC cannot be reproduced by subsequent normalising or other heat treatment.



Notes: AR—As-rolled; N—Normalizing; CR(NR)—Controlled rolling (normalized rolling); QT—Quenching and tempering; TM—Thermo-mechanical controlled process; R—Reduction; (*)Sometimes rolling in the dual-phase temperature region of austenite and ferrite; AcC—Accelerated cooling.

Figure 3.1.2.4 Schematic diagram of steel rolling processes

3.1.2.5 It is the manufacturer's responsibility to ensure that proper process and effective production controls in operation are adhered to within the approved manufacturing specifications. To this effect, the actual rolling records are to be reviewed by the manufacturer and occasionally by the Surveyor.

3.1.2.6 When deviation from the programmed rolling schedules or normalizing or quenching and tempering procedures occurs, or where control imperfection inducing possible inferior quality of product

occurs, the manufacturer is to:
(1) find the reasons and take measures to prevent it from reoccurrence. Meanwhile, a report is to be submitted to the Surveyor for information.
(2) Where the affected steel is required to be used, the manufacturer is to carry out the test for each affected piece and the results are to comply with the requirements of the Rules.
(3) The frequency of testing subsequent products offered may be increased to gain confidence in the quality at the discretion of CCS.
3.1.2.7 The specified tests on mechanical properties are to be carried out in the presence of the Surveyor or his authorized deputy.

3.1.3 Dimensional tolerance

3.1.3.1 The responsibility for verification and maintenance of the production within the required tolerances rests with the manufacturer. The Surveyor may require to witness some measurements.
The length, width and flatness of steel plates are to meet recognized national or international standards.
3.1.3.2 The responsibility for proper transport and storage of the delivered products without significant corrosion or other damages rests with the parties concerned. The products are to be maintained with an acceptable level of surface conditions before they are used in fabrication.
3.1.3.3 The nominal thickness is to be mutually agreed in the contract. The tolerances on thickness of a given product are defined as follows:
(1) minus tolerance is the lower limit of the acceptable range below the nominal thickness;
(2) plus tolerance is the upper limit of the acceptable range above the nominal thickness.
3.1.3.4 Unless otherwise agreed mutually in the contract, the thickness of steel plates, wide flats equal to or over 600 mm in width and sections mentioned in this Chapter is to comply with the following requirements:
(1) The tolerances on nominal thickness for sections below 5 mm may be accepted in accordance with a recognized standard.
(2) For steel plates and wide flats intended for hull structures as detailed in Sections 2, 3 and 4 of this Chapter, except those intended for pressure vessels for the transportation of chemicals or liquefied gases in bulk as well as independent tank structures, thickness measurements are to be carried out for the mother plates produced (i.e. steel plates rolled directly from one slab or steel ingot and not cut) according to the provisions of 3.1.3.5, and the arithmetic mean of the measurements is not to be less than the nominal thickness, and the minus tolerance of individual measuring points is not to exceed 0.3 mm. If steel plates are rolled by such technological means that the thickness of any measuring point is not less than the nominal thickness, the arithmetic mean need not be calculated, but the steel mill is to demonstrate to the satisfaction of CCS that the number of measurements and measurement distribution is appropriate to establish that the mother plates produced are at or above the specified nominal thickness.
(3) For steels for boilers and pressure vessels as detailed in Section 5 of this Chapter as well as steels for independent tanks for the transportation of chemicals or liquefied gases in bulk, the minus tolerance on thickness of products is not to exceed 0.3 mm unless mutually agreed.
(4) For steel plates and wide flats intended for machinery as detailed in Section 6 of this Chapter, the under thickness tolerances are to comply with Table 3.1.3.4(4).

Under Thickness Tolerance of Steel Plates and Wide Flats for Machinery Table 3.1.3.4(4)

Nominal thickness t (mm)	Minus tolerance (mm)
$5 \le t < 8$	< 0.4
$8 \le t < 15$	< 0.5
$15 \le t < 25$	< 0.6
$25 \le t < 40$	< 0.8
$t \ge 40$	< 1.0

(5) For steel plates and wide flats detailed in Sections 7, 8 and 9 of this Chapter and where in the order specifications it is not specified that the nominal thickness is to be taken as the minimum thickness, the under thickness tolerance is not to exceed 0.3 mm for plate thickness not exceeding 10 mm, and 0.5 mm for plate thickness exceeding 10 mm.
(6) For steels as detailed in Sections 10 and 11 of this Chapter, the thickness tolerance is to comply with the requirements for parent steel.
(7) The plus tolerances on nominal thickness of all steels may be accepted in accordance with a recognized

national or international standard.

3.1.3.5 Except that the thickness of steel plates for hull structure is to comply with the following requirements, the measurement for other steel plates may be in accordance with national or international standards:

(1) Automated method or manual method is applied to the thickness measurements.

(2) Measuring locations of steel plates are to comply with the following requirements:

a. at least two lines among Line 1, Line 2 or Line 3 as shown in Figure 3.1.3.5(2), are to be selected for the thickness measurements and at least three points on each selected line as shown in Figure 3.1.3.5(2) are to be selected for thickness measurement. If more than three points are taken on each line, the number of points is to be equal on each line;

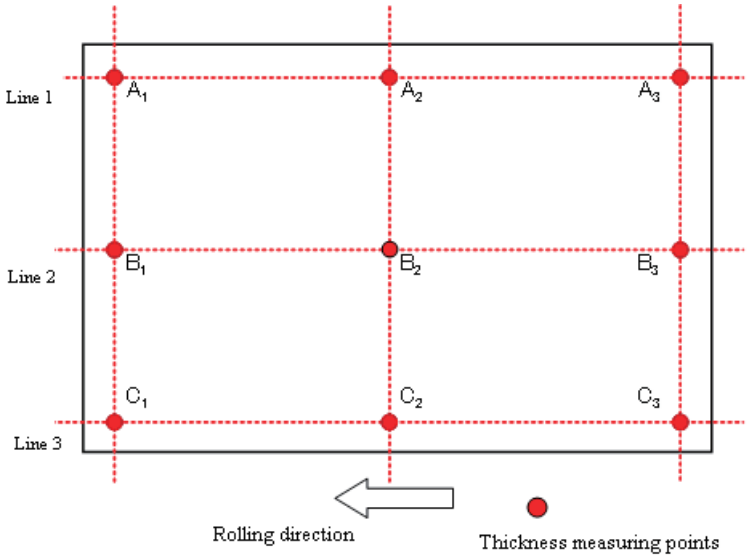


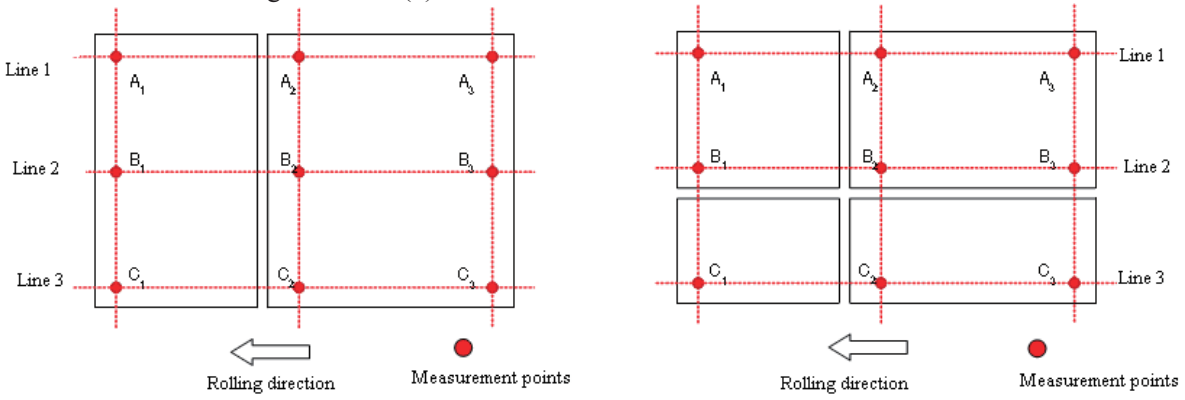
Figure 3.1.3.5(2) Locations of Thickness Measuring Points for the Original Steel Plates

b. 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;

c. 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.

The procedure and the records of measurements are to be maintained by the manufacturer, available to the Surveyor and copies provided on request.

(3) The measurement locations apply to a product rolled directly from one slab or steel ingot even if the product is to be later cut by the manufacturer. Examples of the original measurements relative to later cut products are shown in Figure 3.1.3.5(3).



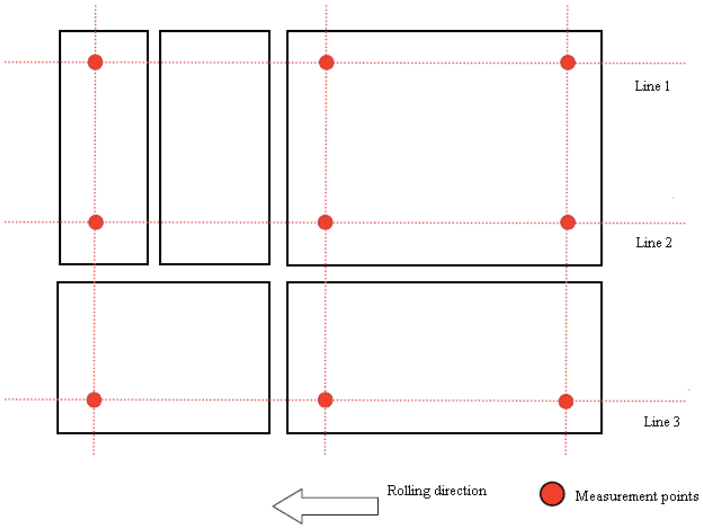


Figure 3.1.3.5(3) Locations of Thickness Measuring Points for the Cut Steel Products

3.1.4 Preparation of specimens

3.1.4.1 Depending on the type of product, steel may be presented for individual item testing or for batch testing as laid down in relevant Sections of this Chapter.

Where the latter is permitted, all materials in a batch presented for acceptance tests are to be of the same product form (e.g. plates, flat bars, sections, etc.) from the same cast by the same rolling procedure, and in the same condition of supply.

3.1.4.2 The size of test material is to be dependent on the dimensions, number and direction of cutting of the test specimens. Test material is to be taken from the following positions (for smaller steels, the cutting positions are to be as close as possible to those specified) after heat treatment:

(1) for plates and flats equal to or greater than 600 mm wide, at approximately 1/4 of the width from an edge, as shown in Figure 3.1.4.2(1);

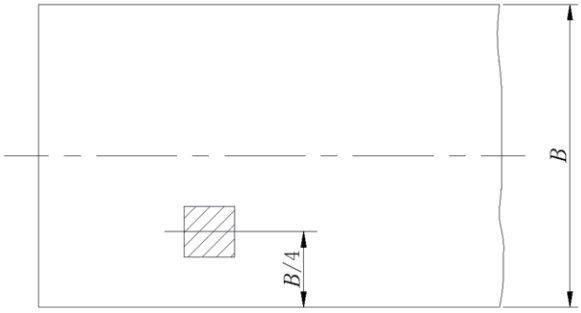
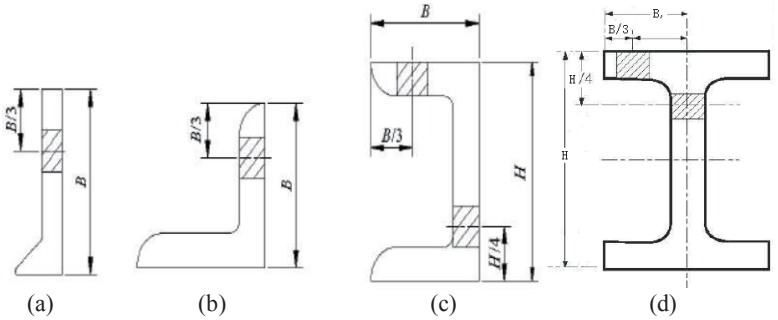


Figure 3.1.4.2(1)

(2) for flats less than 600 mm in width, bulb flats, angles and other sections, at approximately 1/3 of the width from one edge, as shown in Figure 3.1.4.2(2). For channels and beams, at approximately 1/4 of the width from the web edge, as shown in Figure 3.1.4.2(2)(c);



(a) (b) (c) (d)

Figure 3.1.4.2(2)

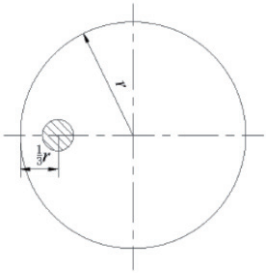


Figure 3.1.4.2(3)

(3) for bars or similar products as detailed in Sections 2, 3, 4 and 6 of this Chapter, at approximately 1/3 of the radius from the outer surface or 1/6 of the diagonal from the outer surface, as shown in Figure 3.1.4.2(3);
(4) for bars or similar products as detailed in Sections 5, 7 and 8 of this Chapter, at approximately 12.5 mm below the surface. For smaller bars, the test specimens may be machined coaxially.
3.1.4.3 For steel plates or flats, full-thickness tensile specimens are generally to be prepared in such a manner as to maintain the rolling scale at least at one side; When the capacity of the test machine is exceeded by the use of a full thickness specimen or the product thickness exceeds 40 mm, sub-sized flat tensile specimens representing either the full thickness or half of the product thickness retaining one rolled surface are to be used. Alternatively, round cross-sectional specimens the axis of which is located as near as possible to 1/4 of the plate thickness may be used.
3.1.4.4 For the steels accepted in a batch, the impact specimen is to be taken from that with the maximum thickness in the batch.
3.1.4.5 When the specimens are cut from the test material, attention is to be paid to the relationship between the axes of specimens and the final direction of rolling:
(1) For tensile specimens: steel plates and flats equal to or more than 600 mm in width: axes of specimens perpendicular to the final direction of rolling;
other products: axes of specimens parallel to the final direction of rolling.
(2) For impact specimens: longitudinal test: axes of specimens parallel to the final direction of rolling;
transverse test: axes of specimens perpendicular to the final direction of rolling.

3.1.5 Surface inspection and non-destructive testing

3.1.5.1 Visual inspection and verification of dimensions on all steels for meeting relevant quality requirements are the responsibility of the steel maker, who is to take the necessary manufacturing precautions and is to inspect the products prior to delivery. At that stage, however, rolling or heat treatment scale may conceal surface discontinuities and defects. If the material is found to be defective during the subsequent descaling or working operations, CCS may require materials to be repaired or rejected (refused/removed).
3.1.5.2 The surface quality inspection method is to be in accordance with recognized national or international standards agreed between purchaser and manufacturer, accepted by CCS. The finished material is to have a surface quality in accordance with a recognized standard such as EN 10163, or an equivalent standard accepted by the CCS, unless otherwise specified in this Chapter.
3.1.5.3 For steel plates and wide flats, imperfections of a harmless nature, for example pitting, rolled-in scale, indentations, roll marks, scratches and grooves, regarded as being inherent of the manufacturing process, are permissible irrespective of their number, provided that all of the following conditions are met:
(1) The maximum permissible limits of Class A of EN 10163-2 or limits specified in a recognized equivalent standard accepted by CCS, are not exceeded;
(2) The remaining plate or wide flat thickness remains within the average allowable minus thickness tolerance specified in 3.1.3.4 of this Section;
(3) Total affected area with imperfection not exceeding the specified limits in (1) are not to exceed 15% of the total surface in question.
The surface quality and conditions of supply for sections and bars may be accepted according to a recognized standard.
3.1.5.4 Affected areas with imperfections with a depth exceeding the limits specified in 3.1.5.3(1) are to be repaired irrespective of their number.
Cracks, injurious surface flaws, shells (over lapping material with non-metallic inclusion), sand patches, laminations and sharp edged seams (elongated defects) visually evident on surface and/or edge of plate are considered defects, which would impair the end use of the product and which require rejection or repair, irrespective of their size and number.
3.1.5.5 Unless otherwise specified in relevant Sections of this Chapter, the non-destructive testing of materials is not required for acceptance purposes. However, steelmakers are expected to employ suitable methods for the general maintenance of quality standards. The acceptance by CCS of material does not absolve the steelmaker of the responsibility of ensuring the internal quality of the material. If plates and wide flats are ordered with ultrasonic inspection, this is to be made in accordance with a recognized standard.

3.1.6 Rectification of defects

3.1.6.1 For plates or wide flats intended for structural purposes as detailed in Sections 2, 3, 4 and 6 of this Chapter, surface defects may be removed by grinding provided all the conditions below are adhered to:
(1) Each single ground area does not exceed 0.25 m^2. (Ground areas lying in a distance less than their average breadth to each other are to be regarded as one single area.) All ground areas do not exceed 2% of the total surface in question;
(2) The nominal product thickness will not be reduced by more than 7% or 3 mm, whichever is the less;
(3) Ground areas lying opposite each other on both surfaces are not to decrease the product thickness by values exceeding the limits as stated under (2);
(4) Defects or unacceptable imperfections are to be completely removed by grinding and the remaining plate or wide flat thickness is to remain within the average allowable minus thickness tolerance specified in 3.1.3.4 of this Section;
(5) The ground areas are to be a smooth transition to the surrounding surface of the product;
(6) Complete elimination of the defect is to be verified by magnetic particle or by liquid penetrant testing.
3.1.6.2 Surface defects which cannot be dealt with as in 3.1.6.1 above may be repaired by chipping or grinding followed by welding, subject to agreement of CCS, provided that:
(1) any one single welded area is not to exceed 0.125 m^2 and the total welded area is not to exceed 2% of the total area of the surface in question;
(2) two repair welded areas are considered as one defect where the distance between them is less than their average width;
(3) after removal of the defect and before welding, the thickness of the material is not to be less than 80% of the nominal thickness. For occasional defects with depths exceeding the limit, special consideration at the Surveyor's discretion will be necessary;
(4) the repair is to be carried out by qualified welders using an approved method and procedure for the appropriate steel grade. The electrodes are to be of low hydrogen type and be dried in accordance with the manufacturer's requirements and protected against rehumidification before and during welding;
(5) after welding, the repaired area is to be ground smooth and subjected to magnetic particle or liquid penetrant testing for proving good welding quality. If weld repair depth exceeds 3 mm, UT may be requested by CCS. If required, UT is to be carried out in accordance with an approved procedure;
(6) if required by the Surveyor, the item is normalized or otherwise suitably heat-treated after welding and grinding.
3.1.6.3 For materials intended for the applications as detailed in Sections 5, 7 and 8 of this Chapter, surface defects may be rectified in accordance with 3.1.6.1 and 3.1.6.2 of this Section, but the reduction in thickness will be subjected to special consideration. And after welding, suitable heat treatment and non-destructive testing of the repaired area is required.

3.1.7 Identification and certification of materials

3.1.7.1 Every finished item (small items may be fastened in bundles) is to be clearly marked, at least at one position, by the manufacturer with the CCS stamp and the following particulars:
(1) the manufacturer's name or trade mark;
(2) the grade of steel;
(3) cast number and identification number or initials which will enable the full history of the item to be traced;
(4) delivery condition of steels for structures (e.g. N, NR, TM, TM+AcC, TM+DQ or Q&T);
(5) if required by the purchaser, his order number or other identification mark.
The above stamps and marks are to be encircled with paint for easy recognition.
3.1.7.2 In the event of any material bearing CCS stamp failing to comply with the test requirements in subsequent mechanical tests, the CCS stamp is to be unmistakably defaced.
3.1.7.3 The steelmaker is to provide certificates for all accepted materials in duplicate to the Surveyor. In addition to the name of the steelmaker, the certificate of conformity for steels is to include the following particulars:
(1) purchaser's name and order number, and if known, the ship's name or machinery number for which the material is intended;
(2) cast/piece number and chemical composition of ladle samples;
(3) technical specification/grade and size;
(4) number and weight of the cargo;
(5) carbon equivalent (Ceq, C_{ET} or P_{cm} value) (where applicable);
(6) mechanical test results, including traceable test identification;

(7) condition of supply when other than as rolled (for high strength steels supplied in a heat treated condition in Section 4, the heat treatment temperature is to be attached);
(8) surface quality and inspection results;
(9) UT result, where applicable.

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

3.1.7.5 When steel ingots or billets are not produced at works where they are rolled, a certificate of conformity is to be supplied by the steelmaker stating the process of manufacture, the cast number and the chemical composition of ladle samples. The works where the steel was produced is to be approved by CCS.

Section 2 NORMAL STRENGTH HULL STRUCTURAL STEELS

3.2.1 Application

3.2.1.1 Normal strength hull structural steel is subdivided into four grades as A, B, D and E. The requirements of this Section apply to steel plates and wide flats not more than 150 mm in thickness and sections and bars not more than 50 mm in thickness.

3.2.2 Deoxidation and chemical composition

3.2.2.1 The method of deoxidation and the chemical composition of ladle samples for normal strength hull structural steel are to comply with the requirements of Table 3.2.2.1.

Deoxidation and Chemical Composition **Table 3.2.2.1**

Grade		A	B	D	E
Deoxidation thickness t (mm)		For $t \le 50$, any method except rimmed steel①; for $t > 50$, killed	For $t \le 50$, any method except rimmed steel; for $t > 50$, killed	For $t \le 25$, killed; for $t > 25$, killed and fine grain treated	Killed and fine grain treated
Chemical composition (%)⑦⑧⑨	C②	≤ 0.21③	≤ 0.21	≤ 0.21	≤ 0.18
	Mn②	≥ 2.5C	≥ 0.80④	≥ 0.60	≥ 0.70
	Si	≤ 0.50	≤ 0.35	≤ 0.35	≤ 0.35
	S	≤ 0.035	≤ 0.035	≤ 0.035	≤ 0.035
	P	≤ 0.035	≤ 0.035	≤ 0.035	≤ 0.035
	Al (acid soluble)	—	—	≥ 0.015⑤⑥	≥ 0.015⑥

Notes: ① Where agreed by CCS and the purchaser for grade A, rimmed steel may be accepted for sections up to 12.5 mm in thickness, provided that this is stated in the certificate.
② For all grades: C (%) + 1/6 Mn (%) ≤ 0.40%.
③ For sections, the maximum carbon content may be 0.23%.
④ Where Grade B steel is impact tested, the minimum manganese content may be reduced to 0.6%.
⑤ For Grade D steel over 25 mm in thickness.
⑥ For Grade D steel over 25 mm in thickness and Grade E steel, 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 0.02%. Other suitable grain refining elements may be used with prior approval of CCS.
⑦ Where the steel is supplied in TMCP condition, the chemical composition may vary from the requirements in the Table with special approval of CCS.
⑧ The residual content of copper in the steel is not to exceed 0.35% and that of chromium and nickel is not to exceed 0.30% respectively.
⑨ Where any other element has been added as part of the steelmaking practice, the content is to be stated in the certificate.

3.2.3 Heat treatment

3.2.3.1 All materials are to be supplied in a condition complying with the requirements of Table 3.2.3.1.

Condition of Supply for Normal Strength Hull Structural Steel **Table 3.2.3.1**

Grade	Deoxidation	Products	Condition of supply①②				
			Thickness t (mm)				
			$t \le 12.5$	$12.5 < t \le 25$	$25 < t \le 35$	$35 < t \le 50$	$50 < t \le 150$
A	Rimmed steel	Sections	A(-)	Not applicable			
	For $t \le 50$ mm, any method except rimmed steel; for $t > 50$, killed	Plates	A(-)				N(-), TM(-), CR(50), AR*(50)
		Sections	A(-)				Not applicable
B	For $t \le 50$ mm, any method except rimmed steel; for $t > 50$, killed	Plates	A(-)		A(50)		N(50), TM(50), CR(25), AR*(25)
		Sections	A(-)		A(50)		Not applicable
D	Killed	Plates, Sections	A(50)		Not applicable		
	Killed and fine grain treated	Plates	A(50)			N(50), CR(50), TM(50)	N(50), TM(50), CR(25)
		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)				
		Sections	N(25), TM(25), AR*(15), CR*(15)				Not applicable

Notes: ① Condition of supply: A: any; N: normalized; CR: controlled; TM (TMCP): thermo-mechanical controlled process; AR*: as-rolled condition subject to special approval of CCS; CR*: controlled rolled condition subject to special approval of CCS.

② The number in parentheses denotes the batch weight for impact test (in t), (-) means impact tests are not required. One set of three Charpy V-notch impact test specimens is to be taken from each batch weight.

3.2.4 Mechanical properties

3.2.4.1 The tensile and impact tests for steel plates, flat bars and sections are to comply with the requirements of Chapter 2 of this PART, as well as the following requirements:

(1) The flat proportional specimen given in Item 1 of Table 2.2.2.1 of Chapter 2 of this PART is to be used for tensile test; if the thickness of the material exceeds 40 mm, the round specimen given in Item 2 may be accepted, in which case the axis of the specimen is to be at 1/4 of the thickness.

(2) Where the thickness of the product does not exceed 40 mm, the impact test specimen is to be close to the surface, i.e. its edge is to be within 2 mm from the rolled surface; where the thickness exceeds 40 mm, the axis of the specimen is to be at 1/4 of the thickness. The notch of the impact test specimen is to be cut in a face of the test specimen which was originally perpendicular to the rolled surface.

3.2.4.2 The number of test specimens is to be as follows:

(1) For each batch presented, one tensile test specimen is to be made from the thickest piece unless the weight of finished material is greater than 50 t, in which case one extra test specimen is to be made from a different piece from each 50 t or fraction thereof. Additional tests are to be made for every variation of 10 mm in thickness or diameter of products from the same cast. For sections, the thickness to be considered is the thickness of the product at the point where samples are taken for mechanical tests. A piece is to be regarded as the rolled product from a single ingot (or a single slab or billet).

(2) The number of impact test specimens is to comply with the requirements in Table 3.2.3.1.

3.2.4.3 The mechanical properties of normal strength hull structural steels are to comply with Table 3.2.4.3.

Mechanical Properties of Normal Strength Hull Structural Steel **Table 3.2.4.3**

Grade	Yield strength R_{eH} min. (N/mm^2)	Tensile strength R_m (N/mm^2)	Elongation A_5 min. (%)	Charpy V-notch impact test						
				Test temp. (℃)	Average impact energy min. (J)					
					Thickness t (mm)					
					$t \le 50$		$50 < t \le 70$		$70 < t \le 150$	
					Long.②	Trans.②	Long.	Trans.	Long.	Trans.
A	235	400 – 520①	22	20	–	–	34④	24④	41④	27④
B				0	27③	20③				
D				-20						
E				-40						

Notes: ① For sections in Grade A, the upper limit of the tensile strength range as specified in the Table may be exceeded subject to special approval of CCS.

②Generally for product thickness not exceeding 50 mm, impact tests need only be made in the longitudinal direction, except when required by the purchaser or CCS; however, satisfactory transverse test results for plates and wide flats are to be guaranteed by the manufacturer.

③ Grade B steel up to 25 mm in thickness may be exempted from impact tests subject to agreement of CCS.

④ Impact tests for Grade A steels over 50 mm in thickness are not required when the steels are manufactured by grain refining treatment and supplied in a normalized condition; Grade A steels supplied in TMCP condition may be accepted without impact tests subject to special approval of CCS.

⑤ Transverse impact tests are generally not required for sections.

3.2.4.4 For full-thickness flat test specimens with a width of 25 mm and a gauge length of 200 mm, the minimum elongation is to comply with Table 3.2.4.4.

Minimum Elongation of Full-Thickness Flat Test Specimens Table 3.2.4.4

Thickness t (mm)	$t \leq 5$	$5 < t \leq 10$	$10 < t \leq 15$	$15 < t \leq 20$	$20 < t \leq 25$	$25 < t \leq 30$	$30 < t \leq 40$	$40 < t \leq 50$
Elongation A (%)	14	16	17	18	19	20	21	22

Section 3 HIGHER STRENGTH HULL STRUCTURAL STEELS

3.3.1 Grades

3.3.1.1 Higher strength hull structural steels are to be subdivided into strength levels in accordance with the specified minimum yield strength, and each strength level is further subdivided into four grades as A, D, E and F in accordance with different levels of notch toughness. The requirements of this Section apply to Grades AH32, DH32, EH32, FH32, AH36, DH36, EH36, FH36, AH40, DH40, EH40 and FH40 steel plates and wide flats of thickness not exceeding 150 mm, as well as to sections and bars of the above-mentioned grades and of thickness not exceeding 50 mm.

3.3.1.2 Higher strength hull structural steels for large container ships with thicknesses of 50 mm to 100 mm and the specified minimum yield strength not less than 460 N/mm^2 are to comply with the requirements of CCS Guidelines for Inspection of Thick Higher Strength Steel Plates for Ships.

3.3.2 Deoxidation and chemical composition

3.3.2.1 All grades of higher strength hull structural steels are to be killed and fine-grain treated, and the chemical composition of ladle samples is to comply with the requirements of Table 3.3.2.1.

Chemical Composition of Higher Strength Hull Structural Steels Table 3.3.2.1

Grade		AH32, AH36, AH40, DH32, DH36, DH40, EH32, EH36, EH40	FH32，FH36，FH40
Chemical composition (%)⑤⑥	C	≤ 0.18	≤ 0.16
	Mn	0.90 ~ 1.60①	0.90 ~ 1.60
	Si	≤ 0.50	≤ 0.50
	S	≤ 0.035	≤ 0.025
	P	≤ 0.035	≤ 0.025
	Al(acid soluble)	≥ 0.015②③	≥ 0.015②③
	Nb④	0.02 ~ 0.05③	0.02 ~ 0.05③
	V④	0.05 ~ 0.10③	0.05 ~ 0.10③
	Ti④	≤ 0.02	≤ 0.02
	Cu	≤ 0.35	≤ 0.35
	Cr	≤ 0.20	≤ 0.20
	Ni	≤ 0.40	≤ 0.80
	Mo	≤ 0.08	≤ 0.08
	N	–	≤ 0.009 (≤ 0.012 if Al is present)

Notes: ① For steels up to 12.5 mm in thickness, the minimum manganese content may be reduced to 0.70%.

② The total aluminium content may be determined instead of the acid soluble content. In such cases the total aluminium content is to be not less than 0.02%.

③ The steel is to contain suitable grain refining elements (Al, Nb, V, etc.), either singly or in any combination. When used singly, the steel is to contain the specified minimum content of the grain refining element; and when used in combination, the specified minimum content of each element is not applicable. However, the approved technical conditions are to be satisfied.

④ The contents of Nb, V and Ti are, in addition, to comply with Nb% + V% + Ti% ≤ 0.12%.

⑤ Where the steel is supplied in TMCP condition, the chemical composition is to comply with 3.3.2.3 of this Section.
⑥ Where any other element has been added as part of the steelmaking practice, the content is to be stated in the certificate.

3.3.2.2 The carbon equivalent C_{eq} may be required, which is to be calculated from the ladle analysis using the following formula:

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

The maximum value of the carbon equivalent is not to exceed the agreed permissible value.

3.3.2.3 For steels supplied in TMCP condition, the following requirements are also to be complied with:

(1) The carbon equivalent C_{eq} is to be calculated from the chemical composition of ladle samples using the formula given in 3.3.2.2 of this Section, and is to comply with Table 3.3.2.3(1).

(2) If needed, the cold cracking susceptibility P_{cm} may be used instead of the carbon equivalent for evaluating weldability, in which case the following formula is to be used:

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

The P_{cm} value so obtained is to comply with an appropriate recognized standard.

Carbon Equivalent C_{eq} of TMCP Higher Strength Steel up to 150 mm in Thickness

Table 3.3.2.3(1)

Grade	Carbon equivalent① C_{eq} (%) thickness t (mm)		
	$t \leq 50$	$50 < t \leq 100$	$100 < t \leq 150$
AH32, DH32, EH32, FH32	≤0.36	≤0.38	≤0.40
AH36, DH36, EH36, FH36	≤0.38	≤0.40	≤0.42
AH40, DH40, EH40, FH40	≤0.40	≤0.42	≤0.45

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

3.3.3 Heat treatment

3.3.3.1 Steels are to be supplied in conditions complying with Table 3.3.3.1.

Condition of Supply for Higher Strength Hull Structural Steel **Table 3.3.3.1**

Grade	Grain refining element	Product	Condition of supply (batch weight for impact test)①② thickness t (mm)					
			$t \leq 12.5$	$12.5 < t \leq 20$	$20 < t \leq 25$	$25 < t \leq 35$	$35 < t \leq 50$	$50 < t \leq 150$
AH32 AH36	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 or Al and Ti	Plates	A(50)		AR*(25)		Not applicable	
					N(50), CR(50), TM(50)			N(50), CR(25), TM(50)
		Plates	A(50)	N(50), CR(50), TM(50), AR*(25)				Not applicable
AH40	Any	Plates	A(50)	N(50), CR(50), TM(50)				N(50), TM(50), QT (each length heat treated)
		Sections	A(50)	N(50), CR(50), TM(50)				Not applicable
DH32 DH36	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 or Al and Ti	Plates	A(50)		AR*(25)		Not applicable	
					N(50), CR(50), TM(50)			N(50), CR(25), TM(50)
		Sections	A(50)		N(50), CR(50), TM(50), AR*(25)			Not applicable
DH40	Any	Plates	N(50), CR(50), TM(50)					N(50), TM(50), QT (each length heat treated)
		Sections	N(50), CR(50), TM(50)					Not applicable
EH32 EH36	Any	Plates	N (each piece), TM (each piece)					
		Sections	N(25), TM(25), AR*(15), CR*(15)					Not applicable
EH40	Any	Plates	N (each piece), TM (each piece), QT (each length heat treated)					
		Sections	N(25), TM(25), QT(25)					Not applicable
FH32 FH36	Any	Plates	N (each piece), TM (each piece), QT (each length heat treated)					
		Sections	N(25), TM(25), QT(25), CR*(15)					Not applicable
FH40	Any	Plates	N (each piece), TM (each piece), QT (each length heat treated)					
		Sections	N (25), TM (25), QT (25)					Not applicable

Notes: ① Condition of supply: A: any; N: normalized; CR: controlled rolled; TM (TMCP): thermomechanically

controlled-rolled; QT: quenched and tempered; AR*: as-rolled condition subject to special approval of CCS; CR*: controlled rolled condition subject to special approval of CCS.

② The number in parentheses denotes the batch weight for impact test (in *t*). One set of three Charpy V-notch test specimens is to be taken from each batch weight or fraction thereof.

3.3.4 Mechanical properties

3.3.4.1 The tensile and impact tests for higher strength hull structural steel plates, flat bars and sections are to comply with the requirements of Chapter 2 of this PART as well as the following requirements:

(1) The flat test specimen given in Item 1 of Table 2.2.2.1 of Chapter 2 of this PART is to be used for tensile testing; for products over 40 mm in thickness, round test specimens given in Item 2 may be accepted, in which case the axis of the specimen is to be at 1/4 of the thickness.

(2) In case the thickness of products does not exceed 40 mm, the impact test specimen is to be close to the surface, i.e., its edge is to be within 2 mm from the rolled surface; where the thickness exceeds 40 mm, the axis of the specimen is to be at 1/4 of the thickness. The notch of the impact test specimen is to be cut in a face of the test specimen which was originally perpendicular to the rolled surface.

3.3.4.2 The number of test specimens is to comply with the following:

(1) The number of tensile test specimens is to comply with the requirements of 3.2.4.2(1) of this Chapter.

(2) The number of impact test specimens is to comply with Table 3.3.3.1.

3.3.4.3 The mechanical properties of higher strength hull structural steels are to comply with Table 3.3.4.3.

Mechanical Properties of Higher Strength Hull Structural Steel Table 3.3.4.3

Grade	Yield strength R_{eH} min. (N/mm^2)	Tensile strength R_m (N/mm^2)	Elongation A_5 min. (%)	Charpy V-notch impact test①					
				Test temp. (℃)	Average energy min. (J)				
					Thickness t (mm)				
					$t \le 50$		$50 < t \le 70$		$70 < t \le 150$	
					Long.	Trans.	Long.	Trans.	Long.	Trans.
AH32	315	440 ~ 570	22	0	31②	22②	38	26	46	31
DH32				-20						
EH32				-40						
FH32				-60						
AH36	355	490 ~ 630	21	0	34②	24②	41	27	50	34
DH36				-20						
EH36				-40						
FH36				-60						
AH40	390	510 ~ 660	20	0	39	26	46	31	55	37
DH40				-20						
EH40				-40						
FH40				-60						

Notes: ① Generally, impact tests need only be made in the longitudinal direction, except when required by the purchaser or CCS; however, satisfactory transverse test results for plates and wide flats are to be guaranteed by the manufacturer. Generally, impact tests need only be made in the longitudinal direction for sections.

② For Grades AH32 and AH36 steels, a relaxation in the number of impact tests for acceptance purposes may be permitted by CCS provided that satisfactory results are obtained from occasional check tests.

3.3.4.4 For full-thickness flat test specimens with a width of 25 mm and a gauge length of 200 mm, the minimum elongation is to comply with Table 3.3.4.4.

Minimum Elongation of Full-Thickness Flat Test Specimens Table 3.3.4.4

Thickness t (mm)	Grade	$t \le 5$	$5 < t \le 10$	$10 < t \le 15$	$15 < t \le 20$	$20 < t \le 25$	$25 < t \le 30$	$30 < t \le 40$	$40 < t \le 50$
Elongation A (%)	AH32, DH32, EH32, FH32	14	16	17	18	19	20	21	22
	AH36, DH36, EH36, FH36	13	15	16	17	18	19	20	21
	AH40, DH40, EH40, FH40	12	14	15	16	17	18	19	20

Section 4 HIGH STRENGTH QUENCHED AND TEMPERED STEELS FOR WELDED STRUCTURES

3.4.1 Application

3.4.1.1 These requirements apply to hot-rolled, fine-grain, weldable high strength structural steels intended for use in marine and offshore structural applications. These requirements do not apply to steels intended for hull structures as specified in sections 2 and 3 of this Chapter.

The requirements of this Section may apply to products other than steel plates, such as sections or seamless tubulars, etc.

3.4.1.2 Steels covered by this section are specified in eight yield strength levels of 420, 460, 500, 550, 620, 690, 890 and 960 N/mm^2 based on the minimum required yield strength. For each yield strength level grades A, D, E and F are specified, based on the impact test temperature, except for yield strength level of 890 and 960 N/mm^2 for which grade F is not applicable.

The full list of grades is:

AH420	DH420	EH420	FH420
AH460	DH460	EH460	FH460
AH500	DH500	EH500	FH500
AH550	DH550	EH550	FH550
AH620	DH620	EH620	FH620
AH690	DH690	EH690	FH690
AH890	DH890	EH890	
AH960	DH960	EH960	

3.4.1.3 The requirements of this section apply to steel plates and flats with thickness not greater than 250 mm, the sections with thickness not greater than 50 mm and bars with diameter/thickness not exceeding 250 mm. Steels with a thickness beyond the maximum thickness as given above are to be subject to the special consideration of CCS.

3.4.1.4 Steels covered by this Section may be delivered in Normalized (N)/Normalized rolled (NR); Thermo-mechanical controlled rolled (TM) or Quenched and Tempered (QT) condition. TM delivery conditions may include Thermo-mechanical controlled rolled (TM), Thermo-mechanical controlled rolled with Accelerated cooling (TM+AcC) and Thermo-mechanical controlled rolled with direct quenching followed by tempering (TM+DQ).

3.4.1.5 Steels which have been specially approved by CCS and which differ from the requirements of the Rules are to have the letter “S” after the identification mark (e.g. EH620S).

3.4.2 Method of manufacture

3.4.2.1 The high strength steel specified by this Section is to be manufactured, by the basic oxygen, basic electric arc furnace or by processes specially approved by CCS.

3.4.2.2 Vacuum degassing is to be used for any of the following:

(1) All steels with enhanced through-thickness properties (“Z” quality);

(2) All steels of strength levels 690, 890 and 960 N/mm^2.

3.4.3 Deoxidation and chemical composition

3.4.3.1 The high strength steel as specified in this Section is to be fully killed, and is to be fine grain treated in accordance with an approved manufacturing process. A fine grain structure is to have an equivalent index ≥ 6 determined by micrographic examination in accordance with ISO 643 or alternative test method.

3.4.3.2 The aim analysis for chemical composition is to be carried out in accordance with the approved manufacturing specification. All elements listed in table 3.4.3.2 are to be reported. Steels of different delivery conditions are to meet the corresponding composition requirements.

Chemical Composition of High Strength Steels for Welded Structures Table 3.4.3.2

Delivery condition①	N/NR		TM		QT	
Steel grade / Chemical Composition②	AH420 DH420 AH460 DH460	EH420 EH460	AH420 DH420 AH460 DH460 AH500 DH500 AH550 DH550 AH620 DH620 AH690 DH690 AH890	EH420 FH420 EH460 FH460 EH500 FH500 EH550 FH550 EH620 FH620 EH690 FH690 DH890 EH890	AH420 DH420 AH460 DH460 AH500 DH500 AH550 DH550 AH620 DH620 AH690 DH690 AH890 AH960	EH420 FH420 EH460 FH460 EH500 FH500 EH550 FH550 EH620 FH620 EH690 FH690 DH890 EH890 DH960 EH960
C (%)	≤0.20	≤0.18	≤0.16	≤0.14	≤0.18	
Mn (%)	1.0~1.70		1.0~1.70		≤1.70	
Si (%)	≤0.60		≤0.60		≤0.80	
P③ (%)	≤0.030	≤0.025	≤0.025	≤0.020	≤0.025	≤0.020
S③ (%)	≤0.025	≤0.020	≤0.015	≤0.010	≤0.015	≤0.010
Al(total)④ (%)	≥0.02		≥0.02		≥0.018	
Nb⑤ (%)	≤0.05		≤0.05		≤0.06	
V⑤ (%)	≤0.20		≤0.12		≤0.12	
Ti⑤ (%)	≤0.05		≤0.05		≤0.05	
Ni⑥ (%)	≤0.80		≤2.00⑥		≤2.00⑥	
Cu (%)	≤0.55		≤0.55		≤0.50	
Cr⑤ (%)	≤0.30		≤0.50		≤1.50	
Mo⑤ (%)	≤0.10		≤0.50		≤0.70	
N (%)	≤0.025		≤0.025		≤0.015	
O⑦ (ppm)	Not applicable		Not applicable	≤50	Not applicable	≤30

Notes: ① See 3.4.4.1 for definition of delivery conditions.
② The chemical composition is to be determined by ladle analysis and is to meet the approved manufacturing specification.
③ For sections the P and S content can be 0.005% higher than the value specified in the table.
④ The total aluminium to nitrogen ratio is to be a minimum of 2:1. When other nitrogen binding elements are used, the minimum Al value and Al/N ratio do not apply.
⑤ Total Nb+V+Ti ≤ 0.26% and Mo+Cr ≤ 0.65%, not applicable for QT steels.
⑥ Higher Ni content may be approved at the discretion of CCS.
⑦ The requirement on maximum Oxygen content is only applicable to DH890, EH890, DH960 and EH960.

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

3.4.3.4 The carbon equivalent value C_{eq} is to be calculated from the ladle analysis. Maximum values are specified in Table 3.4.3.4.

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

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

(2) For steel grades H460 and higher, *CET* may be used instead of C_{eq} at the discretion of the manufacturer, and is to be calculated according to the following formula:

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

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

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

Requirements for Carbon Equivalent of High Strength Steel (%) Table 3.4.3.4

Carbon Equivalent (%)	C_{eq}						CET	P_{cm}
Product form	Plates			Sections	Bars	Tubulars	all	all
Thickness / Steel grade and delivery condition	$t\leq50$ (mm)	$50<t\leq100$ (mm)	$100<t\leq250$ (mm)	$t\leq50$ (mm)	T(or d) ≤250 (mm)	$t\leq65$ (mm)	all	all
H420N/NR	0.46	0.48	0.52	0.47	0.53	0.47	-	
H420TM	0.43	0.45	0.47	0.44	-	-		
H420QT	0.45	0.47	0.49	-	-	0.46		
H460N/NR	0.50	0.52	0.54	0.51	0.55	0.51	0.25	
H460TM	0.45	0.47	0.48	0.46	-	-	0.30	0.23
H460QT	0.47	0.48	0.50	-	-	0.48	0.32	0.24
H500TM	0.46	0.48	0.50	-		-	0.32	0.24
H500QT	0.48	0.50	0.54			0.50	0.34	0.25
H550TM	0.48	0.50	0.54			-	0.34	0.25
H550QT	0.56	0.60	0.64			0.56	0.36	0.28
H620TM	0.50	0.52	-			-	0.34	0.26
H620QT	0.56	0.60	0.64			0.58	0.38	0.30
H690TM	0.56	-				-	0.36	0.30
H690QT	0.64	0.66	0.70			0.68	0.40	0.33
H890TM	0.60	-				-	0.38	0.28
H890QT	0.68	0.75	-			-	0.40	-
H960QT	0.75	-				-	0.40	-

Note: "-" = Not applicable.

3.4.4 Delivery condition

3.4.4.1 High strength steel specified in this Section is to be delivered in accordance with the following condition:

(1) Normalized (N)/Normalized rolled (NR);

(2) Thermo-mechanical controlled rolled (TM), including TM+AcC and TM+DQ;

(3) Quenched and Tempered condition (QT) (including direct quenching after hot-rolling followed by tempering).

3.4.5 Rolling reduction ratio

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

3.4.6 Thickness limits

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

3.4.6.2 Maximum thickness of plates, sections, bars and tubulars over which a specific delivery condition is applicable are shown in Table 3.4.6.2.

Maximum thickness limits for Different Forms of Products Table 3.4.6.2

Delivery condition	Maximum thickness/diameter (mm)			
	Plates	Sections	Bars	Tubulars
N	250②	50	250	65
NR	150	①		
TM	150	50	Not applicable	Not applicable
QT	150②	50	Not applicable	50

Notes: ① The maximum thickness limits of sections, bars and tubulars produced by NR process route are generally less than those manufactured by N route, and is to be at the discretion of CCS.

② Approval for N steels with thickness larger than 250 mm and QT steels with thickness larger than 150 mm is subject to the special consideration of CCS.

3.4.7 Mechanical properties

3.4.7.1 Test frequency for mechanical properties is to meet the following requirements:

(1) Tensile test sample is to be randomly selected from each batch, that is to be less than or equal to 25 tonnes, and to be from the same cast, in the same delivery condition and of the same thickness.

(2) Charpy V-notch impact test specimens are to be taken in accordance with following requirements:
a. For steel plates or flats in N, NR or TM condition test sample is to be taken from each piece.
b. For steel plates or flats in QT condition test sample is to be taken from each individually heat treated part thereof.
c. For sections, bars and tubulars, test sample is to be taken from each batch of 25 tonnes or fraction thereof.

(3) For continuous heat treated product special consideration may be given to the number and location of impact test specimens required by the manufacturer to be agreed by CCS.

3.4.7.2 In addition to the following requirements, the position and direction of the specimens taken for mechanical property tests are to be in accordance with the relevant requirements of 3.1.4 of this chapter.

(1) Where round cross-sectional tensile specimens are used for the steel with thickness above 100 mm, the specimens are to be located at a position lying at a distance of t/4 from the surface and additionally at t/2.

(2) The Charpy V-notch impact test specimens for plates and wide flats over 600 mm in width are to be taken with their axes transverse to the final rolling direction; for other product forms, the impact tests are to be in the longitudinal direction.

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

(4) Impact test for a nominal thickness less than 6 mm is normally not required.

3.4.7.3 Test specimens and test procedures for mechanical properties are to be in accordance with the provisions of Chapter 2 of the Rules.

3.4.7.4 The results of the tests are to comply with the appropriate requirements of Table 3.4.7.4. In the case of product forms other than plates and wide flats where longitudinal tests are agreed, the elongation values are to comply with the longitudinal requirements as listed in Table 3.4.7.4.

Mechanical properties of High Strength Steels for Welded Structures Table 3.4.7.4

Steel Grade & delivery condition / Mechanical properties		Minimum yield strength R_{eH} (N/mm^2) Nominal thickness (mm)			Ultimate tensile strength R_m (N/mm^2) Nominal thickness (mm)		Minimum percentage elongation after fracture A_5 (%) $L_0=5.65\sqrt{S_0}$		Charpy V-notch impact test		
									Test temp (°C)	Minimum impact energy (J)	
		≥3 ≤50	>50 ≤ 100	>100 ≤250①	≥3 ≤100	>100 ≤250①	T	L		T	L
H420N/NR H420TM H420QT	A D E F	420	390	365	520~680	470~650	19	21	0 -20 -40 -60	28	42
H460N/NR H460TM H460QT	A D E F	460	430	390	540~720	500~710	17	19	0 -20 -40 -60	31	46
H500TM H500QT	A D E F	500	480	440	590~770	540~720	17	19	0 -20 -40 -60	33	50
H550TM H550QT	A D E F	550	530	490	640~820	590~770	16	18	0 -20 -40 -60	37	55
H620TM H620QT	A D E F	620	580	560	700~890	650~830	15	17	0 -20 -40 -60	41	62
H690TM H690QT	A D E F	690	650	630	770~940	710~900	14	16	0 -20 -40 -60	46	69
H890TM H890QT	A D E	890	830	Not applicable	940~1100	Not applicable	11	13	0 -20 -40	46	69
H960QT	A D E	960	Not applicable	Not applicable	980~1150	Not applicable	10	12	0 -20 -40	46	69

Note: ① For plates and sections for applications, such as racks in offshore platforms etc., where the design requires that tensile properties are maintained through the thickness, a decrease in the minimum specified tensile properties is not permitted with an increase in the thickness.

3.4.7.5 For full thickness flat test specimens with a width of 25 mm and a gauge length of 200 mm the elongation is to comply with the minimum values shown in Table 3.4.7.5.

Elongation Minimum Values for Full Thickness Flat Test Specimens① Table 3.4.7.5

Strength level	Thickness (mm)						
	≤10	>10 ≤15	>15 ≤20	>20 ≤25	>25 ≤40	>40 ≤50	>50 ≤70
H420	11	13	14	15	16	17	18
H460	11	12	13	14	15	16	17
H500	10	11	12	13	14	15	16
H550	10	11	12	13	14	15	16
H620	9	11	12	12	13	14	15
H690	9②	10②	11②	11	12	13	14

Notes: ① The tabulated elongation minimum values are the requirements for testing specimen in transverse direction.

② For H690 plates with thickness ≤ 20 mm, round specimen in accordance with Section 2, Chapter 2 of this PART may be used instead of the flat tensile specimen. The minimum elongation for testing specimen in transverse direction is 14%.

③ H890 and 960 specimens and specimens which are not included in this table are to be proportional specimens with a gauge length of $L_0=5.65\sqrt{S_0}$.

3.4.7.6 For steels designated with improved through thickness properties ("Z" quality), tests are to be performed in accordance with Section 10 of this Chapter. Through thickness tensile strength is not to be less than 80% of the specified minimum tensile strength.

3.4.8 Stress relieving heat treatment and other heat treatments

3.4.8.1 Steels approved with respect to heat treatment are suitable for stress relieving heat treatment such as post-weld heat treatment and stress relieving heat treatment after cold forming for the purpose of reducing the risk of brittle fracture, increasing the fatigue lifetime and dimensional stability for machining.

Section 5 STEELS FOR BOILERS AND PRESSURE VESSELS

3.5.1 Application

3.5.1.1 This Section applies to the carbon, carbon-manganese and alloy steel plates, flat bars or sections intended for use in the construction of boilers and pressure vessels.

3.5.2 Deoxidation and chemical composition

3.5.2.1 The method of deoxidation and the chemical composition of ladle samples of the steel intended to be used for boilers and pressure vessels are to comply with the requirements given in Table 3.5.2.1.

Deoxidation and Chemical Composition of Steels Used for Boilers and Pressure Vessels Table 3.5.2.1

Grade	Deoxidation	Chemical composition (%)								
		C	Si	Mn	P	S	Al	Cr	Mo	Other elements
360A	Killed	≤0.17	0.10~0.35	0.40~1.20	≤0.04	≤0.04	②	–	–	Cr≤0.25 Cu≤0.30 Ni≤0.30 Mo≤0.10 Total≤0.70
360B	Killed and fine grain treated	≤0.17	0.15~0.35	0.40~1.20	≤0.04	≤0.04	0.015~0.065	–	–	
410A	Killed	≤0.20	0.10~0.35	0.50~1.30	≤0.04	≤0.04	②	–	–	
410B	Killed and fine grain treated	≤0.20	0.15~0.35	0.50~1.30	≤0.04	≤0.04	0.015~0.065	–	–	
460A	Killed	≤0.20①	0.10~0.40	0.80~1.40	≤0.04	≤0.04	②	–	–	
460B	Killed and fine grain treated	≤0.20①	0.15~0.40	0.80~1.40	≤0.04	≤0.04	0.010~0.065	–	–	
490A	Killed	≤0.20①	0.15~0.50	0.90~1.60	≤0.04	≤0.04	②	–	–	
490B	Killed and fine grain treated	≤0.20①	0.15~0.50	0.90~1.60	≤0.04	≤0.04	0.015~0.065	–	–	
1Cr0.5Mo	Killed	0.10~0.18	0.10~0.35	0.40~0.80	≤0.035	≤0.035	≤0.020	0.70~1.30	0.40~0.60	Cu≤0.30 Ni≤0.30
2.25Cr1Mo	Killed	0.08~0.18	0.10~0.50	0.40~0.80	≤0.035	≤0.035	≤0.020	2.0~2.50	0.90~1.10	Cu≤0.30 Ni≤0.30

Notes: ① For thickness greater than 30 mm, the carbon content may be ≤ 0.22%.

② May be deoxidated by aluminum.

3.5.3 Heat treatment

3.5.3.1 Carbon and carbon-manganese steels with a tensile strength of 360 ~ 490 N/mm^2 are to be supplied in normalized or controlled rolled condition, and alloy steels of 1Cr0.5Mo and 2.25Cr1Mo are to be supplied in normalized and tempered condition, except that, when agreed, material intended for hot forming may be supplied in the as rolled condition.

3.5.4 Mechanical properties

3.5.4.1 The number of test specimens is to be as follows:

(1) For plates, a tensile specimen and a set of three impact test specimens are to be taken from one end of each piece when the mass does not exceed 5 t or the length does not exceed 15 m. When either of these limits is exceeded, one tensile and a set of three impact test specimens are to be taken from both ends of each piece. A piece denotes a rolled product from a single ingot (or billet, slab).

(2) For strips, one tensile test specimen and a set of three impact specimens are to be taken from both ends of each coil.

(3) Sections and bars may be presented for acceptance tests in batches containing not more than 50 lengths and with a mass not exceeding 10 t. 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 and a set of three impact test specimens are to be taken from the material representative of each batch. When the mass of a batch exceeds 10 t, one extra tensile test specimen and one extra set of specimens are to be taken from each 10 t or fraction thereof.

3.5.4.2 The position of test specimens to be taken is to comply with the requirements of 3.2.4.1 of this Chapter. For rectangular hollow sections, the specimen is to be taken from the centre of any side as shown in Figure 3.5.4.2, and for circular hollow sections, at any position on the periphery.

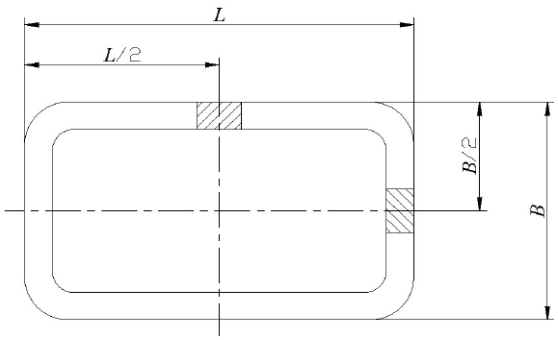


Figure 3.5.4.2

3.5.4.3 The mechanical properties of steels intended to be used for boilers and pressure vessels are to comply with the requirements given in Table 3.5.4.3.

Mechanical Properties of Steels Used for Boilers and Pressure Vessels Table 3.5.4.3

Grade		Tensile strength R_m (N/mm^2)	Yield strength R_{eH} min. (N/mm^2)			Elongation A_5 min. (%)		Charpy V-notch impact test	
			Thickness (mm)			Thickness (mm)		Test temp. (℃)	Average impact energy (J)
			$t \le 16$	$16 < t \le 40$	$40 < t \le 60$	$t \le 40$	$40 < t \le 60$		
360	A	360 ~ 480	205	195	183	26	25	20	≥ 27
	B		235	215	195	26	25	0	
410	A	410 ~ 530	235	225	215	24	23	20	
	B		265	245	235	24	23	0	
460	A	460 ~ 580	285	255	245	22	21	20	
	B		295	285	275	22	21	0	
490	A	490 ~ 610	305	275	265	21	20	20	
	B		315	315	305	21	20	0	
1Cr0.5Mo		440 ~ 590	305	305	305	20	19	20	
2.25Cr1Mo		480 ~ 630	275	265	265	18	17	20	

3.5.5 Mechanical properties at elevated temperature

3.5.5.1 For steels intended for use at a working temperature of 50℃ or higher, the value of yield strength R_{eH}^T at the working temperature is to be verified through testing at elevated temperatures. Nominal values of

yield strength R_{eH}^{T} at elevated temperatures are given in Table 3.5.5.1. These values are intended for design purposes only, and verification is not required for acceptance except that when the steel intended for boilers is listed in certain standards or when an initial approval is made to a new steel. If no such data are available or the working temperature is higher than specified in the Table, at least one tensile test specimen is to be taken from each cast (where materials of more than one thickness are supplied from one cast, the thickest material is to be tested) and the test is to be carried out at the design temperature or at any other agreed temperature.

3.5.5.2 For steels intended for structural components subject to load at elevated temperatures, the rupture stress at elevated temperatures is to be verified in addition to the tensile strength. The rupture stress $R_{m100000}^{T}$ is the average breaking stress of materials at design temperature in 100,000 h. The values of rupture stress $R_{m100000}^{T}$ of materials are given in Table 3.5.5.2 and may be used for design purposes.

Yield Strength R_{eH}^{T} at Elevated Temperature **Table 3.5.5.1**

Grade		Thickness t (mm)	Design temperature (℃)											
			50	100	150	200	250	300	350	400	450	500	550	600
			Yield strength R_{eH}^{T} min. (N/mm^2)											
360	A	$t \le 16$	183	175	172	168	150	124	117	115	113			
		$16 < t \le 40$	173	171	169	162	144	124	117	115	113			
		$40 < t \le 60$	166	162	158	152	141	124	117	115	113			
	B	$t \le 16$	214	204	185	165	145	127	116	110	106			
		$16 < t \le 40$	200	196	183	164	145	127	116	110	106			
		$40 < t \le 60$	183	179	172	159	145	127	116	110	106			
410	A	$t \le 16$	220	211	208	201	180	150	142	138	136			
		$16 < t \le 40$	204	201	198	191	171	150	142	138	136			
		$40 < t \le 60$	196	192	188	181	168	150	142	138	136			
	B	$t \le 16$	248	235	216	194	171	152	141	134	130			
		$16 < t \le 40$	235	228	213	192	171	152	141	134	130			
		$40 < t \le 60$	222	215	204	188	171	152	141	134	130			
460	A	$t \le 16$	260	248	243	235	210	176	168	162	158			
		$16 < t \le 40$	235	230	227	220	198	176	168	162	158			
		$40 < t \le 60$	227	222	218	210	194	176	168	162	158			
	B	$t \le 16$	276	262	247	223	198	177	167	158	153			
		$16 < t \le 40$	271	260	242	220	198	177	167	158	153			
		$40 < t \le 60$	262	251	236	217	198	177	167	158	153			
490	A	$t \le 16$	280	270	264	255	228	192	183	177	172			
		$16 < t \le 40$	255	248	245	237	214	192	183	177	172			
		$40 < t \le 60$	245	240	236	227	210	192	183	177	172			
	B	$t \le 16$	297	284	265	240	213	192	182	173	168			
		$16 < t \le 40$	293	279	260	237	213	192	182	173	168			
		$40 < t \le 60$	283	272	256	234	213	192	182	173	168			
1Cr0.5Mo		$t \le 60$	284	270	265	248	236	216	205	199	194	188	181	174
2.25Cr1Mo		$t \le 60$	255	249	241	233	226	219	212	207	194	180	160	137

Average Rupture Stress at Elevated Temperature $R_{m100000}^{T}$ **Table 3.5.5.2**

Temperature (℃)	Grade	Temperature (℃)	Grade	
	360A 360B 410A 410B	460A 460B 490A 490B		1Cr0.5Mo	2.25Cr1Mo
	$R_{m100000}^{T}$ (N/mm^2)			$R_{m100000}^{T}$ (N/mm^2)	
380	171	227	480	210	170
390	155	203	490	177	153
400	141	179	500	146	137
410	127	157	510	121	122
420	114	136	520	99	107
430	102	117	530	81	93
440	90	100	540	67	79
450	78	85	550	54	69
460	67	73	560	43	59
470	57	63	570	35	51
			580		44

Section 6 STEELS FOR MACHINERY STRUCTURES

3.6.1 General requirements

3.6.1.1 Rolled steels intended for use in the construction of welded machinery structures, such as engine frames, bedplates, turbine cylinders, reduction gear casings etc., are to be of killed steel having a carbon content not exceeding 0.23%.

3.6.1.2 Where it is intended to use any grade of normal or higher strength hull structural steel for the construction of machinery structures, such steels are to comply with the relevant requirements of Sections 2 and 3 of this Chapter.

3.6.1.3 Any grade of carbon or carbon-manganese steel for boilers and pressure vessels as detailed in Section 5 of this Chapter may be used for the construction of machinery structures. When such steels are used for machinery structures, they may be accepted in batches. The size of a batch and the number of tensile tests are to comply with the requirements of 3.2.4.2 of this Chapter.

For important machinery structures subject to a working temperature higher than 50℃, details of elevated temperature properties used for design purposes are to be submitted to CCS for reference.

Section 7 STEELS FOR LOW TEMPERATURE SERVICE

3.7.1 Application

3.7.1.1 This Section applies to carbon-manganese and nickel alloy steels not over 40 mm in thickness, intended for use in the construction of cargo tanks of liquefied gas carriers and the hull structures adjacent to these tanks. Such steels are to comply with the relevant requirements of CCS Rules for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk in addition to the requirement of this Section.

3.7.1.2 Carbon-manganese and nickel alloy steels over 40 mm in thickness are to be specially considered.

3.7.1.3 The minimum specified yield strength of carbon-manganese steel complying with the requirement of 3.7.1.1 is 315, 355, 390 N/mm^2 respectively and the toughness grade is represented by CL-I, CL-II and CL-III (where: C stands for the first letter of CCS and L for low temperature).

3.7.1.4 In addition to the purposes mentioned in 3.7.1.1 above, the steels specified in this Section may apply to other purposes where the operating temperature is below 0℃.

3.7.2 Deoxidation and chemical composition

3.7.2.1 All materials are to be of fully killed steels and fine grain treated with aluminum.

3.7.2.2 The chemical composition of carbon-manganese steel is shown in Table 3.7.2.2.

3.7.2.3 The chemical composition of nickel alloy steel is shown in Table 3.7.2.3.

Chemical Composition of carbon-manganese steel **Table 3.7.2.2**

Grade	Chemical composition (%)					
	C	Mn	Si	P	S	Other elements
CL-I-2, CL-II-2 CL-I-3, CL-II-3 CL-I-4, CL-II-4	≤0.18	0.70~1.60	0.10~0.50	≤0.025	≤0.025	Ni≤0.80, Cr≤0.25 Mo≤0.08, Cu≤0.35 Nb≤0.05, V≤0.10
CL-III-2 CL-III-3 CL-III-4	≤0.16					
Total quantity of Al content ≥0.02% (acid soluble ≥0.015%)						

Chemical Composition of nickel alloy steel **Table 3.7.2.3**

Grade	Chemical composition (%)						
	C	Mn	Si	P	S	Ni	Other elements
1.5Ni	≤0.14	0.30~1.50	0.10~0.35	≤0.025	≤0.02	1.30~1.70	Cr≤0.25 Mo≤0.08 Cu≤0.35 Cr+Mo+Cu≤0.60 Al(acid soluble)≥0.015
2.25Ni	≤0.14	≤0.70	≤0.30	≤0.025	≤0.025	2.10~2.50	
3.5Ni	≤0.12	0.30~0.80	0.10~0.35	≤0.025	≤0.02	3.20~3.80	
5Ni	≤0.12	0.30~0.90	0.10~0.35	≤0.025	≤0.02	4.70~5.30	
9Ni	≤0.10	0.30~0.90	0.10~0.35	≤0.025	≤0.02	8.5~10.0	

Note: ① Nitrogen content is not to exceed 0.009% (or 0.012% where aluminium is present).

3.7.2.4 Carbon equivalent C_{eq} is to be calculated from the ladle analysis, using the formula below:

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

The maximum value of carbon equivalent is not to exceed the agreed permissible value.

3.7.3 Heat treatment and mechanical properties

3.7.3.1 The conditions of supply and mechanical properties of carbon and carbon-manganese steels are to comply with the requirements given in Table 3.7.3.1.

3.7.3.2 The conditions of supply and mechanical properties of nickel alloy steel are to comply with the requirements given in Table 3.7.3.2.

Conditions of supply and mechanical properties of carbon-manganese steel① Table 3.7.3.1

Grade	Condition of supply②	Yield strength R_{eH} min. (N/mm^2)	Tensile strength R_m (N/mm^2)	Elongation A_5 min. (%)	Charpy V-notch impact tests				Design Temp. min. (℃)
					Material thickness t (mm)	Test Temp. T (℃)	Average energy of test specimens, min. (J)		
							Long.	Trans.	
CL-I-2	Normalized or quenched and tempered	315	440-570	22	$t\leq25$ $25<t\leq30$ $30<t\leq35$ $35<t\leq40$	-20 -25 -30 -35	41	27	-15
CL-II-2		315	440-570	22	$t\leq25$ $25<t\leq30$ $30<t\leq35$ $35<t\leq40$	-40 -45 -50 -55	41	27	-35
CL-III-2		315	440-570	22	$t\leq25$ $25<t\leq30$ $30<t\leq35$ $35<t\leq40$	-60 -65 -70 -75	41	27	-55
CL-I-3		355	490-630	21	$t\leq25$ $25<t\leq30$ $30<t\leq35$ $35<t\leq40$	-20 -25 -30 -35	41	27	-15
CL-II-3		355	490-630	21	$t\leq25$ $25<t\leq30$ $30<t\leq35$ $35<t\leq40$	-40 -45 -50 -55	41	27	-35
CL-III-3		355	490-630	21	$t\leq25$ $25<t\leq30$ $30<t\leq35$ $35<t\leq40$	-60 -65 -70 -75	41	27	-55
CL-I-4		390	510-660	20	$t\leq25$ $25<t\leq30$ $30<t\leq35$ $35<t\leq40$	-20 -25 -30 -35	41	27	-15
CL-II-4		390	510-660	20	$t\leq25$ $25<t\leq30$ $30<t\leq35$ $35<t\leq40$	-40 -45 -50 -55	41	27	-35
CL-III-4		390	510-660	20	$t\leq25$ $25<t\leq30$ $30<t\leq35$ $35<t\leq40$	-60 -65 -70 -75	41	27	-55

① The requirement is applicable to materials not over 40 mm in thickness. For materials over 40 mm in thickness, the energy value of Charpy V-notch impact test is subject to agreement of CCS.

② Controlled rolling process or TMCP may replace normalized or quenched and tempered.

③ In the table, the transverse values of impact tests apply to plates and the longitudinal values to sections.

Conditions of supply and mechanical properties of nickel alloy steel Table 3.7.3.2

Grade	Condition of supply	Proof strength $R_{p0.2}$ min. (N/mm^2)	Tensile strength R_m (N/mm^2)	Elongation A_5 min. (%)	Charpy V-notch impact tests				Design Temp. min. (℃)
					Material thickness t (mm)	Test Temp. T (℃)	Average energy of test specimens, min. (J)		
							Long.	Trans.	
1.5Ni	Normalized or normalized and tempered or quenched and tempered or TMCP①	275	470~640	22	$t\leq25$ $25<t\leq30$ $30<t\leq35$ $35<t\leq40$	-65 -70 -75 -80	41	27	-60
2.25Ni	Normalized or normalized and tempered or quenched and tempered or TMCP①	295	420~570	19	$t\leq25$ $25<t\leq30$ $30<t\leq35$ $35<t\leq40$	-70 -75 -80 -85			-65
3.5 Ni		345	440~690	21	$t\leq25$ $25<t\leq30$ $30<t\leq35$ $35<t\leq40$	-95 -100 -105 -110			-90
5Ni	Normalized or normalized and tempered or quenched and tempered①②	390	520~710	21	$t\leq25$ $25<t\leq30$ $30<t\leq35$ $35<t\leq40$	-110 -115 -120 -125			-105
9Ni	Double normalized and tempered or quenched and tempered	490	640~830	19	$t\leq40$	-196			-165

① Nickel steel supplied in TMCP is subject to agreement of CCS.
② Nickel steel with 5% Ni content after being subject to special heat treatment, such as three stage heat treatment (double quenched and tempered), may be used in locations where the minimum temperature is -165℃. However, impact tests are to be carried out at temperature below -196℃.
③ The requirement is applicable to materials not over 40 mm in thickness. For materials over 40 mm in thickness, the energy value of Charpy V-notch impact test is subject to agreement of CCS.
④ The transverse values of impact tests apply to plates and the longitudinal values to sections.

3.7.3.3 Preparation of the specimens for mechanical tests

(1) For plates: one tensile test specimen and a set of three impact test specimens are to be taken from one end of each rolled piece.

(2) For sections and other steels: one tensile test specimen and a set of three impact test specimens are to be taken from one piece in each batch with similar dimensions, originating from the same heat treatment charge and the same heat of steel by the same rolling procedure. The mass of each batch is not to exceed 10t.

(3) The direction of cut, shape and dimensions of the tensile and impact test specimens are to comply with the relevant requirements of Chapter 2 of this PART and Section 1 of this Chapter. For plates intended for the applications as detailed in 3.7.1.1 above, transverse specimens are to be taken for impact tests. The locations where the specimens are taken and the test values are to be in accordance with the relevant requirements of 6.1.4.1, 6.1.4.2 and 6.1.5, Chapter 6 of CCS Rules for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk.

3.7.3.4 Drop weight test

(1) In addition to the above-mentioned mechanical tests, a drop weight test is to be carried out on plates and sections having a thickness more than 12 mm and working under the following designed operating temperatures:

① carbon-manganese steels intended for use at a designed operating temperature below -40℃;
② 0.5Ni and 1.5Ni steels intended for use at a designed operating temperature below -60℃;
③ 2.25Ni steels intended for use at a designed operating temperature below -65℃;
④ 3.5Ni steels intended for use at a designed operating temperature below -80℃;
⑤ 5Ni steels intended for use at a designed operating temperature below -90℃.

(2) For drop weight tests, one set of two specimens are to be taken from the thickest plate or section of each batch from the same cast.

(3) Drop weight test is to be carried out at a temperature 5℃ lower than the designed operating temperature.

Section 8 AUSTENITIC AND DUPLEX STAINLESS STEELS

3.8.1 Application

3.8.1.1 This Section applies to austenitic stainless steels and austenitic/ferritic duplex stainless steels (hereinafter referred to as duplex stainless steels) intended for use in the construction of cargo tanks, process pressure vessels for oil, gas and water as well as other components of bulk chemical tankers and liquefied gas carriers.

3.8.2 General requirements

3.8.2.1 The austenitic stainless steels covered by this Section may also be used for the construction of pressure vessels where the design temperature is not lower than -165℃.

3.8.2.2 The duplex stainless steels covered by this Section may generally be used for the construction of structural members where the design temperature is 0℃ to 300℃.

3.8.2.3 The austenitic stainless steels are also suitable for service at elevated temperatures and for such applications, details of the chemical composition, mechanical properties at both ambient and working temperatures, and heat treatment are to be submitted to CCS.

3.8.3 Chemical composition

3.8.3.1 The chemical composition of ladle samples of austenitic stainless steels is to comply with the following requirements given in Table 3.8.3.1.

Chemical Composition of Austenitic Stainless Steels **Table 3.8.3.1**

Grade	Uniform numbercode	Chemical composition (%)									
		C	Si	Mn	P	S	Cr	Ni	Mo	N	Other elements
06Cr19Ni10①	S30408	≤0.08	≤1.0	≤2.0	≤0.045	≤0.03	18.0~20.0	8.0~11.0	–	–	
022Cr19Ni10	S30403	≤0.03	≤1.0	≤2.0	≤0.045	≤0.03	18.0~20.0	8.0~12.0	–	–	
022Cr19Ni10N	S30453	≤0.03	≤1.0	≤2.0	≤0.045	≤0.03	18.0~20.0	8.0~11.0	–	0.10~0.16	
06Cr17Ni12Mo2①	S31608	≤0.08	≤1.0	≤2.0	≤0.045	≤0.03	16.0~18.0	10.0~14.0	2.0~3.0	—	
022Cr17Ni12Mo2	S31603	≤0.03	≤1.0	≤2.0	≤0.045	≤0.03	16.0~18.0	10.0~14.0	2.0~3.0	–	
022Cr17Ni12Mo2N	S31653	≤0.03	≤1.0	≤2.0	≤0.045	≤0.03	16.0~18.0	10.0~13.0	2.0~3.0	0.10~0.16	
06Cr19Ni13Mo3①	S31708	≤0.08	≤1.0	≤2.0	≤0.045	≤0.03	18.0~20.0	11.0~15.0	3.0~4.0	—	
022Cr19Ni13Mo3	S31703	≤0.03	≤1.0	≤2.0	≤0.045	≤0.03	18.0~20.0	11.0~15.0	3.0~4.0	–	
022Cr19Ni13Mo4N	S31753	≤0.03	≤1.0	≤2.0	≤0.045	≤0.03	18.0~20.0	11.0~15.0	3.0~4.0	0.10~0.22	
06Cr18Ni11Nb	S34778	≤0.08	≤1.0	≤2.0	≤0.045	≤0.03	17.0~19.0	9.0~12.0	–	–	10C≤Nb≤1.10

Note: ① Generally not used as vessel members having direct contact with corrosive chemicals.

3.8.3.2 The chemical composition of ladle samples of duplex stainless steels is to comply with the following requirements given in Table 3.8.3.2.

Chemical Composition of Duplex Stainless Steels **Table 3.8.3.2**

Grade	Uniform numbercode	Chemical composition (%)									
		C	Mn	Si	P	S	Cr	Ni	Mo	N	Other elements
022Cr22Ni5Mo3N	S22253	≤0.03	≤2.0	≤1.0	≤0.030	≤0.020	21.0~23.0	4.5~6.5	2.5~3.5	0.08~0.20	
022Cr23Ni5Mo3N	S22053	≤0.03	≤2.0	≤1.0	≤0.030	≤0.020	22.0~23.0	4.5~6.5	3.0~3.5	0.14~0.20	
03Cr25Ni6Mo3Cu2N	S25554	≤0.04	≤1.5	≤1.0	≤0.035	≤0.030	24.0~27.0	4.5~6.5	2.9~3.9	0.10~0.25	1.0≤Cu≤2.5
022Cr25Ni7Mo4N	S25073	≤0.03	≤1.2	≤0.8	≤0.035	≤0.020	24.0~26.0	6.0~8.0	3.0~5.0	0.24~0.32	Cu≤0.50

3.8.4 Heat treatment

3.8.4.1 All austenitic and duplex stainless steels are to be supplied in the solution treated condition.

3.8.5 Mechanical properties

3.8.5.1 The test specimens are to be taken in accordance with the requirements of 3.5.4.1 of this Chapter.
3.8.5.2 Unless otherwise agreed, all grades of austenitic stainless steel given in this Section may generally be exempted from impact tests. Where austenitic stainless steel is to be used at a working temperature of -100℃ or lower, Charpy V-notch impact tests at -196℃ may be required. The minimum average energy values of the impact tests are to be no less than 27 J (transverse).
3.8.5.3 The mechanical properties of austenitic stainless steels are to comply with the following requirements given in Table 3.8.5.3.

Mechanical Properties of Austenitic Stainless Steels **Table 3.8.5.3**

Grade	Proof strength $R_{p0.2}$ ① min. (N/mm^2)	Proof strength $R_{p1.0}$ ① min. (N/mm^2)	Tensile strength R_m ② min. (N/mm^2)	Elongation A_5 min. (%)
06Cr19Ni10	205	245	515	40
022Cr19Ni10	175	215	480	40
022Cr19Ni10N	245	285	550	40
06Cr17Ni12Mo2	205	245	515	40
022Cr17Ni12Mo2	175	215	480	40
022Cr17Ni12Mo2N	245	285	550	40
06Cr19Ni13Mo3	205	245	515	40
022Cr19Ni13Mo3	205	245	520	40
022Cr19Ni13Mo4N	275	315	570	40
06Cr18Ni11Nb	205	245	520	40

Notes: ① Proof strength $R_{p0.2}$ is normally to be determined. Where specified otherwise in the contract, the proof strength $R_{p1.0}$ may be set for delivery.
② The upper limit of tensile strength of austenitic stainless steels is not to exceed any value in the Table plus 200 N/mm^2.

3.8.5.4 The mechanical properties of duplex stainless steels are to comply with the following requirements given in Table 3.8.5.4.

Mechanical Properties of Duplex Stainless Steels **Table 3.8.5.4**

Grade	Proof strength $R_{p0.2}$ min. (N/mm^2)	Tensile strength R_m min. (N/mm^2)	Elongation A_5 min. (%)	Charpy V–notch impact test		
				Test temp. (℃)	Impact (J)	
					Long.	Trans.
022Cr22Ni5Mo3N	450	620	25	-20	41	27
022Cr23Ni5Mo3N	450	620	25	-20	41	27
03Cr25Ni6Mo3Cu2N	490	690	25	-20	41	27
022Cr25Ni7Mo4N	550	790	20	-20	41	27

3.8.6 Intergranular corrosion tests
3.8.6.1 When stainless steels are used for certain environment, such as tanks or storage tanks containing corrosive chemicals, test specimens are to be taken and tested together with those for tensile tests according to the requirements in 3.5.4.1 of this Chapter for a set or batch of specimens.
3.8.6.2 The specimens are to be prepared and tested in compliance with Section 7, Chapter 2 of this PART.
3.8.6.3 Where a customer has special requirements for actual cargo loading, corrosion tests for stainless steel are to be carried out according to contract.

Section 9 CLAD STEEL PLATES

3.9.1 Application
3.9.1.1 This Section applies to the clad steel plates intended for use in the construction of cargo or storage tanks of chemical tankers.
3.9.1.2 Clad steel plate is the plate consisting of a base plate clad on one or both sides, continuously and integrally bonded with a thin layer of cladding material.

3.9.2 Base material
3.9.2.1 Any carbon or carbon-manganese steels suitable for roll cladding or explosive bonding may be

accepted as the base material. Where the plates are intended to form a part of the hull structure (e.g. cargo tanks), the base materials are to comply with the requirements of Sections 2 and 3 of this Chapter, and where the plates are intended for pressure vessels, the base materials are to comply with the requirements of Section 5 of this Chapter.

3.9.2.2 Manufacturers are to provide detailed information on the chemical composition and mechanical properties of the base material.

3.9.3 Cladding material

3.9.3.1 Any material suitable for the intended purposes，such as austenitic stainless steel, chromium steel, aluminum alloy or copper-nickel alloy steel etc., may be accepted as cladding material.

3.9.3.2 Manufacturers are to provide a certificate of conformity for the cladding material and to ensure that the chemical composition of the material complies with the relevant requirements. In case of doubt, the Surveyor may require to check the chemical composition.

3.9.4 Heat treatment

3.9.4.1 The plates are to be supplied in a heat treated condition most appropriate to both the base and cladding materials. The heat treatment procedure is to be submitted to CCS for reference.

3.9.5 Bonding

3.9.5.1 The base and cladding materials are to be adequately bonded to each other. The proportion of bonded areas is to be at least 95% unless otherwise agreed. During the subsequent machining and welding, where any unbonded area is found at the welded position, such area is to be rebonded by means of a procedure agreed by CCS.

3.9.5.2 Ultrasonic testing is to be carried out to check the bonding of the base and cladding materials. For plate thickness equal to or greater than 10 mm, each piece is to be tested; for plate thickness less than 10 mm, the quantity of plates to be tested is at the discretion of the Surveyor. The area along the edges of each plate is to be checked 100% for a width of at least 50 mm. For the inner area, continuous checking is to be carried out along all the parallel lines (to edges) spaced 200 mm apart. Isolated unbonded areas not more than 4,000 mm^2 each may be accepted provided that the adjacent unbonded areas are spaced not less than 500 mm apart.

3.9.5.3 The bonding strength of the base and cladding materials may be determined by shear test.

3.9.6 Mechanical tests

3.9.6.1 Tensile and bend test specimens are to be of flat type. The test specimens are normally to have the thickness of the plate. Where the thickness of the plate is more than 50 mm, or in order to suit the capacity of the testing machine, the thickness of the test specimen may be reduced by machining. For single clad steel plates, both sides of the specimen are to be machined to maintain the same ratio of cladding metal to base material as that of the original plate, but the cladding metal is not to be reduced to a thickness less than 3 mm. For double clad steel plates, the specimen may be split into two halves. In this case, both halves are to be tested.

3.9.6.2 Two tensile test specimens are to be prepared from each plate. Where the clad steel plates are intended for the construction of hull structures such as cargo tanks, one from every five plates may be selected for the tensile test in the case of the same cast.

3.9.6.3 The tensile test is to be carried out according to the following procedure:

Firstly, one test specimen representing the full clad steel plate (including the machined test specimen for reduced thickness) is to be tested. The tensile strength R_c obtained is not to be less than the value calculated from the following formula:

$$R_c = \frac{t_1 R_1 + t_2 R_2}{t_1 + t_2} \qquad \text{N/mm}^2$$

where: t_1 — nominal thickness of base material, in mm;

t_2 — nominal thickness of cladding material, mm;

R_1 — specified minimum yield strength (R_{eH}) or proof strength ($R_{p0.2}$) or tensile strength (R_m) of base material, in N/mm^2;

R_2 — specified minimum yield strength (R_{eH}) or proof strength ($R_{p0.2}$) or tensile strength (R_m) of cladding material, in N/mm^2;

R_c — specified minimum yield strength (R_{eH}) or proof strength ($R_{p0.2}$) or tensile strength (R_m) of the clad steel plate, in N/mm^2.

Where the tensile strength R_c obtained is lower than the value calculated from the formula, the other

specimen (from which the cladding material has been removed) is to be tested. The result obtained is to comply with the requirements for the base material.

3.9.6.4 Two bend test specimens are to be prepared from each plate. For single clad steel plates, one test specimen is to be bent with the cladding metal in tension and the other with the cladding metal in compression. For double clad steel plates, the test specimens are to be bent so that both cladding metals are tested for both ways. Where the angle of bend is 180°, the diameter D of the former is to comply with the requirements for base materials. After bending, there is to be no cracks on the outer surface of the specimen and no sign of detachment of the cladding metal from the base material.

3.9.6.5 One transverse test specimen for shear test is to be prepared from each plate, and is to be tested in accordance with relevant standards recognized by CCS. The shearing strength of the bonding is not to be less than the values specified as follows:

(1) For plates having a tensile strength $R_m < 280$ N/mm^2, the shearing strength is to be 50% of the tensile strength.

(2) For plates having a tensile strength $R_m \geq 280$ N/mm^2, the shearing strength is to be 140 N/mm^2.

3.9.6.6 Where the base materials are required to be subjected to impact tests, the clad plates are to be impact tested in accordance with the relevant requirements as specified for the base material.

3.9.7 Corrosion tests

3.9.7.1 Where the cladding material is stainless steel required to be corrosion-resistant, specimens for intergranular tests are to be prepared in accordance with Section 7 of Chapter 2 of this PART.

Section 10 Z-DIRECTION STEELS

3.10.1 General requirements

3.10.1.1 This Section applies to plates and flats with a thickness not less than 15 mm (hereinafter referred to as Z-direction steels), which are to meet property requirements for structural details subject to strains in the through-thickness direction.

3.10.1.2 Z-direction steels are the steels being specially treated (i.e. calcium treatment, vacuum degassing, argon stirring, etc.) and properly heat treated on the basis of certain grades of structural steel (parent steel).

3.10.1.3 Z-direction steels are subdivided into Grade Z25 and Grade Z35 in accordance with the reduction of area of tensile specimens in the through-thickness direction.

3.10.2 Grade marks

3.10.2.1 The grade mark of the Z-direction steels is expressed by a symbol of the grade mark of the parent steel suffixed with Z25 or Z35. The figures after Z indicate the reduction of area Z_Z in minimum through-thickness direction of the Z-direction steels. For example, EH32-Z35 means the Grade EH32 hull structural steel with the reduction of area in minimum through-thickness direction of 35%.

3.10.3 Chemical composition

3.10.3.1 In addition to complying with the requirements of the parent steel, the maximum sulphur content of Z-direction is to be 0.008% determined by the ladle analysis.

3.10.4 Mechanical properties

3.10.4.1 Except the test of mechanical properties of parent steel, the mechanical properties of Z-direction steels in through thickness direction may be tested in batches. Each batch of steels is to be of similar thickness (thicknesses do not differ by more than 5 mm), originating from the same heat treatment charge and the same heat of steel. The piece number of each batch is to be in compliance with the requirements of Table 3.10.4.1.

Required Batch for Test of Mechanical Properties of Z-Direction Steels in Through Thickness

Table 3.10.4.1

Sulphur content	$S > 0.005\%$	$S \leq 0.005\%$
Plates	Each piece	≤ 50 t
Wide flats of thickness ≤ 25 mm	≤ 10 t	≤ 50 t
Wide flats of thickness > 25 mm	≤ 20 t	≤ 50 t

3.10.4.2 A representative steel plate is to be selected from each batch, from which a test sample is to be taken and the specimens are to be prepared in accordance with Section 5 of Chapter 2.
3.10.4.3 Three specimens are to be tested for tensile strength in each batch. The results are to be in compliance with the following requirements:
(1) For Grade Z25 steel, the average value of reduction of area in the through-thickness direction for the three specimens is not to be less than 25%, and one individual value may be less than the specified value, but not less than 15%.
(2) For Grade Z35 steel, the average value of reduction of area in the through-thickness direction for the three specimens is not to be less than 35%, and one individual value may be less than the specified value, but not less than 25%.
3.10.4.4 Where the specimen is broken within the welds or heat-influenced area during the test, the specimen and test result may be discarded. A new substitute specimen is to be taken from the original material.
3.10.4.5 Where the average value of three specimens is less than the specified one or the individual values of two specimens are less than the specified average one but greater than the minimum individual one required in 3.10.4.3, test is to be carried out for the three standby specimens. The average value of the results of the six tests is to be greater than the specified minimum one, as shown in Figure 3.10.4.5.
3.10.4.6 In the case of failure after retest, the batch is to be rejected. Where required by the manufacturer, the remaining pieces of the batch are to be tested one by one in accordance with the requirements of 3.10.4.3 to 3.10.4.5. Those complying with the requirements may be accepted.

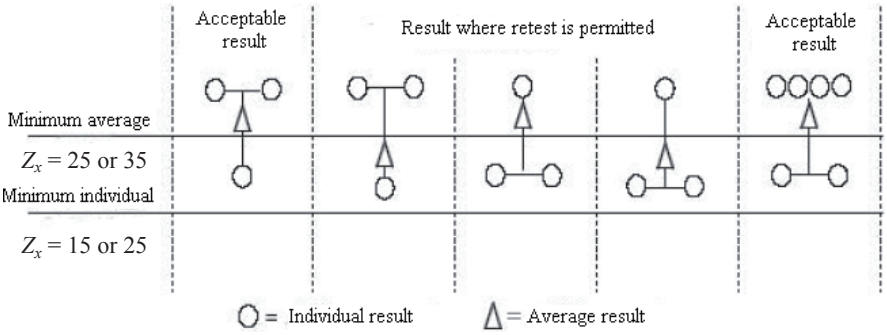


Figure 3.10.4.5 Diagram Showing Acceptance and Retest Criteria

3.10.5 Ultrasonic testing

3.10.5.1 Every piece of Z-direction steels is to be subjected to ultrasonic testing by probes with 3~5 MHz in the final supply condition and in compliance with ISO 17577 or equivalent standards.
3.10.5.2 The result of non-destructive testing is to comply with the requirements of Table 3.10.5.2.

Acceptance requirements for ultrasonic testing of Z-direction steels Table 3.10.5.2

Probe area	Unacceptable individual discontinuity	Unacceptable cluster discontinuities	
		Considered area of each discontinuity in the cluster	Maximum population density
The body of the flat product	s >1000 mm^2	100 mm^2< s ≤1000 mm^2	15/1 m×1 m
Edges zone	l >50 mm, or s >1000 mm^2	25 mm< l ≤50 mm	5/1 m

Section 11 STEELS INTENDED FOR WELDING WITH HIGH HEAT INPUT

3.11.1 General requirements

3.11.1.1 The steels specified in this Section as intended for welding with high heat input are hull structural steels intended for welding with high heat input over 50 kJ/cm.
3.11.1.2 The steels intended for welding with high heat input are steels being slightly adjusted in their chemical composition on the basis of certain grades of structural steel (parent steel). Hence, in addition to the requirements detailed in this Section, all the requirements for the parent steel are to be complied with (see Sections 2 and 3 of this Chapter).

3.11.2 Grade marks

3.11.2.1 The grade mark of the steels intended for welding with high heat input is expressed by a symbol of the grade mark of the parent steel suffixed with the grade mark of being intended for a high heat input. This suffixed mark consists of W and the value of the high heat input. For example, AH32-W60 means AH32 high-strength hull structural steel intended for high heat input up to 60 kJ/cm.

3.11.3 Welding properties

3.11.3.1 Steel manufacturers are to propose, according to their product development, the maximum heat input with which hull structural steels are intended to be welded. Such maximum heat input is to be confirmed through welding tests.

3.11.3.2 Welding tests with high heat input are generally carried out only during approval of steel products. The Surveyor may require such tests of samples according to the results of impact tests during routine surveys.

3.11.3.3 Welding procedure approval tests for butt weld joints of plates as required in Section 2, Chapter 3 of PART THREE of the Rules are applicable to welding tests with high heat input.

3.11.3.4 The welding is to be performed in the downhand position with the maximum heat input proposed by the manufacturer.

3.11.3.5 In addition to the requirements in 3.2.4 of Chapter 3, PART THREE of the Rules, impact tests are to be carried out at the HAZ (heat affected zone) 5 mm and 10 mm from the fusion line respectively.

3.11.3.6 All the test results are to comply with the relevant requirements for parent steels.

Section 12 ROLLED STEEL BARS FOR ANCHOR CHAIN CABLES AND ACCESSORIES

3.12.1 General requirements

3.12.1.1 This Section applies to rolled steel bars intended for anchor chain cables, offshore mooring chains and accessories.

3.12.1.2 The rolled steel bars intended for chain cables are subdivided into eight grades, i.e. M1, M2 and M3 for chain steels and MR3, MR3S, MR4, MR4S and MR5 for offshore mooring chain steels, depending on the nominal tensile strength and applicable product types.

3.12.2 Chemical composition

3.12.2.1 For grades M1, M2 and M3 chain steels, the chemical composition is normally to be in compliance with the requirements of Table 3.12.2.1.

Deoxidation and Chemical Composition of Steel Bars **Table 3.12.2.1**

Grade	Deoxidation method	Chemical composition (%)					
		C	Si	Mn	P	S	Al②
M1	Killed	≤ 0.20	0.15~0.35	≥ 0.40	≤ 0.040	≤ 0.040	−
M2①	Killed and fine grain treated	≤ 0.24	0.15~0.55	≤ 1.60	≤ 0.035	≤ 0.035	≥ 0.020
M3	Killed and fine grain treated	Specification acceptable to CCS③					

Notes: ① If agreed by CCS, alloying elements may be added.

② It means the total aluminum content. Al may be replaced partly by other grain refining elements.

③ For grade M3 chain steels, the manufacturer is to provide relevant specification which includes all necessary details, such as chemical composition, means of deoxidation, manufacturing procedures, heat treatment requirements and mechanical properties.

3.12.2.2 The chemical composition of offshore mooring chain steels is to comply with recognized standards, but for grades MR4, MR4S and MR5 chain, the steels are to contain a minimum of 0.20% molybdenum.

3.12.3 Manufacture

3.12.3.1 The rolled steel bars intended for chain cables, mooring chains and accessories are to be provided by the works approved by CCS, except for steel intended for grade 1 chain cables.

3.12.3.2 The steels intended for chain cables and mooring chains are to be manufactured by basic oxygen, electric furnace or such other process as may be specially approved.

3.12.3.3 All chain steels and mooring chain steels are to be killed and except for grade M1 chain steels, other chain steels and mooring chain steels are to be fine grain treated.

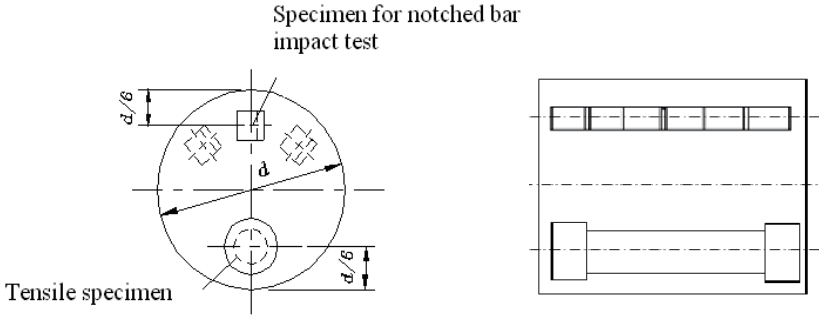
3.12.3.4 Grade MR4S and MR5 mooring chain steels are to be vacuum degassed.
3.12.3.5 The rolling reduction ratio of steel intended for mooring chains is to be at least 5:1. If required by the contract, the rolling reduction ratio used in production can be higher. The rolling reduction ratio means the ratio of sectional area of initial steel to that of finished steel.
3.12.3.6 Except as agreed in the contract, steel bars intended for chains are usually supplied in the as-rolled condition.

3.12.4 Chemical analysis and metallurgical examination

3.12.4.1 The chain steels and mooring chain steels are to be subject to analysis of the chemical composition of each ladle, and the results obtained are to comply with the requirements of 3.12.2 of this Section.
3.12.4.2 For offshore mooring chain steels, a metallographic sample from each ladle is to be taken and measurements for circular sections are to be taken at 1/3 radius to examine the austenitic grain size according to a recognized standard(e.g. ASTM E112). The austenitic grain size is to be 6 or finer.
3.12.4.3 For steels of grades MR4S and MR5, the following information is to be supplied by the bar manufacturer to the mooring chain manufacturer and the results included in the chain documentation:
(1) Non-metallic inclusions: non-metallic inclusions of each heat are to be quantified and assessed in accordance with a recognized standard (e.g. ISO 4967), to be sure inclusion levels are acceptable for the final product.
(2) Macro etching: a sample from each heat is to be macro etched according to a recognized standard (e.g. ASTM E381), to be sure there is no injurious segregation or porosity.
(3) Jominy hardenability test: a sample from each heat is to be tested in accordance with a recognized standard (e.g. ASTM A255).

3.12.5 Mechanical tests

3.12.5.1 Steel bars are to be presented for testing in batches not exceeding 50 t from the same heat and of the same diameter. A test sample having a suitable length is to be taken at random from each batch of steel bars for testing, and be subjected to the heat treatment provided for the finished chain cables.
3.12.5.2 A tensile specimen is to be taken from the test sample. Except for grade 1 chain steels, a set of three Charpy V-notch impact specimens are to be taken from the same test sample. The tensile and impact specimens are to be taken from the sample in the longitudinal direction at a position of 1/6 diameter from the surface or as close as possible to this position, as shown in Figure 3.12.5.2 a or b. The preparation and dimensions of specimens are to comply with the relevant requirements of Chapter 2 of this PART. The cross-sectional area of the tensile specimen is in general not to be less than 150 mm^2. Where the cross-sectional area of the sample is not sufficient for taking these specimens, the tensile specimen in full cross section may also be taken.
The tensile and impact tests and retests are to be carried out in compliance with the relevant requirements of Chapter 2 of this PART and test results are to comply with the requirements of Table 3.12.5.2.



(a) Specimens taken in parallel (b) Specimens taken in series

Figure 3.12.5.2 Position of Taking Specimens

Mechanical Properties of Material Intended for Chain Cables, Mooring Cables and Accessories

Table 3.12.5.2

Grade	Yield point R_{eH} (N/mm^2)	Tensile strength R_m (N/mm^2)	Elongation A_5 (%)	Reduction of area Z (%)	Charpy V-notch impact test	
					Test temperature (℃)	Impact energy (J)
M1	Not required	370 ~ 490	≥ 25	Not required	Not required	Not required
M2	≥ 295	490 ~ 690	≥ 22	Not required	0	≥ 27①
M3	≥ 410	≥ 690	≥ 17	40	0(-20)②	≥ 60(35)
MR3	≥ 410③	≥ 690③	≥ 17	50	0(-20) ②	≥ 60(40)
MR3S	≥ 490③	≥ 770③	≥ 15	50	0(-20) ②	≥ 65(45)
MR4	≥ 580③	≥ 860③	≥ 12	50	-20	≥ 50
MR4S④	≥ 700③	≥ 960③	≥ 12	50	-20	≥ 56
MR5④	≥ 760③	≥ 1000③	≥ 12	50	-20	≥ 58

Notes: ① The impact test for Grade M2 steel may be waived if the steel is to be supplied in a heat treated condition.

② Normally, the temperature of impact test for Grades M3, MR3 and MR3S steel is 0℃. If required by the purchaser, -20℃ may be regarded as a supply condition.

③Aim value of yield to tensile ratio: 0.92 max.

④ Maximum hardness for MR4S is to be 330HBW and for MR5 to be 340HBW.

3.12.5.3 In addition, each heat of Grade MR3S, MR4, MR4S and MR5 steel bars is to be tested for hydrogen embrittlement as follows:

(1) In case of continuous casting, test samples representing both the beginning and the end of the charge are to be taken. In case of ingot casting, test samples representing two different ingots are to be taken.

(2) Two tensile test specimens are to be taken from the central region of bar material which has been subjected to the heat treatment cycle intended to be used in production. A specimen with a diameter of 20 mm (or 14 mm) is preferred.

(3) One of the specimens is to be tested within a maximum of 3 h after machining (for a 14 mm diameter specimen, the time limit is 1.5 h). Where this is not possible, the specimen is to be immediately cooled to -60℃ after machining and kept at that temperature for a maximum period of 5 days. The second specimen is to be tested after baking at 250℃ for 4 h, alternatively 2 h for 14 mm diameter specimen.

(4) A slow strain rate < 0.0003 s^{-1} must be used during the entire test, until fracture occurs (this is approximately 10 min for the 20 mm diameter specimen).

(5) Tensile strength, elongation and reduction of area are to be reported. The acceptance requirement for the test is:

$$Z_1/Z_2 \geq 0.85$$

where: Z_1 = Reduction of area without baking;

Z_2 = Reduction of area after baking.

If the requirement $Z_1/Z_2 \geq 0.85$ is not achieved, the bar material may be subjected to a hydrogen degassing treatment after agreement with CCS. New tests are to be performed after degassing.

3.12.5.4 Failure to meet the requirements will result in rejection of the batch represented, unless it can be clearly attributable to improper simulated heat treatment and the material may be presented for retest after another heat treatment.

3.12.6 Surface quality and tolerances

3.12.6.1 The steel bar is to be free from defects that might impair proper workability and use. Minor surface defects may be repaired by grinding, provided that the admissible tolerance is not exceeded.

3.12.6.2 Unless otherwise specified in the contract, the tolerances of diameter and roundness of steel bars directly used for welding chain cables or mooring chains are to be in compliance with the requirements of Table 3.12.6.2. For steels intended for mooring chains, at least 1% of a batch of steel bars are to be sampled for roundness measurement. The roundness is to be taken by measuring the maximum and minimum diameters at a cross section. The tolerance on roundness is the difference between them.

Tolerance of Diameter and Roundness for Steel Bars **Table 3.12.6.2**

Nominal diameter (mm)	< 25	25 ~ 35	36 ~ 50	51 ~ 80	81 ~ 100	101 ~120	121 ~160	161 ~222
Tolerance on diameter (mm)	-0~+1.0	-0~+1.2	-0~+1.6	-0~+2.0	-0~+2.6	-0~+3.0	-0~+4.0	-0~ + 5.0
Tolerance on roundness (mm)	0.6	0.8	1.1	1.5	1.95	2.25	3.00	4.00

3.12.7 Non-destructive testing

3.12.7.1 Non-destructive testing procedures for the bar material intended for either mooring chain or fittings are to be developed by the bar supplier and submitted together with acceptance criteria to CCS for information at the time of approval.

3.12.7.2 100 percent of bar material intended for either mooring chain or fittings is to be subjected to ultrasonic examination at an appropriate stage of the manufacture in accordance with procedures and acceptance criteria confirmed at the time of approval. The bars are to be free of pipe, cracks and flakes. If the end length of the delivered bars is not subjected to UT then it must be agreed between the bar supplier and the chain manufacturer of what length of bar is to be removed from the ends. The details are to be documented in the approval of each bar supplier. Phased array UT procedures may be applied, subject to approval by CCS.

3.12.7.3 100 percent of the bar material intended for offshore mooring chains is to be examined by magnetic particles, eddy current or magnetic leakage flux testing. Non-destructive testing of surface is to be performed in accordance with recognized standards (e.g. ISO 9934, ISO 15549 etc.). The bars are to be free of injurious surface imperfections such as seams, laps and rolled-in mill scale. Provided that their depth is not greater than 1% of the bar diameter, longitudinal discontinuities may be removed by grinding and blending to a smooth contour.

3.12.7.4 All bars supplied in a machined (peeled) condition are to be 100% visually inspected. CCS may also require: 10% inspected with magnetic particle testing (MT) or eddy current testing (ET) or Magnetic Leakage Flux Testing (MLFT), for longitudinal imperfections. The maximum depth of peeling is to be agreed and documented in the approval of each supplier.

3.12.7.5 The frequency of non-destructive testing may be reduced at the discretion of CCS provided it is demonstrated by statistical means that the quality of products is consistently kept above the required level.

3.12.7.6 Weld repair of bar intended for mooring chain is not permitted.

3.12.8 Marking and certification

3.12.8.1 Each accepted bar is to be stamped with designation on one of the end surfaces according to the requirements of 3.1.7 of this Chapter. For steel bars having diameters of up to and including 40 mm and bundled together for delivery, the marking is to be affixed by a securely fastened tag or label.

3.12.8.2 Each batch of bars is to be furnished with a certificate of conformity signed by CCS Surveyor. The certificate is to contain particulars required by 3.1.7.3 of this Chapter and, when the heat treatment simulated required for the finished chain cables is carried out to specimens according to 3.12.5.1 of this Section, details of heat treatment of specimens, number of specimens and the corresponding mechanical test results. Additionally for Grade MR3S, MR4, MR4S and MR5 bars intended for mooring chains, the certificate is to contain the results of hydrogen embrittlement test, non-destructive testing, etc., and the information of austenitic grain size, non-metallic inclusions and hardenability.

CHAPTER 4 STEEL PIPES AND TUBES

Section 1 GENERAL PROVISIONS

4.1.1 Application

4.1.1.1 The requirements of this Section apply to boiler tubes and superheater tubes, and pipes intended for use in the construction of boilers, pressure vessels and pressure piping systems.

4.1.1.2 For steel tubes subject to elevated working temperatures, details of appropriate mechanical properties at elevated temperatures are to be submitted to CCS for approval.

4.1.1.3 In addition to the requirements of Chapters 1 and 2 of this PART, all pipes and tubes (except Class III pipes) are to be manufactured and tested in accordance with the provisions of relevant Sections of this Chapter (for the grades of piping involved in this Chapter, reference is made to the relevant requirements in Chapter 2 of PART THREE of CCS Rules for Classification of Sea-going Steel Ships).

4.1.1.4 Pipes and tubes for Class III piping systems may be manufactured, tested and accepted in accordance with relevant recognized standards.

4.1.1.5 Pipes and tubes for submarine piping systems and pipes and tubes for offshore engineering steel structures or for transfer of liquid may be manufactured, tested and accepted in accordance with relevant recognized standards.

4.1.1.6 Impact tests for the piping systems (including pipes, valves and fittings) of polar ship which are exposed to low air temperature environments are to satisfy the relevant requirements of Chapter 23, PART EIGHT of Rules for Classification of Sea-going Steel Ships.

4.1.2 Manufacture

4.1.2.1 Pipes and tubes are to be manufactured at works approved by CCS. Unless otherwise agreed, pipes and tubes are to be made of killed steel manufactured by the basic oxygen, electric or open hearth processes, and the steel used is to be manufactured and cast in ingot moulds or by a continuous casting process approved by CCS.

4.1.2.2 Pipes and tubes may be manufactured by any one of the following methods:

(1) hot finished/formed seamless;

(2) cold formed/finished seamless;

(3) electric resistance or induction welded;

(4) electric fusion welded.

4.1.2.3 Care is to be taken during manufacture that the pipe or tube surfaces coming in contact with any non-ferrous metals or their compounds are not contaminated to such an extent as could prove harmful during subsequent fabrication and operation.

4.1.3 Quality

4.1.3.1 The internal and external surfaces of the pipes and tubes are to be free from cracks, laps, laminations, scabs, pinches and hairlines. In case of the foregoing defects, they are to be removed, but the reduction in wall thickness resulting from the removal of defects is not to exceed the permissible minimum wall thickness.

4.1.3.2 The external and internal surfaces of welded pipes are to be free from cracks, scabs, dislocations, burrs, burnings, impressions and deep scratches, but small impressions having a depth not exceeding the minus tolerance in wall thickness, slight dislocations, roll marks and thin scales and traces resulting from grinding and removing of burrs may be accepted.

4.1.3.3 All pipes and tubes are to be reasonably straight and smooth. The ends are to be cut nominally square with the axis of the pipe or tube, and are to be free from excessive burrs.

4.1.3.4 The type and dimensional tolerances of steel pipes and tubes are to comply with relevant recognized standards.

4.1.4 Chemical composition

4.1.4.1 The chemical composition of ladle samples and methods of deoxidation of steel pipes and tubes are to comply with the corresponding requirements specified in relevant Sections of this Chapter.

4.1.5 Heat treatment

4.1.5.1 If required by CCS, pipes and tubes are to be heat treated and supplied in the appropriate

conditions detailed in the relevant Sections of this Chapter.

4.1.6 Test and test specimens

4.1.6.1 Pipes and tubes may be presented for test and inspection in batches. Each batch is to consist of pipes or tubes of the same type of steel, the same size, from the same cast and heat treated in the same furnace charge.

4.1.6.2 For pipes for Class I and II pressure systems and boiler and superheater tubes, the requirements of Table 4.1.6.2 are to be followed. Test specimens are to be cut from at least one pipe selected at random from each batch or part thereof.

Number in Batch of Pipes Table 4.1.6.2

Grade	Outside diameter D (mm)	Number in batch (piece) ①
Class Ⅰ	All	50
Class Ⅱ	D>325	100
	D≤325	200

Note: ① If a steel pipe is made from one slab by rolling and is not subject to heat treatment after saw-cut, all of the sections cut from this pipe can be regarded as one pipe during calculation.

4.1.6.3 Pipes and tubes are to be tested and evaluated and with the test samples prepared in accordance with the relevant requirements given in this Chapter and Chapter 2 of this PART.

4.1.6.4 Normally, longitudinal test specimens are to be taken from the pipes. Where the diameter of pipes is 200 mm or more, test specimens may also be taken transverse to the pipe's axis.

4.1.7 Visual and non-destructive testing

4.1.7.1 All pipes for Class I and II pressure systems, boiler and super heater tubes are to be presented for visual examination of the internal and external surfaces and verification of dimensions.

4.1.7.2 All the welds of welded pipes and tubes are to be examined by non-destructive methods on a continuous basis, and the results of testing are to comply with relevant recognized standards.

4.1.8 Hydraulic test

4.1.8.1 Each pipe or tube is to be subjected to a hydraulic test at the manufacturer's works. Subject to agreement of CCS, either an ultrasonic or eddy current test can be accepted in lieu of the hydraulic test, and technical documents which can demonstrate the efficiency of the method are to be submitted by the manufacturer.

4.1.8.2 The hydraulic test is to be carried out as follows:

(1) The test pressure is to be twice the working pressure of the pipe, and is not to be less than 7.0 MPa. If required by the purchaser, the test pressure may be as specified in the contract, provided that the details are submitted to CCS for information.

(2) The test pressure P mentioned in (1) above need not exceed the value calculated by the following formula:

$$P = 2t\sigma_t / D \quad \text{MPa}$$

where: D — nominal outside diameter of the pipe, in mm;
t — nominal wall thickness of the pipe, in mm;
σ_t — permissible stress, in MPa; for carbon steel pipes, R is to be taken as 80% of the minimum yield strength (R_{eH} or $R_{p0.2}$); for austenitic steel pipes, 80% of the minimum proof strength ($R_{p0.2}$).

(3) The test pressure is to be maintained for sufficient time to permit inspection.

4.1.9 Rectification of defects

4.1.9.1 Surface imperfections may be removed by grinding provided that the thickness of the pipe or tube after dressing is not less than the required minimum thickness. The dressed area is to be blended into the contour of the tube.

4.1.9.2 Where it is proposed to repair minor surface defects by welding, details of the welding procedure specification, including preheating and post weld heat treatment, are to be submitted to CCS for approval. In all cases, the area is to be tested by magnetic particle examination, or, in the case of austenitic steels, by liquid penetrant examination on completion of welding, heat treatment and surface grinding.

4.1.10 Identification

4.1.10.1 Accepted pipes and tubes are to be clearly marked by the manufacturer at the end with CCS stamp and the following:
(1) manufacturer's name and trade mark;
(2) specification of the pipe and grade of steel;
(3) cast number, or marks which will enable the full history of the item to be traced.
Stamps are to be encircled with paint for easy recognition.

4.1.11 Certification
4.1.11.1 The manufacturer is to furnish a certificate giving the following particulars for the pipes and tubes:
(1) purchaser's name and order number;
(2) address to which material is dispatched;
(3) specification or grade of material;
(4) description and dimensions;
(5) cast number and chemical composition of ladle samples;
(6) mechanical test results, and results of intergranular corrosion tests (where applicable);
(7) condition of supply.
Where steel is not produced at the pipe or tube mill, a certificate is to be supplied by the steelmaker stating the process of manufacture, the cast number and the ladle analysis. The works at which the steel was produced are to be approved by CCS.

Section 2 SEAMLESS PRESSURE PIPES

4.2.1 Application
4.2.1.1 The requirements of this Section apply to ferritic steel seamless pressure pipes in carbon, carbon-manganese and low alloy steels.

4.2.2 Manufacture and chemical composition
4.2.2.1 Seamless pressure pipes are to be manufactured by a seamless process and may be hot finished/formed or cold formed/finished.
4.2.2.2 The method of deoxidation and the chemical composition of ladle samples are to comply with the requirements of Table 4.2.2.2.

Deoxidation and Chemical Composition of Seamless Pressure Pipes Table 4.2.2.2

Steel type	Grade (N/mm^2)	Deoxidation	Chemical composition (%)											
			C	Si	Mn	S	P	Ni	Cr	Mo	Cu	Sn	V	Al
Carbon and carbon-manganese	320	Semi-killed or killed	≤ 0.16	-	0.4~0.7	≤0.04	≤0.04	Ni ≤ 0.30 Cr ≤ 0.25 Mo ≤ 0.10 Cu ≤ 0.30 Total ≤ 0.70						
	360		≤ 0.17	≤ 0.35	0.4~0.8	≤0.04	≤0.04							
	410	killed	≤ 0.21	≤ 0.35	0.4~1.2	≤0.04	≤0.04							
	460		≤ 0.22	≤ 0.35	0.8~1.4	≤0.04	≤0.04							
	490		≤ 0.23	≤ 0.35	0.8~1.5	≤0.04	≤0.04							
1Cr0.5Mo	440	killed	0.1~0.18	0.1~0.35	0.4~0.7	≤0.04	≤0.04	≤0.3	0.7~1.1	0.45~0.65	≤ 0.25	≤ 0.03	–	≤0.02
2.25Cr1Mo	410 490		0.08~0.15	0.1~0.35	0.4~0.7	≤0.04	≤0.04	≤0.3	2.0~2.5	0.9~1.2	≤ 0.25	≤ 0.03	–	≤0.02
0.5Cr0.5Mo0.25V	460		0.1~0.18	0.1~0.35	0.4~0.7	≤0.04	≤0.04	≤0.3	0.3~0.6	0.5~0.7	≤ 0.25	≤ 0.03	0.22~0.32	≤0.02

4.2.3 Heat treatment
4.2.3.1 Pipes are to be heat treated and are to comply with the following:
(1) For carbon and carbon-manganese seamless steel pipes, they are to be normalized or normalized and tempered, but may be supplied in the hot finished condition provided that the finishing temperature is sufficiently high to soften the material.
(2) For alloy steel pipes, they are to be heat treated in accordance with the requirements of Table 4.2.3.1(2).

Heat Treatment of Seamless Alloy Pipes **Table 4.2.3.1(2)**

Alloy steel	Method of heat treatment
1Cr0.5Mo	Normalized and tempered
2.25Cr1Mo Grade 410 Grade 490	Fully annealed Normalized and tempered (tempered in 650℃~780℃ or 650℃~750℃)
0.5Cr 0.5Mo 0.25V	Normalized and tempered

4.2.4 Mechanical and technical properties

4.2.4.1 Pipes may be presented for acceptance in batches, and the number of test specimens are to be in accordance with the requirements of 4.1.6 of this Chapter. Each test pipe is to be subjected to tensile and flattening or bend testing. The results of the tests are to comply with the requirements of Table 4.2.4.1.

Mechanical and Technical Properties of Seamless Pressure Pipes **Table 4.2.4.1**

Steel type	Grade (N/mm^2)	Tensile strength R_m min. (N/mm^2)	Yield strength R_{eH} min. (N/mm^2)	Elongation A_5 min. (%)	Flattening test constant C	Bend test diameter of former (mm)
Carbon and carbon-manganese	320	320	195	25	0.10	4t (t being thickness)
	360	360	215	24	0.10	
	410	410	235	22	0.08	
	460	460	265	21	0.07	
	490	490	285	21	0.07	
1Cr0.5Mo	440	440	275	22	0.07	4t
2.25Cr1Mo	410	410	135	20	0.07	4t
	490	490	275	16		
0.5Cr0.5Mo0.25V	460	460	275	15	0.07	4t

Notes: ① For carbon and carbon-manganese steels, the tensile strength range for all grades in the Table is 120 N/mm^2.
② For alloy steels, the tensile strength range for all grades in the Table is 150 N/mm^2.

4.2.4.2 The mechanical properties of seamless pressure pipes at elevated temperatures are given for design purpose in Tables 4.2.4.2(1) and (2).

Yield Strength of Seamless Pressure Pipes at Elevated Temperatures **Table 4.2.4.2(1)**

Steel type	Grade (N/mm^2)	Yield Strength at Elevated Temperatures R^T_{eH} min. (N/mm^2)											
		Temperature (℃)											
		50	100	150	200	250	300	350	400	450	500	550	600
Carbon and carbon-manganese	320	172	168	158	147	125	100	91	88	87	–	–	–
	360	192	187	176	165	145	122	111	109	107	–	–	–
	410	217	210	199	188	170	149	137	134	132	–	–	–
	460	241	234	223	212	195	177	162	159	156	–	–	–
	490	256	249	237	226	210	193	177	174	171	–	–	–
1Cr0.5Mo	440	254	240	230	220	210	183	169	164	161	156	151	–
2.25Cr1Mo	410①	121	108	99	92	85	80	76	72	69	66	64	62
	490②	268	261	253	245	236	230	224	218	205	189	167	145
0.5Cr0.5Mo0.25V	460	266	259	248	235	218	192	184	177	168	155	148	–

Notes: ① Annealed condition.
② Normalized and tempered condition.

Average Rupture Stress of Seamless Pressure Pipes at Elevated Temperatures Table 4.2.4.2(2)

Steel type	Grade (N/mm^2)	Estimated value of stress R^T_m to rupture in 100,000 h (N/mm^2)																				
		Temperature (℃)																				
		380	390	400	410	420	430	440	450	460	470	480	490	500	510	520	530	540	550	560	570	580
Carbon and carbon-manganese	320	171	155	141	127	114	102	90	78	67	57	47	36	–	–	–	–	–	–	–		–
	360	171	155	141	127	114	102	90	78	67	57	47	36	–	–	–	–	–	–	–	–	–
	410	171	155	141	127	114	102	90	78	67	57	47	36	–	–	–	–	–	–	–	–	–
	460	227	203	179	157	136	117	100	85	73	63	55	47	41	–	–	–	–	–	–	–	–
	490	227	203	179	157	136	117	100	85	73	63	55	47	41	–	–	–	–	–	–	–	–
1Cr0.5Mo	440	–	–	–	–	–	–	–	–	–	–	210	177	146	121	99	81	67	54	43	35	–
2.25Cr1Mo	410 (Annealed)	–	–	–	–	–	–	–	196	182	168	154	141	127	115	102	90	78	69	59	51	44
	490① (Normalized & tempered)	–	–	–	–	–	–	–	221	204	186	170	153	137	122	107	93	79	69	59	51	44
0.5Cr0.5Mo0.25V	460	–	–	–	–	–	–	–	–	–	–	218	191	170	150	131	116	100	85	72	59	46

Note: ① When the tempering temperature exceeds 750℃, the values for Grade 410 N/mm^2 are to be used.

Section 3 WELDED PRESSURE PIPES

4.3.1 Application

4.3.1.1 The requirements of this Section apply to welded ferritic steel pressure pipes in carbon, carbon-manganese and low alloy steels.

4.3.1.2 Where it is proposed to use submerged arc longitudinally welded pipes, details of the specification are to be submitted to CCS for approval.

4.3.2 Manufacture and chemical composition

4.3.2.1 Pipes are to be manufactured by the electric resistance or induction welding process.

4.3.2.2 The method of deoxidation and the chemical composition of ladle samples of the pipes are to comply with the requirements of Table 4.2.2.2 of this Chapter, except Grade 490 N/mm^2 carbon and carbon-manganese steels and 2.25CrlMo and 0.5Cr0.5Mo0.25V alloy steels listed therein.

4.3.3 Heat treatment

4.3.3.1 Steel pipes are to be heat treated as follows:

(1) If required by CCS, pipes in carbon and carbon-manganese steels are to be normalized, or normalized and tempered;

(2) Pipes in alloy steels are to be normalized and tempered.

4.3.4 Mechanical and technical properties

4.3.4.1 All pipes are to be presented in batches as specified in 4.1.6 of this Chapter. Test specimens are to be taken from welded pipes in such a way that they are alternately with or without the weld in the middle of the specimens. Reinforcement welds situated within the gauge length of the specimen are to be machined off.

4.3.4.2 Each test pipe is to be subjected to tensile and flattening or bend testing. The test results of pipes are to comply with the requirements given in Table 4.2.4.1 except Grade 490 N/mm^2 carbon and carbon-manganese steels and 2.25CrlMo and 0.5Cr0.5Mo0.25V alloy steels listed therein.

4.3.4.3 The mechanical properties at elevated temperatures for carbon and carbon-manganese steels Grade 320 N/mm^2 to 460 N/mm^2 and 1Cr0.5Mo steel are to comply with the requirements given in Tables 4.2.4.2(1) and (2) of this Chapter.

Section 4 BOILER AND SUPERHEATER TUBES

4.4.1 Application

4.4.1.1 The requirements of this Section apply to boiler and superheater tubes made of carbon, carbon-manganese and alloy steels.

4.4.2 Manufacture and chemical composition

4.4.2.1 Boiler and superheater tubes are to be seamless or welded and are to comply with the relevant requirements of Sections 2 and 3 of this Chapter. The method of deoxidizing and the chemical composition of ladle samples are to comply with the requirements given in Table 4.2.2.2 of this Chapter, except Grade 490 N/mm^2 carbon and carbon-manganese steels and 0.5Cr0.5Mo0.25V alloy steel listed therein.

4.4.3 Heat treatment

4.4.3.1 Boiler and superheater tubes are to be heat treated and are to comply with the appropriate requirements of Table 4.4.3.1.

Condition of Supply of Boiler and Superheater Tubes Table 4.4.3.1

Steel type		Condition of supply
Carbon and carbon-manganese		Normalized or normalized and tempered①
1Cr0.5Mo		Normalized and tempered②
2.25Cr1Mo	Grade 410	Fully annealed
	Grade 490	Normalized and tempered at 650℃~780℃ or 650℃~750℃

Notes: ① Boiler and superheater tubes hot or cold finished seamless may be supplied in the hot finished condition provided that the finishing temperature is sufficiently high to soften the material.

② 1Cr0.5Mo steel may be supplied in the normalized condition when the carbon content exceeds 0.15%.

4.4.4 Mechanical and technical properties

4.4.4.1 Tubes are to be presented for testing in batches in accordance with the requirements of 4.1.6 of this Chapter. Each test pipe is to be subjected at least to tensile, flattening testing or bend, drift expanding testing or flanging testing. The results of the tests are to comply with the requirements given in Table 4.4.4.1.

Mechanical and Technical Properties of Boiler and Superheater Tubes Table 4.4.4.1

Steel type	Grade (N/mm^2)	Tensile strength R_m Min. (N/ mm^2)①	Yield strength R_{eH} Min. (N/mm^2)①	Elongation A_5 Min. (%)	Flattening test constant C	Bend test diameter of former (mm)	Drift expanding or flanging test increase in outside diameter (%) Inside/outside diameter		
							≤ 0.6	> 0.6 ≤ 0.8	> 0.8
Carbon and carbon-manganese	320	320	195	25	0.10	4t (t being thickness)	12	15	19
	360	360	215	24	0.10		12	15	19
	410	410	235	22	0.08		10	12	17
	460	460	265	21	0.07		8	10	15
1Cr0.5Mo	440	440	275	22	0.07	4t	8	10	15
2.25Cr1Mo	410	410	135	20	0.07	4t	8	10	15
	490	490	275	16					

Notes: ① For carbon and carbon-manganese steels, the tensile strength range for all grades in the Table is 120 N/mm^2.

② For alloy steels, the tensile strength range for all grades in the Table is 150 N/mm^2.

4.4.4.2 The mechanical properties at elevated temperatures of carbon and carbon-manganese steels Grades 320 N/mm^2 to 460 N/mm^2 and 1Cr0.5Mo and 2.25Cr1Mo alloy steels are to comply with the requirements given in Tables 4.2.4.2(1) and (2) of this Chapter.

Section 5 FERRITIC STEEL PRESSURE PIPES FOR LOW TEMPERATURE SERVICE

4.5.1 Application

4.5.1.1 The requirements of this Section apply to carbon, carbon-manganese and nickel alloy pipes suitable for use in the piping arrangements for cargo tanks and processing equipment of liquefied gas carriers where the design temperature is 0℃to -165℃.

4.5.2 Manufacture and chemical composition

4.5.2.1 The pipes are to be manufactured in accordance with the methods given in Table 4.5.2.1.

Method of Manufacture of Ferritic Steel Pressure Pipes for Low Temperature Service

Table 4.5.2.1

Steel type	Method of manufacture
Carbon and carbon-manganese	Hot or cold finished seamless or electric resistance or induction welded
Nickel alloy	Hot or cold finished seamless

4.5.2.2 Pipes using longitudinal welding and spiral welding are to comply with the relevant requirements of Section 3 of this Chapter on welded pressure pipes in addition to satisfying the requirements of this Section.

4.5.2.3 The method of deoxidation and the chemical composition of ladle samples are to comply with the appropriate requirements given in Table 4.5.2.3.

Deoxidation and Chemical Composition of Ferritic Steel Pressure Pipes for Low Temperature Service

Table 4.5.2.3

Steel type	Grade (N/mm^2)	Deoxidation	Chemical composition (%)							
			C	Si	Mn	P	S	Ni	Residual elements	Other elements①②
Carbon	360	Fully killed grain practice	≤0.17	0.10~0.35	0.40~1.00	≤0.03	≤0.025		Cr≤0.25; Cu≤0.30 Mo≤0.10; Ni≤0.30 Total≤0.70	Al≥0.015 (Acid soluble)
Carbon-manganese	410 460		≤0.20	0.10~0.35	0.60~1.40	≤0.03	≤0.025			Al≥0.015 (Acid soluble)
3.5Ni	440	Fully killed	≤0.15	0.10~0.35	0.30~0.90	≤0.040	≤0.040	3.25~3.75	0≤0.25 Cu≤0.30 Mo≤0.10 Total≤0.60	–
9Ni	690		≤0.13	0.10~0.35	0.30~0.90	≤0.040	≤0.040	8.50~9.50		–

Notes: ① Al may be wholly or partly replaced by other fine grain elements

② Where a minimum Al of 0.015% is specified, the determination of the total aluminum is acceptable provided that the result is not less than 0.020%.

4.5.3 Heat treatment

4.5.3.1 The heat treatment of the pipes is to comply with the requirements given in Table 4.5.3.1.

Heat Treatment of Ferritic Steel Pressure Pipes for Low Temperature Service Table 4.5.3.1

Steel type	Delivery condition
Carbon or carbon-manganese	Normalized or agreed heat treatment
3.5Ni	Normalized or normalized and tempered or quenched and tempered
9Ni	Double normalized and tempered or quenched and tempered

4.5.4 Mechanical and technical properties

4.5.4.1 All pipes are to be presented for tensile and flattening or bend tests in batches as defined in 4.1.6.2 and 4.1.6.3 of this Chapter.

Where the wall thickness allows for standard specimen the width of which is 5 mm or greater to be taken, an impact test is to be carried out at the test temperatures specified in Table 4.5.4.2 for each pipe to be tested. The impact tests are to be carried out for one set of three Charpy V-notch test specimens cut in the longitudinal direction and with the notch perpendicular to the original surface of the pipe. The dimensions of the test specimens and the testing methods are to be in accordance with the relevant requirements of Section 3, Chapter 2 of this PART.

4.5.4.2 The results of all tests are to comply with the appropriate values given in Table 4.5.4.2.

Mechanical and Technical Properties of Ferritic Steel Pressure Pipes for Low Temperature Service

Table 4.5.4.2

Steel type	Grade (N/mm^2)	Tensile strength① R_m min. (N/mm^2)	Yield strength① R_{eH} min. (N/mm^2)	Elongation A_5 min. (%)	Flattening test constant C	Bend test diameter of former (mm)	Charpy V-notch impact test	
							Test temp (℃)	Average energy② min.(J)
Carbon	360	360	210	24	0.10	$4t$②	③	27
Carbon-manganese	410	410	235	22	0.08	$4t$		27
	460	460	260	21	0.07			
3.5Ni	440	440	245	16	0.08	$4t$	-95	34
9Ni	690	690	510	15	0.08	$4t$	-196	41

Notes:① For carbon and carbon-manganese steels, the tensile strength range for all grades in the Table is 120 N/mm^2. For nickel alloy steels, the tensile strength range for all grades in the Table is 150 N/mm^2.

② t is thickness of the specimen.

③ The test temperature is to be 5℃ below the design temperature or -20℃, whichever is the lower.

Section 6 AUSTENITIC AND AUSTENITIC/FERRITIC DUPLEX STAINLESS STEEL PRESSURE PIPES

4.6.1 Application

4.6.1.1 The requirements of this Section apply to austenitic stainless steel pressure pipes where the design temperature is not less than -165℃and austenitic stainless steel and austenitic/ferritic duplex stainless steel pressure pipes used in corrosive environment.

4.6.1.2 Austenitic stainless steel pressure pipes are also suitable for service at elevated temperatures. When such applications are proposed, details of the chemical composition, mechanical properties and heat treatment are to be submitted to CCS for approval.

4.6.1.3 Austenitic/ferritic duplex stainless steels are generally used where the design temperature is between 0℃ to 300℃.

4.6.2 Manufacture and chemical composition

4.6.2.1 Pipes are to be manufactured by a seamless or a continuous automatic electric fusion welding process. Welding is to be in a longitudinal direction.

4.6.2.2 The chemical composition of the ladle samples is to comply with the appropriate requirements of Table 4.6.2.2(1) or 4.6.2.2(2).

Chemical composition of Austenitic Stainless Steel Pressure Pipes Table 4.6.2.2(1)

Grade	Uniform number code	Chemical composition (%)									
		C	Si	Mn	P	S	Cr	Ni	Mo	N	Other elements
06Cr19Ni10	S30408	≤0.08	≤1.00	≤2.00	≤0.045	≤0.030	18.0~20.0	8.0~11.0	—	—	—
022Cr19Ni10	S30403	≤0.03	≤1.00	≤2.00	≤0.045	≤0.030	18.0~20.0	8.0~12.0	—	—	—
06Cr17Ni12Mo2	S31608	≤0.08	≤1.00	≤2.00	≤0.045	≤0.030	16.0~18.0	10.0~14.0	2.0~3.0	—	—
022Cr17Ni12Mo2	S31603	≤0.03	≤1.00	≤2.00	≤0.045	≤0.030	16.0~18.0	10.0~14.0	2.0~3.0	—	—
06Cr19Ni13Mo3	S31708	≤0.08	≤1.00	≤2.00	≤0.045	≤0.030	18.0~20.0	11.0~15.0	3.0~4.0	—	—
022Cr19Ni13Mo3	S31703	≤0.03	≤1.00	≤2.00	≤0.045	≤0.030	18.0~20.0	11.0~15.0	3.0~4.0	—	—
06Cr18Ni10Ti	S32168	≤0.08	≤1.00	≤2.00	≤0.045	≤0.030	17.0~19.0	9.0~12.0	—	—	5C≤Ti≤0.80
06Cr18Ni11Nb	S34778	≤0.08	≤1.00	≤2.00	≤0.045	≤0.030	17.0~19.0	9.0~12.0	—	—	10C≤Nb≤1.10

Chemical Composition of Duplex Stainless Steel Table 4.6.2.2(2)

Grade	Uniform number code	Chemical composition (%)									
		C	Mn	Si	P	S	Cr	Ni	Mo	N	Other elements
022Cr22Ni5Mo3N	S22253	≤0.03	≤2.0	≤1.0	≤0.030	≤0.020	21.0~23.0	4.5~6.5	2.5~3.5	0.08~0.20	
022Cr23Ni5Mo3N	S22053	≤0.03	≤2.0	≤1.0	≤0.030	≤0.020	22.0~23.0	4.5~6.5	3.0~3.5	0.14~0.20	
03Cr25Ni6Mo3Cu2N	S25554	≤0.04	≤1.5	≤1.0	≤0.035	≤0.030	24.0~27.0	4.5~6.5	2.9~3.9	0.10~0.25	1.5≤Cu≤2.5
022Cr25Ni7Mo4N	S25073	≤0.03	≤1.2	≤0.8	≤0.035	≤0.020	24.0~26.0	6.0~8.0	3.0~5.0	0.24~0.32	Cu≤0.50

4.6.3 Heat treatment

4.6.3.1 All pipes are to be supplied in the solution treated condition.

4.6.4 Mechanical and technical properties

4.6.4.1 All austenitic stainless steel or austenitic/ferritic duplex stainless steel pressure pipes are to be presented in batches as defined in 4.1.6 of this Chapter for Class I and II piping systems. Each pipe selected for test is to be subjected to tensile and flattening or bend tests. The results of all tests are to comply with the appropriate requirements given in Table 4.6.4.1(1) or 4.6.4.1(2).

Mechanical and Technical Properties of Austenitic Stainless Steel Pressure Pipes Table 4.6.4.1(1)

Grade	Uniform number code	Proof strength $R_{p0.2}$ min. (N/mm^2)	Proof strength $R_{p1.0}$ min. (N/mm^2)	Tensile strength R_m (N/mm^2)	Elongation A_5 min. (%)	Flattening test constant C	Bend test diameter of former (mm)
06Cr19Ni10	S30408	205	245	520 ~ 720	35	0.09	3t (t being thickness)
022Cr19Ni10	S30403	175	205	480 ~ 680	35	0.09	3 t
06Cr17Ni12Mo2	S31608	205	245	520 ~ 720	35	0.09	3 t
022Cr17Ni12Mo2	S31603	175	205	480 ~ 680	35	0.09	3 t
06Cr19Ni13Mo3	S31708	205	245	520 ~ 720	35	0.09	3 t
022Cr19Ni13Mo3	S31703	175	205	480 ~ 680	35	0.09	3 t
06Cr18Ni10Ti	S32168	205	245	520 ~ 720	35	0.09	3 t
06Cr18Ni11Nb	S34778	205	245	520 ~ 720	35	0.09	3 t

Notes: ① The tensile strength range for all grades in the Table is 200 N/mm^2.

② The proof strength values $R_{p1.0}$ are given for information purposes only and unless otherwise agreed, are not required to be verified by testing.

Mechanical Properties of Duplex Stainless Steel Table 4.6.4.1(2)

Grade	Uniform number code	Proof strength $R_{p0.2}$ min. (N/mm^2)	Tensile strength R_m min. (N/mm^2)	Elongation A_5 min. (%)	Flattening test constant C	Bend test diameter of former D
022Cr22Ni5Mo3N	S22253	450	620	25	0.09	$3t$①
022Cr23Ni5Mo3N	S22053	450	620	25	0.09	$3t$①
03Cr25Ni6Mo3Cu2N	S25554	490	690	25	0.09	$3t$①
022Cr25Ni7Mo4N	S25073	550	790	20	0.09	4t

Note: ① For bend tests carried out on the welds of the welding tubes, the diameter of the former may be 4t.

4.6.4.2 Unless otherwise agreed, austenitic stainless steel pipes listed in this Section are generally not required to be impact tested. Where austenitic stainless steel pipes (seamless and welded) are used in working temperature at -100℃ and below, and where the wall thickness allows standard impact specimens the width of which is 5 mm or greater to be taken, Charpy V-notch impact tests at temperature below -196℃ may be required. The minimum average value of the test is not to be lower than 41 J (specimen taken longitudinally).

4.6.5 Intergranular corrosion test

4.6.5.1 For steel pipes having direct contact with corrosive chemicals, 1% of the number of pipes is to be taken from each batch as specified in 4.1.6 of this Chapter, with a minimum of one pipe, and test specimens are prepared and intergranular corrosion tests are carried out according to the provisions of Section 7, Chapter 2 of the Rules.

CHAPTER 5 STEEL FORGINGS

Section 1 GENERAL PROVISIONS

5.1.1 Application

5.1.1.1 This Chapter applies to steel forgings intended for use in the construction of ships, machinery, pressure vessels and piping systems, which are to be manufactured in accordance with 3.1.2.2 and 3.1.2.3 of this PART. Where it is proposed to use carbon or carbon-manganese steels or alloy steels other than those specified in this Chapter, details of the chemical composition, mechanical properties and heat treatment process are to be submitted to CCS for approval, and such steels, subject to agreement of CCS, may be accepted in accordance with the relevant recognized standards.

5.1.1.2 Impact tests for the steel forgings of polar ship which are exposed to low air temperature environments are to satisfy the relevant requirements of Chapter 23, PART EIGHT of Rules for Classification of Sea-going Steel Ships.

5.1.1.3 The requirements of this Chapter are also applicable to rolled slabs and billets used as a substitute for forgings and to rolled bars used for the manufacture (by machining operations only) of shafts, bolts, studs and other components of similar shape.

5.1.1.4 Forgings are to be made at works which have been approved by CCS. The steel used is to be manufactured at steel works approved by CCS.

5.1.2 Chemical composition

5.1.2.1 The chemical composition of each heat is generally to be determined on a sample taken during the pouring of the heat. When multiple heats are tapped into a common ladle, the ladle analysis is to apply. The chemical composition of ladle samples is to comply with the requirements detailed in subsequent sections of this Chapter. The chemical composition selected is to be appropriate for the type of steel, dimensions and required mechanical properties of the forgings being manufactured.

5.1.2.2 Suitable grain refining elements such as aluminum, niobium or vanadium may be used at the discretion of the manufacturer. The content of such elements is to be reported in the ladle analysis.

5.1.2.3 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.

5.1.3 Forging and welding

5.1.3.1 All forgings are to be made from killed steel.

5.1.3.2 When forgings are made directly from ingots or from billets forged from ingots, the ingots are to be cast in chill moulds with the larger cross-section uppermost and with efficient feeder heads.

5.1.3.3 The forgings are to be gradually and uniformly heated and are to be formed as closely as possible to the finished shape and size with a reasonable machining allowance.

5.1.3.4 Adequate top and bottom discards are to be made to ensure freedom from piping and harmful segregations in the finished forgings.

5.1.3.5 The centre areas of all forgings are to have adequate plastic deformation. The plastic deformation is to be such as to ensure soundness, uniformity of structure and satisfactory mechanical properties after heat treatment. For steel forgings in which the fibre deformation is mainly longitudinal, the reduction ratio is not to be less than that shown in Table 5.1.3.5.

Forging Reduction Ratio of Steel Forgings **Table 5.1.3.5**

Method of forging	Total reduction ratio①②
Made directly from ingots or from billets forged from ingots	3:1 for $L > D$ 1.5:1 for $L \leq D$
Made from rolled products③	4:1 for $L > D$ 2:1 for $L \leq D$

Notes: ① The reduction ratio means the ratio of the average cross-sectional area of an ingot to that of a forging (billet).Where an ingot is initially upset, this reference area may be taken as the average cross-sectional area after this operation.

② L and D are the length and diameter of the finished forging.

③ Where rolled bars are used as a substitute for forgings, the total reduction ratio is to be not less than 6:1.

Disc type forgings, such as gear wheels, are to be made by upsetting, and the thickness of any part of the

disc is to be not more than half of the length of the billet from which it was formed, provided that this billet has received an initial forging reduction of not less than 1.5:1. Where the piece used has been cut directly from an ingot, or where the billet has received an initial reduction of less than 1.5:1, the thickness of any part of the disc is to be not more than one third of the length of the original piece.

5.1.3.6 Rings and other types of hollow forgings are to be made from pieces cut from ingots or billets and which have been suitably punched, bored or trepanned prior to expanding or hollow forging. Alternatively, pieces from hollow cast ingots may be used. The wall thickness of the forging is to be not more than half of the thickness of the prepared hollow piece from which it was formed. Where this is impracticable, the forging procedure is to be such as to ensure that adequate work is given to the piece prior to punching, etc. This may be either longitudinal or upset working of not less than 2:1.

5.1.3.7 Where the operating loads imposed on certain components, e.g. crank shafts, necessitate a particular fibre flow, the method of manufacture is to be submitted to CCS for approval.

5.1.3.8 Where two or more forgings are joined by welding to form a composite component, or the forgings are joined with other steel members by welding to form a composite component, the welding procedure specification is to be submitted to CCS for approval. If necessary, welding procedure approval tests may be required.

5.1.4 Heat treatment

5.1.4.1 At an appropriate stage of manufacture, after completion of all hot working operations, forgings are to be suitably heat treated to refine the grain structure and to obtain the required mechanical properties.

5.1.4.2 If for any reason a forging is subsequently heated for further hot working, the forging is to be reheat-treated.

5.1.4.3 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.

5.1.4.4 Where a forging is subject to local heating and hot or cold straightening, after the final heat treatment, a subsequent stress relief heat treatment is to be considered.

5.1.4.5 Where it is intended to surface harden forgings, full details of the proposed procedure and specification are to be submitted to CCS for approval. For the purposes of this approval, the manufacturer is required to demonstrate by tests 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.

5.1.4.6 The forge is to maintain records of heat treatment identifying the furnace used, furnace charge, date, temperature and time at temperature. The records are to be presented to the Surveyor on request.

5.1.5 Test material and testing

5.1.5.1 Test material, sufficient for the required tests and for possible retest purposes, is to be provided with a cross-sectional area of not less than that part of the forging which it represents. The test material is to be integral with each forging except as provided in 5.1.5.2 and 5.1.5.3. Separately forged test material is to have a reduction ratio similar to that used for the forgings represented.

5.1.5.2 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.

5.1.5.3 Where a number of small forgings of about the same shape and size are made from one cast and heat treated in the same furnace charge, batch testing procedures may be adopted in accordance with the following requirements:

(1) For normalized forgings with mass up to 1,000 kg each, the weight of each batch does not exceed 6 t.

(2) For quenched and tempered forgings with mass up to 500 kg each, the weight of each batch does not exceed 3 t.

(3) For rolled bars of the same diameter, the weight of each batch does not exceed 2.5 t.

Where the batch testing procedure is adopted, one of the forgings for test purposes, or alternatively, separately forged test samples may be used. These test samples are to have a forging reduction similar to that used for the forgings which they represent, and are to be properly identified and heat treated together with the forgings.

5.1.5.4 Normally a set of tests is to consist of one tensile test specimen and, when required, three impact test specimens. The longitudinal axis of tensile and impact test specimens is to be parallel (for longitudinal specimens) to the axis of steel forgings or tangential (for tangential specimens) to the concentric circle of

steel forgings. Test specimens are to be prepared in accordance with the relevant requirements of Chapter 2 of this PART and of this Chapter.

5.1.5.5 Unless specified otherwise, when a test specimen is taken, the longitudinal axis of the specimen is to be positioned as follows:

(1) For thickness or diameter up to maximum 50 mm, the axis is to be at the mid-thickness or the center of the cross section.

(2) For thickness or diameter greater than 50 mm, the axis of the middle of the specimen is to be at one quarter thickness (mid-radius) or 80 mm, whichever is less, below any heat treated surface.

5.1.5.6 Unless specified otherwise, test samples are not to be taken from a forging until all heat treatment has been completed.

5.1.5.7 The tensile test specimens are to have a cross-sectional area of not less than 150 mm^2. Where this is precluded by the dimensions of the forging, the test specimen is to be of the largest practicable cross-sectional area, subject to agreement of CCS. Charpy V-notch test specimens are to be used for the impact specimens.

5.1.5.8 The procedures used for tensile and impact tests are to be in accordance with the requirements of Chapter 2 of this PART. Hardness tests are to be carried out whenever specified in subsequent sections of this Chapter. Unless otherwise agreed upon, all tests are to be carried out in the presence of the Surveyor.

5.1.6 Visual and non-destructive testing

5.1.6.1 Before acceptance, all forgings are to be presented to the Surveyor for visual examination. Where applicable, this is to include the examination of internal surfaces and bores. Unless otherwise agreed, the manufacturer is to be responsible for checking the accuracy of dimensions of forgings.

5.1.6.2 During visual examination, the surfaces of forgings are to be kept clean, and free of substances that interfere with the examination, such as oxide scales and oil. The surfaces of forgings may be treated by local grinding, shot or sand blasting, flame chipping, wire brushing, pickling or other chemical means as necessary.

5.1.6.3 When required by the construction Rules, or by the approved procedure for welded composite components in accordance with 5.1.3.8 of this Section, appropriate non-destructive testing is to be carried out before acceptance and the results are to be reported by the manufacturer.

5.1.6.4 Non-destructive testing is to be carried out after the forgings have been machined to a condition suitable for this type of examination and after the final heat treatment, and the following requirements are to be complied with:

(1) the test methods and extent are to comply with the requirements of Appendix 7A, Chapter 7 of CCS Guidelines for Inspection of Hull Welds;

(2) where current flow methods are used for magnetization, particular care is to be taken to avoid damaging machined surfaces by contact burns from the prods;

(3) radial and axial scanning is generally to be carried out when carrying out ultrasonic examination. When the dimensions and shape are limited, radial or axial scanning may be carried out;

(4) unless specified by the plan or otherwise agreed, the results of non-destructive testing are to comply with the requirements of Appendix 7A, Chapter 7 of CCS Guidelines for Inspection of Hull Welds.

5.1.6.5 Unless agreed by CCS Surveyor, these tests are to be carried out in the presence of the Surveyor.

5.1.7 Rectification of defects

5.1.7.1 Small surface imperfections may be removed by grinding or by chipping and grinding provided that the component dimensions are acceptable. The resulting grooves are to have a bottom radius of at least 3 times the groove depth, with edges being sufficiently rounded. Complete removal of these imperfections may be proved by magnetic particle or dye penetrant testing, as appropriate.

5.1.7.2 Repair welding of forgings except crankshaft forgings may be permitted subject to prior approval of CCS. 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 to CCS for approval.

5.1.7.3 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.

5.1.8 Identification

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

5.1.8.2 All forgings which have been satisfactorily inspected by CCS are to be clearly marked by the manufacturer in at least one place with the following:
(1) CCS logo;
(2) cast number or other marking which will enable the full history of the forging to be traced;
(3) test pressure (if any);
(4) brand or grade of forging material;
(5) abbreviated name of the survey unit and personal stamp of Surveyor responsible for inspection;
(6) certificate number.
When the area is not enough for all marks, at least the items (1) to (3) are to be marked.
Any mark is to be encircled with paint for easy recognition.
5.1.8.3 Where small forgings are manufactured in large numbers, modified arrangements for identification may be submitted by the manufacturer to CCS for information.

5.1.9 Certification
5.1.9.1 The manufacturer is to provide the required type of inspection certificate giving the following particulars for each forging or batch of forgings which has been accepted:
(1) purchaser's name and order number;
(2) description of forgings (name) and steel quality (grade), and marking which will enable the full history of the forging to be traced;
(3) steelmaking process, cast number and chemical analysis of ladle sample;
(4) details of heat treatment, including temperature and holding times;
(5) results of mechanical tests;
(6) results of macrostructure examination (if any);
(7) forging reduction ratio;
(8) test pressure (if any);
(9) method and results of non-destructive testing (where applicable).

Section 2 FORGINGS FOR HULL STRUCTURES

5.2.1 Application
5.2.1.1 The requirements of this Section apply to carbon, carbon manganese or alloy steel forgings intended for use in hull structures such as rudder axles, rudder posts, rudder stocks, rudder pintles, stems and stern frames.

5.2.2 Chemical composition
5.2.2.1 For hull structural forgings either intended for welding or not intended for welding, the chemical composition of ladle samples is to comply with the requirements given in Table 5.2.2.1.

Chemical Composition of Forgings for Hull Structures **Table 5.2.2.1**

Steel type	Chemical composition (%)									
	C	Si	Mn	S	P	Cr	Mo	Ni	Cu	Total residuals
Carbon and carbon-manganese	≤ 0.23①②	≤ 0.45	0.30~1.50	≤ 0.035	≤ 0.035	≤ 0.30③	≤ 0.15③	≤ 0.40③	≤ 0.30③	≤ 0.85
Alloy	④	≤ 0.45	④	≤ 0.035	≤ 0.035	④	④	④	≤ 0.30③	–

Notes: ① The carbon content may be increased above this level provided that the carbon equivalent (C_{eq}) is not more than 0.41%, calculated using the following formula:

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

② The carbon content of carbon and carbon-manganese steel forgings not intended for welded construction may be 0.65% maximum.
③ Elements are considered as residual elements.
④ Specification is to be submitted for information.
⑤ Rudder stocks and pintles are to be of weldable quality.

5.2.3 Heat treatment
5.2.3.1 Unless otherwise provided, forgings are to be supplied in one of the following conditions:

(1) fully annealed;
(2) normalized;
(3) normalized and tempered (tempered at a temperature not less than 550℃);
(4) quenched and tempered (tempered at a temperature not less than 550℃).

5.2.3.2 Unless otherwise provided, alloy steels are to be supplied in the quenched and tempered condition (tempered at a temperature not less than 550℃).

5.2.4 Mechanical properties

5.2.4.1 Preparation of test specimens for forgings

(1) At least one tensile specimen is generally to be taken from each forging in a longitudinal direction. At the discretion of the manufacture, the alternative directions or positions as shown in Figure 5.3.4.4 may be used.

(2) Where a forging exceeds both 4000 kg in mass and 3 m in length, tensile test specimens are to be taken from each end. These limits refer to the "as forged" mass and length but excluding the test material.

5.2.4.2 The results of all tensile tests of steel forgings are to comply with the requirements given in Table 5.2.4.2.

For large forgings, where tensile tests are taken from each end, the variation in tensile strength is not to exceed 70 N/mm^2.

Mechanical Properties for Hull Steel Forgings **Table 5.2.4.2**

Steel type	Tensile strength①② R_m min. (N/mm^2)	Yield strength R_{eH} min. (N/mm^2)	Elongation A_5 min. (%)		Reduction of area Z min. (%)	
			Long.	Tang.	Long.	Tang.
Carbon and carbon-manganese	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

Notes: ① For forgings with a specified minimum tensile strength < 600 N/mm^2, the tensile strength range is 120 N/mm^2; for forgings with a specified minimum tensile strength ≥ 600 N/mm^2, the tensile strength range is 150 N/mm^2.
②Where 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.

5.2.4.3 For ships navigating in ice with an Ice Class Notation B1* or B1, the forgings for the rudder stock, axle or pintle are, in addition to the tests required by 5.2.4.1 of this Section, to be subjected to Charpy V-notch impact tests at -10℃. A set of three impact test specimens is to be provided, and the average impact energy is not to be lower than 27 J.

5.2.5 Non-destructive testing

5.2.5.1 Hull structural forgings such as rudder stocks and axles, and flanges of cranes are to be ultrasonically examined. For the root of flange and taper, surface examination is to be carried out.

Section 3 FORGINGS FOR SHAFTING AND MACHINERY

5.3.1 Application

5.3.1.1 The requirements of this Section apply to carbon and carbon-manganese steel forgings for shafting and other items of machinery which are not within the scope of Sections 4 to 8 of this Chapter.

5.3.1.2 Where it is proposed to use alloy steel forgings, details of the chemical composition, mechanical properties and heat treatment process are to be submitted to CCS for approval.

5.3.1.3 Hot rolled steel bars used in the construction (by machining operations only) of intermediate shafts, tailshafts, screwshafts, etc., are to have a diameter not exceeding 250 mm.

5.3.2 Chemical composition

5.3.2.1 The chemical composition of ladle samples for forgings is to comply with the requirements of Table 5.3.2.1.

Chemical Composition of Forgings for Shafting and Machinery **Table 5.3.2.1**

Steel type	Chemical composition (%)									
	C	Si	Mn	S	P	Cr	Mo	Ni	Cu②	Total residuals
Carbon and carbon-manganese	≤ 0.65①	≤ 0.45	0.30~1.50	≤ 0.035	≤ 0.035	≤ 0.30②	≤ 0.15②	≤ 0.40②	≤ 0.30	≤ 0.85
Alloy③	≤ 0.45	≤ 0.45	0.30~1.00	≤ 0.035	≤ 0.035	≥ 0.40④	≥ 0.15④	≥ 0.40④	≤ 0.30	–

Notes: ① The carbon content of carbon and carbon-manganese steel forgings intended for welded construction is to be 0.23 maximum. The carbon content may be increased above 0.23% provided that the carbon equivalent (C_{eq}) is not more than 0.41%, calculated using the following formula:

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

② Elements are considered as residual elements unless shown as a minimum.

③ Where alloy steel forgings are intended for welded constructions, the proposed chemical composition is subject to approval by CCS.

④ One or more of the elements is to comply with the minimum content.

5.3.2.2 Where the carbon equivalent of carbon and carbon-manganese steel forgings intended for welded construction is above 0.41%, an approval test of the welding procedure is to be taken into consideration.

5.3.2.3 Where there are cleanliness requirements for forgings, concentration of hazardous elements and gas is to be strictly controlled.

5.3.3 Heat treatment

5.3.3.1 Carbon or carbon-manganese steel forgings are to be heat treated as follows:

(1) fully annealed; or

(2) normalized; or

(3) normalized and tempered; or

(4) quenched and tempered.

The tempering temperature is not to be less than 550℃.

Forgings having a tensile strength exceeding 700 N/mm^2 are to be quenched and tempered.

5.3.3.2 Alloy steel forgings are to be heat treated as follows:

(1) quenched and tempered; or

(2) normalized and tempered.

The tempering temperature is not to be less than 550℃.

Where alloy steel forgings are supplied in the normalized and tempered condition, the mechanical properties are to be in compliance with the requirements of recognized international or national standards.

5.3.4 Tests and test specimens

5.3.4.1 At least one test sample sufficient for the preparation of various test specimens is to be made at one end (corresponding to the top end of the forged ingot) of each forging. For forgings made from one ingot and heat treated in the same furnace charge or small forgings in batches, at least one forging is to be taken as the test sample.

5.3.4.2 Where a forging exceeds both 4 t in mass and 3 m in length, one set of test specimens is to be taken from each end. These limits refer to the "as forged" mass and length but excluding the test material.

5.3.4.3 The tests and number of test specimens for forgings are to comply with the requirements of Table 5.3.4.3.

Tests and Number of Test Specimens of Forgings for Shafting and Machinery **Table 5.3.4.3**

Forgings	Tests and number of test specimens	
	Carbon and carbon-manganese steel	Alloy steel
Intermediate shafts, thrust shafts, tube shafts, screwshafts, connecting rods, piston rods, crossheads, supercharger rotor shafts, forgings for shafts, studs of cylinder heads, tie bolts, main bearing studs, shaft coupling bolts, top and bottom end bolts of connecting rods, suction and exhaust valves, important forgings for the transmission of shafting	1. Chemical analysis 2. Tensile test, at least one test specimen	1. Chemical analysis 2. Tensile test, at least one test specimen 3. Impact test, at least one set of three test specimens 4. Inclusion analysis①

Note: ① Applicable to intermediate shaft forgings specified by 5.3.4.5 of this Section.

5.3.4.4 The test specimens are in general to be taken in the longitudinal direction (position A), but the manufacturer may use alternative directions or positions as shown in Figures 5.3.4.4(1), (2) and (3).

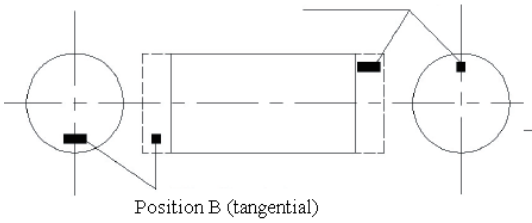


Figure 5.3.4.4(1)

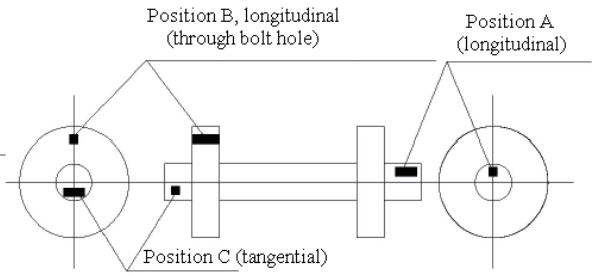
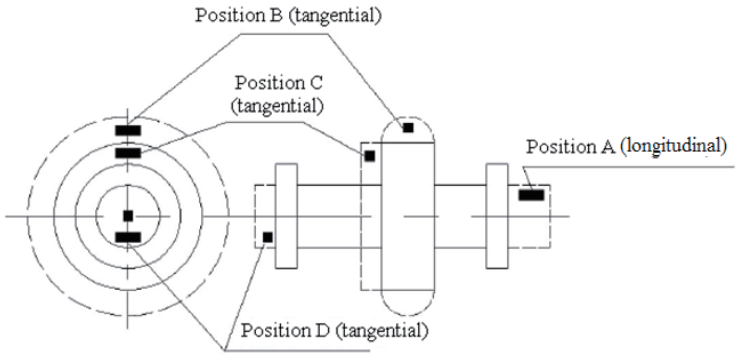


Figure 5.3.4.4(2)



Flanged shaft with collar

Figure 5.3.4.4(3)

5.3.4.5 For alloy steel forgings which use R_m value greater than 800 N/mm^2 to calculate shaft diameter according to 11.2.2.1, PART THREE of the Rules for Classification of Sea-going Steel Ships and which have a tensile strength greater than 800 N/mm^2, but less than 950 N/mm^2 intended for use as intermediate shaft material, a test specimen for inclusion analysis is to be taken from the location as close to the head of the representative forging (or rolled piece) as possible in each heat. The specimen is to be analyzed in accordance with ISO 4967 method A and the inclusions are not to be greater than those required by Table 5.3.4.5.

Cleanliness Requirements for Forgings **Table 5.3.4.5**

Inclusion group	A		B		C		D		DS
Series	Fine	Thick	Fine	Thick	Fine	Thick	Fine	Thick	—
Limiting chart diagram index	1	1	1.5	1	1	1	1	1	1

5.3.5 Mechanical properties

5.3.5.1 The mechanical properties of forgings for shafting and machinery are to comply with the requirements of Table 5.3.5.1.

Mechanical Properties of Forgings for Shafting and Machinery **Table 5.3.5.1**

Steel type	Tensile strength①② R_m min. (N/mm^2)	Yield strength R_{eH} or $R_{p0.2}$ min. (N/mm^2)	Elongation A_5 min. (%)		Reduction of area Z min. (%)		Hardness③ (HB)
			Long.	Tang.	Long.	Tang.	
Carbon and carbon-manganese	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
	1000	700	12	8	35	24	290 ~ 365
	1100	770	11	7	35	24	320 ~ 385

Notes: ① For forgings with a specified minimum tensile strength < 900 N/mm^2, the tensile strength range is 150 N/mm^2; for forgings with a specified minimum tensile strength ≥ 900 N/mm^2, the tensile strength range is 200 N/mm^2.
② Where it is proposed to use a steel with a specified minimum tensile strength intermediate to those given, corresponding minimum values for the other properties may be obtained by interpolation.
③ Hardness values are given for information purposes only.

5.3.5.2 The results of impact tests for alloy steel forgings in the normalized and tempered or quenched and tempered condition are to comply with the requirements of Table 5.4.6.2 of this Chapter.
5.3.5.3 For ships navigating in ice with an Ice Class Notation B1* or B1, the forgings for the screwshaft of all steel types listed in Table 5.3.5.1 are to be subject to Charpy V-notch impact tests at -10℃. A set of three impact test specimens is to be provided (from the propeller end of each shaft), and the average impact energy is not to be lower than 27 J.
5.3.5.4 Where tensile test specimens are taken from different positions of a forging, the variation in tensile strength is not to exceed the following:

Tensile strength (N/mm^2)	Difference in tensile strength (N/mm^2)
< 600	≤ 70
≥ 600	≤ 100

5.3.6 Non-destructive testing
5.3.6.1 Non-destructive testing is to be carried out on the forged components required to be subject to non-destructive testing in Section 2, Chapter 9, PART THREE of CCS Rules for Classification of Sea-going Steel Ships in accordance with the requirements of 5.1.6 of this Chapter:
5.3.6.2 Ultrasonic testing is to be carried out on shafts having a finished diameter of 250 mm or larger when intended for main propulsion such as tube shafts, screwshafts, thrust shafts, intermediate shafts and shafts for other essential services in accordance with the requirements of 5.1.6 of this Chapter.
5.3.6.3 The non-destructive testing for other forgings may be carried out in accordance with the requirements given in the drawings approved by CCS.

Section 4 FORGINGS FOR CRANKSHAFTS

5.4.1 Application
5.4.1.1 The requirements of this Section apply to solid forged crankshafts and forgings for use in the construction of fully built and semi-built crankshafts, made of carbon or carbon-manganese steel.
5.4.1.2 Where it is proposed to use alloy steel forgings, particulars of the chemical composition, heat treatment and mechanical properties are to be submitted to CCS for approval. The minimum tensile strength of the alloy steel crankshaft forging is not to exceed 1,000 N/mm^2.

5.4.2 Manufacture
5.4.2.1 Solid forged crankshafts may be made by the closed die or continuous grain flow method. Full details of the proposed forging method are to be submitted to CCS for approval. When necessary, the manufacturer is required to carry out tests to demonstrate that a satisfactory structure and grain flow are obtained.
5.4.2.2 For semi-built crankshaft forgings, the proposed method of forging and fitting and the manufacturing procedure specification are to be submitted to CCS for approval.
5.4.2.3 Where crankwebs are flame cut from forged or rolled slabs, the procedure used is to be in compliance with the requirements of 5.1.4.3 of this Chapter and additionally a depth of at least 7.5 mm is to be removed by machining from all flame-cut surfaces.

5.4.3 Chemical composition

5.4.3.1 For crankshaft steel forgings, the chemical composition of ladle samples is to comply with the requirements given in Table 5.3.2.1 of this Chapter.

5.4.4 Heat treatment

5.4.4.1 For forgings in all types of steels, the heat treatment is to be either:

(1) normalizing and tempering; or

(2) quenching and tempering.

The temperature used for tempering is not to be less than 550℃.

5.4.4.2 Where it is proposed to surface harden crankshaft forgings by carburizing, nitriding or high frequency quenching, the requirements of 5.1.4.5 of this Chapter are to be complied with.

5.4.5 Mechanical tests

5.4.5.1 The following tests are to be carried out on each crankshaft forging:

(1) tensile test;

(2) impact test;

(3) hardness test (if applicable).

5.4.5.2 The number of test specimens for crankshaft forgings is to comply with the following:

(1) For solid open die-forged crankshafts, at least one set of longitudinal specimens is to be taken from the coupling end (position A) of each forging, as shown in Figure 5.4.5.2(1). Where the mass of a solid forged crankshaft exceeds 3 t (excluding the mass of the test material), one set of longitudinal specimens is to be taken from each end (position A and position B).

Where the crankthrows are formed by machining or flame cutting, the second set of test specimens is to be taken in a tangential direction from material removed from the crankthrow at the end opposite the coupling (position C).

(2) For crankwebs of combined crankshafts, one set of tests is to be taken from each forging in a tangential direction.

(3) For crankshaft forgings manufactured according to the approval method in 5.4.2.1 of this Section, the number of test specimens and the location where test specimens are taken are to be agreed by CCS.

(4) One set of specimens: for carbon and carbon-manganese steels, one tensile test specimen is to be taken from each crankshaft forging; for alloy steels, one tensile and a set of three impact test specimens are required.

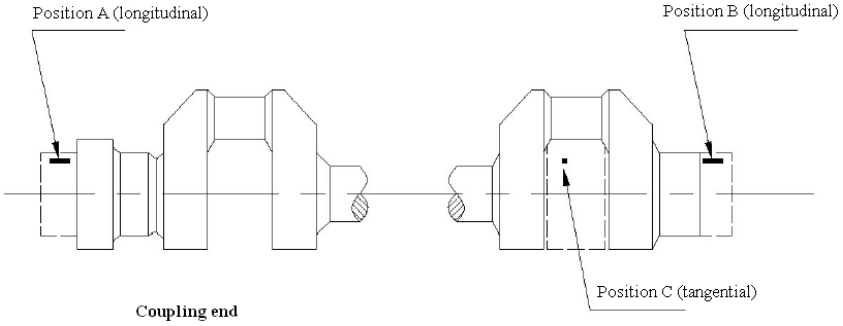


Figure 5.4.5.2(1)

5.4.6 Mechanical properties

5.4.6.1 For steel forgings for crankshafts, the results of tensile tests are to comply with the requirements of Table 5.3.5.1 of this Chapter.

5.4.6.2 The Charpy V-notch impact tests for alloy steel forgings for crankshafts at ambient temperature are to comply with the requirements of Table 5.4.6.2.

Impact Test Requirements for Alloy Forgings for Crankshafts① **Table 5.4.6.2**

Specified min. tensile strength R_m (N/mm^2)			600	700	800	900	1000	1100
Minimum average energy (J) for Charpy V-notch impact test	Normalized and tempered	Long.	25	20	15	–	–	–
		Tang.	15	12	9	–	–	–
	Quenched and tempered	Long.	41	32	30	27	25	21
		Tang.	24	22	20	18	16	13

Note: ① Where it is proposed to use a steel with a specified minimum tensile strength intermediate to those given, corresponding minimum average energy may be obtained by interpolation.

5.4.6.3 Where two or more tensile tests are taken from a forging, the variation in tensile strength is to comply with the requirements given in Table 5.4.6.3.

Difference in Tensile Strength **Table 5.4.6.3**

Tensile strength R_m (N/mm^2)	Difference in tensile strength, maximum (N/mm^2)
≥ 600 < 900	100
≥ 900	120

5.4.6.4 Hardness tests are to be carried out on each forging for small crankshaft forgings which have been batch tested, and the hardness values are generally to comply with the requirements of Table 5.3.5.1 of this Chapter.

5.4.7 Non-destructive testing

5.4.7.1 Non-destructive testing is to be carried out on the crankshaft forgings of diesel engines required to be subject to non-destructive testing in Section 2, Chapter 9, PART THREE of CCS Rules for Classification of Sea-going Steel Ships in accordance with the requirements of 5.1.6 of this Chapter, and particular attention is to be given to the following positions during magnetic particle testing::

(1) pins, journals and associated fillet radii of solid forged crankshafts;

(2) pins and fillet radii of combined web and pin forgings.

5.4.7.2 The non-destructive testing for other forgings for crankshafts may be carried out in accordance with the requirements given in the drawings approved by CCS.

Section 5 FORGINGS FOR GEARING

5.5.1 Application

5.5.1.1 The requirements of this Section apply to forgings for gearing where the transmitted power exceeds 147 kW for main propulsion and 100 kW for auxiliary drives. For other forgings for gearing with less transmitted power, these requirements may be used as guidance.

5.5.1.2 Gear wheel and rim forgings with a minimum tensile strength not less than 400 N/mm^2 and not in excess of 760 N/mm^2 may be made in carbon or carbon-manganese steel. Gear wheel or rim forgings where the minimum tensile strength is in excess of 760 N/mm^2, and all pinion or pinion sleeve forgings, are to be made in a suitable alloy steel. Specifications for alloy steel are to be submitted to CCS for approval.

5.5.1.3 Forgings for flexible couplings, quill shafts and gear wheel shafts are also to comply with the relevant requirements of Section 3 of this Chapter.

5.5.2 Manufacture

5.5.2.1 All forgings are to be made with sufficient material to allow an adequate machining allowance on all surfaces for the removal of unsound or decarburized material, taking into account any bending or distortion which may occur in heat treatment.

5.5.3 Chemical composition

5.5.3.1 For carbon and carbon-manganese steel forgings for gearing, the chemical composition of ladle samples is to comply with the requirements of Table 5.3.2.1 of this Chapter.

5.5.4 Heat treatment

5.5.4.1 Except as provided in 5.5.4.2 to 5.5.4.5 of this Section, the heat treatment of forgings for gearing is to be either:

(1) normalized and tempered; or

(2) quenched and tempered.

The tempering temperature is to be not less than 550℃. Where forgings for gearing are not intended for surface hardening, lower tempering temperature may be allowed.

5.5.4.2 When the tensile strength exceeds 700 N/mm^2, the carbon and carbon-manganese steel forgings are to be heat treated only in the quenched and tempered condition.

5.5.4.3 When the teeth of a pinion or gear wheel are to be surface hardened by carburizing, nitriding or high frequency quenching, the proposed procedures and specifications are to be submitted to CCS for approval. For purposes of initial approval, the gear manufacturer is required to demonstrate by test that the surface hardening of the teeth is uniform and of the required depth and that it does not impair the soundness

and quality of the steel.

5.5.4.4 Where high frequency quenching or nitriding is to be carried out after machining of the gear teeth, the forgings are to be heat treated at an appropriate stage to a condition suitable for this subsequent surface hardening.

5.5.4.5 Where carburizing is to be carried out, forgings are to be heat treated at an appropriate stage (generally either by full annealing or by normalizing and tempering) to a condition suitable for subsequent machining and carburizing.

5.5.5 Test specimens

5.5.5.1 Each forging, from which specimens are to be taken, is to provide test material sufficient for the preparation of at least one group of specimens, including one tensile specimen and a set of three impact specimens. The specimens are to be taken as follows:

(1) For pinion forgings where the finished diameter of the toothed portion exceeds 200 mm, test specimens are to be taken in a tangential direction and adjacent to the toothed portion (test position B in Figure 5.5.5.1(1)).Where the dimensions preclude the preparation of test specimens from position B, specimens in a tangential direction are to be taken from the end of the journal (test position C in Figure 5.5.5.1(1)). If, however, the journal diameter does not exceed 200 mm, test specimens are to be taken in a longitudinal direction (test position A in Figure 5.5.5.1(1)). Where the finished length of the toothed portion exceeds 1.25 m, test specimens are to be taken from each end.

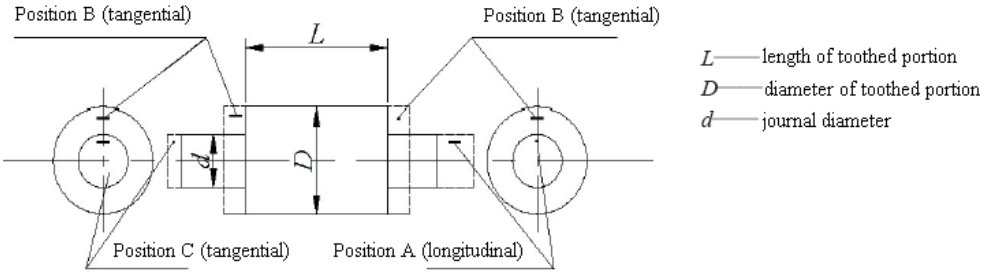


Figure 5.5.5.1(1)

(2) For small pinion forgings where the finished diameter of the toothed portion does not exceed 200 mm, test specimens are to be taken in a longitudinal direction from position A as shown in Figure 5.5.5.1(1).

(3) For gear wheel forgings, test specimens are to be taken in a tangential direction at position A or position B as shown in Figure 5.5.5.1(3).

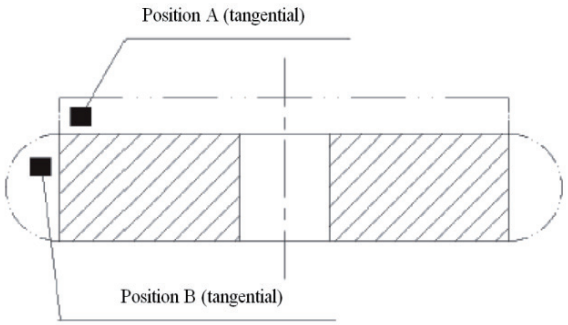


Figure 5.5.5.1(3)

(4) For gear wheel rim forgings, test specimens are to be taken in a tangential direction at position A or position B as shown in Figure 5.5.5.1(4). Where the finished diameter exceeds 2.5 m or the mass (as heat treated but excluding test material) exceeds 3 t, test specimens are to be taken from two diametrically opposite positions, i.e. position A and position B, as shown in Figure 5.5.5.1(4). The mechanical properties of test specimens are to be in compliance with the longitudinal requirements.

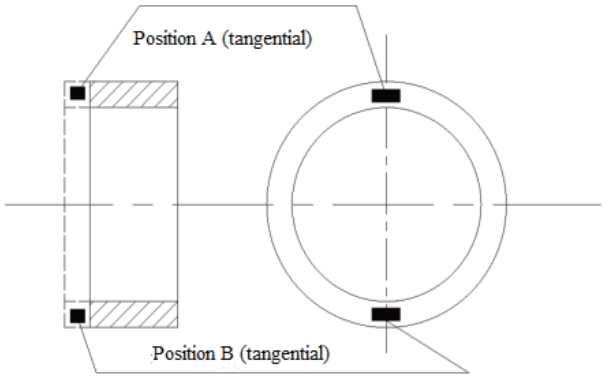


Figure 5.5.5.1(4)

(5) For pinion sleeve forgings, test specimens are to be taken in a tangential direction at position A or position B, as shown in Figure 5.5.5.1(5). Where the finished length exceeds 1.25 m, test specimens are to be taken from each end.

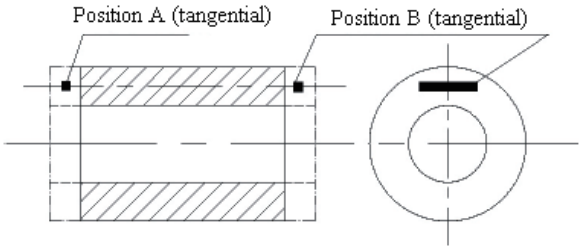


Figure 5.5.5.1(5)

5.5.5.2 For forgings which are to be carburized, or for hollow forgings where the ends are to be subsequently closed, sufficient test material may be cut from a forging prior to the final heat treatment. The test material so cut is to be heat treated together with the forging in the same furnace charge.

5.5.5.3 For forgings which are to be carburized, sufficient test materials are to be provided for both preliminary tests at forging stage and final tests after completion of carburizing.

For this purpose, duplicate sets of test material are to be taken from one position as detailed in 5.5.5.1 irrespective of the dimensions or mass of the forgings. In the case of forgings with integral journals, the test material is to be cut in a longitudinal direction.

This test material is to be machined to a diameter of $D/4$ or 60 mm, whichever is less, where D is the finished diameter of the toothed portion.

For preliminary tests at forging stage, one set of test material is to be given a blank carburizing and heat treatment cycle simulating that which will be subsequently applied to the forgings.

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.

In addition, a test sample of about 30 mm in diameter is to be carburized together with the workpiece to determine the depth and hardness of the hardened zone.

5.5.6 Mechanical properties

5.5.6.1 The mechanical properties for gear forgings made in carbon or carbon-manganese steel and alloy steel are to comply with the requirements of Tables 5.3.5.1 and 5.4.6.2 of this Chapter respectively. For carburized gear forgings to which low temperature tempering heat treatment has applied, the up limit of tensile strength in Table 5.3.5.1 is not applicable.

5.5.6.2 Where more than one tensile test specimen is taken from a forging, the variation in tensile strength is not to exceed those given in Table 5.5.6.2.

Difference in Tensile Strength **Table 5.5.6.2**

Tensile strength R_m (N/mm^2)	Difference in tensile strength, maximum (N/mm^2)
< 600	70
≥ 600 < 900	100
≥ 900	120

5.5.6.3 Small gear forgings may be batch tested in accordance with the requirements of 5.1.5.2 of this Chapter, but at least one hardness test is to be carried out on each forging.

5.5.7 Surface hardening

5.5.7.1 Where the gear forgings are intended to be surface hardened by nitriding, or high frequency quenching, the tensile strength is not to be less than 800 N/mm^2. Where it is intended to carburize a gear forging, details of carburizing procedure, preparation of test specimens and test procedures etc., are to be submitted to CCS for information. The tensile strength is not to be less than 750 N/mm^2. The results of all impact tests are to comply with the appropriate strength requirements for forgings in the quenched and tempered condition as given in Table 5.4.6.2 of this Chapter.

5.5.7.2 Hardness tests may be required on the following:

(1) Hardness tests are to be carried out on all 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 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.

(2) For small gear forgings which have been accepted in batch, at least one hardness test is to be carried out on each forging.

5.5.7.3 The results of hardness tests are to be reported and to comply with the requirements of Table 5.3.5.1 of this Chapter. After hardness test, the difference between the highest and lowest values on any one gear forging is to comply with the requirements of Table 5.5.7.3.

Permissible Difference in Hardness **Table 5.5.7.3**

Tensile strength R_m (N/mm^2)	Difference in hardness, maximum (HB)
< 600	25
≥ 600 < 900	35
≥ 900	42

5.5.7.4 Hardness tests may be required on forgings which have been induction hardened, nitride or carburized. For gear forgings these tests are to be carried out on the teeth after, where applicable, they have been surface hardened and ground to the finished profile. The test methods and results are to comply with the relevant recognized standards.

5.5.7.5 For forgings which are to be carburized, the test samples which are to be carburized and heat treated together with the forgings are to be sectioned for determining hardness, shape and depth of the locally hardened zone. The results are to be in compliance with the approved specifications.

5.5.8 Non-destructive testing

5.5.8.1 Magnetic particle or liquid penetrant testing is to be carried out on all gear forgings and on all surface hardened (carburized, nitrided or high frequency quenched) forgings, and the results are to comply with the relevant recognized standards.

5.5.8.2 Ultrasonic examination is to be carried out on all forgings where the finished diameter of the surfaces, where teeth will be cut, is in excess of 200 mm, and the results are to comply with the relevant recognized standards.

5.5.8.3 Determination of the depth of the hardened zone may be required if deemed necessary by the Surveyor.

Section 6 FORGINGS FOR TURBINES

5.6.1 Application

5.6.1.1 This Section applies to carbon or carbon-manganese steel forgings for main shafts, solid forged rotors, discs and blades of turbines, and for the turbine-driven generator rotors and compressor rotors.

5.6.1.2 Where it is proposed to use alloy steel forgings, details of the specifications are to be submitted to CCS for approval.

5.6.1.3 Where it is proposed to use rotors of welded construction, details of the chemical composition and heat treatment are to be submitted to CCS for approval.

5.6.1.4 Turbine forgings, which are subject to an operating temperature above 450℃, are to be in heat-resisting alloy steel.

5.6.2 Chemical composition

5.6.2.1 For forgings in carbon or carbon-manganese steel the chemical composition of ladle samples is to comply with Table 5.6.2.1.

Chemical Composition of Forgings for Turbines **Table 5.6.2.1**

Steel type	Chemical composition (%)				
	C	Mn	Si	S	P
Carbon and carbon-manganese steel	≤ 0.45	≥ 0.40	≤ 0.45	≤ 0.035	≤ 0.035

Note: Where forgings are intended for welded construction, the carbon content is in general not to exceed 0.23%.

5.6.3 Heat treatment

5.6.3.1 Forgings are to be heat treated as follows:

(1) normalized and tempered; or

(2) quenched and tempered.

5.6.3.2 The heat treatment at all stages is to be such as to avoid the formation of cracks and brittle fracture. At a suitable stage of manufacture, the forgings are to be reheated above the upper critical point to refine the grain, cooled in an approved manner and then tempered to produce the desired mechanical properties.

5.6.3.3 Where forgings receive their main heat treatment before machining, they are to be stress relieved after rough machining. Forgings heat treated in the rough machined condition need not be stress relieved provided that they have been slowly cooled from the tempering temperature.

5.6.3.4 The tempering and stress relieving temperatures are to be not less than 550℃ for carbon and carbon-manganese steels, and not less than 600℃ for alloy steels. The holding times and subsequent cooling rates are to be such that the forging in its final condition is free from harmful residual stresses.

5.6.4 Test specimens

5.6.4.1 The number of test specimens and the method of providing the test material for each forging are to be as follows:

(1) Rotor shafts: at least one longitudinal tensile test specimen is to be taken from one end (corresponding to the top end of the ingot) of the forging, i.e. position A as shown in Figure 5.6.4.1(1); for single forging exceeding 3 t in mass or 2 m in length, test specimens are to be taken from each end. Tangential test specimens are also to be taken from position B as shown in Figure 5.6.4.1(1) for each forging. Where the dimensions permit, radial tensile test specimens are also to be taken from position C as shown in Figure 5.6.4.1(1).

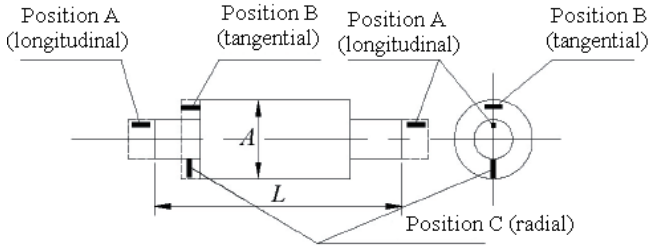


Figure 5.6.4.1(1)

(2) Solid forged rotors: in addition to the test specimens required by (1) above, a second tensile test specimen is to be taken from the end face of the drum or of an end disc (position B). Where the diameter D is not greater than 500 mm, the specimen is to be transverse; where D is greater than 500 mm, the specimen is to be tangential.
(3) Each turbine disc forging: at least one tangential or transverse test specimen is to be taken from material at the hub as shown in Figure 5.6.4.1(3).
(4) Turbine blades: blades are to be presented for testing in batches, the material in each batch is to be manufactured from the same cast and heat treated in the same furnace charge. At least two forged billets are to be selected from each batch, and one tensile test specimen is to be cut from each billet. Where the dimensions of billets are such that the tensile specimen cannot be provided, then a metallographic examination and hardness test are to be carried out on the billets.

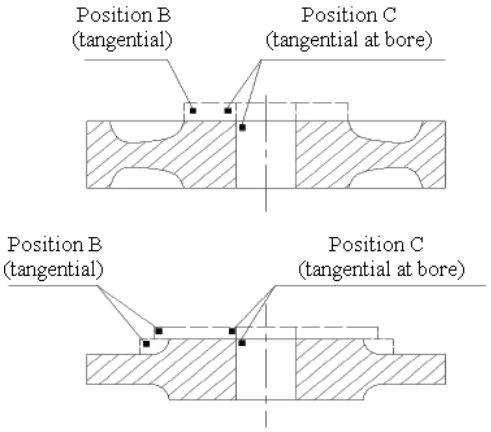


Figure 5.6.4.1(3)

5.6.4.2 For the preparation of test specimens required by 5.6.4.1 of this Section, sufficient test material is to be left on each forging and is not to be removed until all heat treatment, including stress relieving, has been completed.

5.6.5 Mechanical properties

5.6.5.1 For turbine forgings in carbon or carbon-manganese steel, the mechanical properties after normalizing and tempering are to comply with the requirements of Table 5.6.5.1.

Mechanical Properties of Forgings for Turbines **Table 5.6.5.1**

Tensile strength R_m min. (N/mm^2)	Yield strength R_{eH} min. (N/mm^2)	Elongation A_5 min. (%)			Reduction of area Z min. (%)		
		Long.	Tang.	Radial	Long.	Tang.	Radial
400	200	26	22	18	50	40	35
440	220	24	21	17	50	40	35
480	240	22	19	15	45	35	30
520	260	21	18	14	45	35	30
560	280	20	17	13	40	30	25
600	300	18	15	12	40	30	25

Notes: ① Test specimens are to be taken in the directions as indicated in Figures 5.6.4.1(1) and (3).
② For intermediate values of tensile strength, the minimum values of R_{eH}, A_5 and Z may be obtained by interpolation.
③ For all grades of forgings in the Table, the tensile strength range is 120 N/mm^2.
④ For monobloc rotor forgings, the tensile strength is not to exceed 800 N/mm^2.

5.6.5.2 For turbine forgings in alloy steel, the mechanical properties after quenching and tempering or normalizing and tempering are to comply with the requirements of Table 5.6.5.2.

Mechanical Properties of Alloy Steel Forgings for Turbines Table 5.6.5.2

Tensile strength R_m min. (N/mm^2)	Yield strength R_{eH} or $R_{p0.2}$ min. (N/mm^2)		Elongation A_5 min. (%)			Reduction of area Z min. (%)		
	Normalized and tempered	Quenched and tempered	Long.	Tang.	Radial	Long.	Tang.	Radial
500	275	–	22	20	18	50	40	35
550	300	–	20	18	16	50	40	35
600	330	410	18	16	14	50	40	35
650	355	450	17	15	13	50	40	35
700	385	490	16	14	12	45	35	30
750	–	530	15	13	11	45	35	30
800	–	590	14	12	10	45	35	30
850	–	640	13	11	9	40	30	25
900	–	690	13	11	9	40	30	25
950	–	750	12	10	8	40	30	25
1000	–	810	12	10	8	40	30	25

Notes: ① Test specimens are to be taken in the directions as indicated in Figures 5.6.4.1(1) and (3).
② For intermediate values of tensile strength, the minimum values of R_m, A_5 and Z may be obtained by interpolation.
③ For all grades of forgings in the Table, the tensile strength range is 150 N/mm^2.
④ For monobloc rotor forgings, the tensile strength is not to exceed 800 N/mm^2.

5.6.6 Testing and non-destructive testing

5.6.6.1 The following examination and tests are to be carried out on the internal and external surfaces of the turbine forgings:

(1) Endoscopic examination: forgings are to be hollow bored and the surface of the bore is to be examined by means of an optical instrument for flakes, cracks, porosities, pores and non-metallic inclusions. Pickling and sulphur print test may be required by the Surveyor for the turbine forgings when necessary.

(2) Thermal stability test: forgings for solid forged rotors or rotors of welded construction of the main propulsion machinery are to be subjected to thermal stability test to verify their satisfactory thermal stability at elevated operating temperatures. The test procedures and specifications are to be submitted to CCS for approval.

(3) Determination of residual tangential stress: where the turbine discs of fabricated rotors have a diameter greater than 600 mm and where the disc bodies of solid forged rotors have a diameter greater than 300 mm, test specimens are to be taken from the turbine discs or disc bodies for the determination of residual tangential stress. For turbine discs manufactured in batches, one disc is to be selected from each 20 discs which have been heat treated in the same furnace charge for the determination of residual tangential stress. A ring test material is to be cut from the hub of turbine discs, and the size of the cross section of the ring is to be 25 mm × 25 mm; for solid forged rotors, the test ring may be cut from the rim of the disc body. The residual tangential stress σ_t may be obtained from the following formula:

$$\sigma = E\delta / D \quad N/mm^2$$

where: δ — mean increment of the ring diameter, mm;
E — modulus of elasticity of the material of forgings, taken as 1.96×10^5 N/mm^2;
D — mean diameter of ring prior to cutting, mm.

The residual tangential stress thus obtained is to comply with the requirements given in Table 5.6.6.1(3).

If the residual tangential stress exceeds the specified value given in the Table, the forging is permitted to be subjected to an additional tempering, after that the residual tangential stress is to be re-measured.

Allowable Residual Stress of Forgings for Turbines Table 5.6.6.1(3)

Forgings		Residual stress σ_t (MPa)
Turbine discs	Diameter ≤ 1000 mm	≤ 39
	Diameter > 1000 mm	≤ 49
Solid forged rotors	$R_{p0.2} \le 490$ N/mm^2	$\le 0.1\ R_{p0.2}$
	$R_{p0.2} > 490$ N/mm^2	$\le 0.08\ R_{p0.2}$

5.6.6.2 The end faces of the boss of each turbine disc, the whole surface of each turbine rotor or main shaft and blades are to be subjected to magnetic particle examination after heat treatment, and the results of the examination are to comply with the relevant recognized standards.

5.6.6.3 Each turbine forging is to be subjected to an ultrasonic examination, and the results of the examination are to comply with the relevant recognized standards.
5.6.6.4 The bore surfaces of turbine forgings with large bores are to be subjected to magnetic particle and ultrasonic examinations.

5.6.7 Properties at elevated temperatures
5.6.7.1 Where the turbine forgings are subject to a working temperature equal to 350℃ or more, test specimens are to be provided for the determination of mechanical properties at elevated temperatures.

Section 7 FORGINGS FOR BOILERS, PRESSURE VESSELS AND PIPING SYSTEMS

5.7.1 Application
5.7.1.1 This Section applies to carbon, carbon-manganese and low alloy steel forgings intended for use in the construction of boilers, pressure vessels and piping systems.
5.7.1.2 Forgings used in the construction of equipment for the containment of liquefied gases are to comply with the requirements of Section 8 of this Chapter except for those used in piping systems, where the design temperature is not lower than 0℃. Forgings for other pressure vessels and piping systems, where the use of steels with guaranteed impact properties at low temperatures is required, are also to comply with Section 8 of this Chapter.
5.7.1.3 Where forgings are joined by welding, details of the chemical composition, mechanical properties, heat treatment and welding procedure are to be submitted to CCS for approval.

5.7.2 Chemical composition
5.7.2.1 The chemical composition of ladle samples for carbon, carbon-manganese steel and alloy steel forgings is to comply with the requirements of Table 5.7.2.1.

Chemical Composition of Forgings for Boilers, Pressure Vessels and Piping Systems

Table 5.7.2.1

Steel type	Tensile strength R_m min. (N/mm^2)	Chemical composition (%)							
		C	Si	Mn	P	S	Al	Residual elements	
Carbon and carbon-manganese steel	410	≤0.20	0.10~0.40	0.50~1.20	≤0.04	≤0.04	①	Ni ≤0.40, Cr ≤0.25 Mo ≤0.10, Cu ≤0.30 Total ≤0.80	
	460	≤0.23	0.10~0.40	0.60~1.40	≤0.04	≤0.04			
	490	≤0.25	0.10~0.40	0.90~1.70	≤0.04	≤0.04			
1Cr0.5Mo	410	≤0.20	0.15~0.40	0.40~0.70	≤0.04	≤0.04	≤0.02②	Cr	Mo
								0.85~1.15	0.45~0.65
2.25Cr1Mo	490	≤0.15	0.15~0.40	0.40~0.70	≤0.04	≤0.04	≤0.02②	2.0~2.50	0.90~1.20

Notes: ① Fine grained steels are to contain: aluminium (acid soluble) 0.015% minimum, or aluminium (total) 0.018% minimum.
② For alloy steels, aluminum (acid soluble) 0.020% maximum. The determination of the aluminum (total) content is acceptable provided 0.020% is not exceeded.

5.7.3 Heat treatment
5.7.3.1 Carbon and carbon-manganese steel forgings are to be heat treated as follows:
(1) normalized; or
(2) normalized and tempered; or
(3) quenched and tempered.
5.7.3.2 Alloy steel forgings are to be heat treated as follows:
(1) normalized and tempered; or
(2) quenched and tempered.

5.7.4 Test specimens
5.7.4.1 The test specimens for the forgings are to be taken as follows:
(1) Except as provided in 5.7.4.1(4), at least one tensile test specimen is to be taken from each forging and, where the dimensions and shape allow, the test specimen is to be cut in the longitudinal direction.
(2) On seamless drums and headers which are initially forged with open ends, test material is to be

provided at each end of each forging. Where forged with one solid end, test material is to be provided at the open end only.
(3) Where the ends are to be closed, rings of test material are to be cut off prior to the closing operation and are to be heat treated with the finished forging. Where the ends are to be subsequently closed by forging, the test material is not to be removed until heat treatment has been completed.
(4) Small forgings may be batch tested in accordance with 5.1.5.2 of this Chapter provided that hardness tests are carried out on each forging. In such cases, the mass of each forging is not to exceed 1 t and that of the batch is not to exceed 10 t.
(5) Unless otherwise agreed, tensile test specimens are to be taken with their axis at approximately 12.5 mm below the surface of the forgings.

5.7.5 Mechanical properties

5.7.5.1 The mechanical properties of carbon, carbon-manganese steel and alloy steel forgings are to comply with the appropriate requirements of Table 5.7.5.1.

Mechanical Properties of Forgings for Boilers, Pressure Vessels and Piping Systems

Table 5.7.5.1

Steel type	Diameter or equivalent thickness t (mm)	Tensile strength R_m min. (N/mm^2)	Yield strength R_{eH} min. (N/mm^2)	Elongation A_5 min. (%)	Hardness (HB)
Carbon and carbon-manganese steel	$t \leq 63$	410	215	20	110 ~ 155
	$63 < t \leq 250$		205		
	$t \leq 63$	460	245	18	130 ~ 170
	$63 < t \leq 250$		235		
	$t \leq 63$	490	265	16	140 ~ 180
	$63 < t \leq 250$		255		
Carbon and carbon-manganese steel, fine grained	$t \leq 63$	410	235	20	110 ~ 155
	$63 < t \leq 250$		220		
	$t \leq 63$	460	275	18	130 ~ 170
	$63 < t \leq 250$		255		
	$t \leq 63$	490	305	16	140 ~ 80
	$63 < t \leq 250$		280		
1Cr0.5Mo	$t \leq 100$	410	255	18	110 ~ 160
2.25Cr1Mo	$t \leq 100$	490	275	18	140 ~ 185

Notes: ① For intermediate values of tensile strength, the minimum values for R_{eH} and A_5 may be obtained by interpolation.
② For all grades of carbon and carbon-manganese steel in the Table, the tensile strength range is 120 N/mm^2; for alloy steel, the tensile strength range is 150 N/mm^2.
③ Where test specimens are taken from each end of the forgings, the variation in tensile strength is not to exceed 70 N/mm^2.
④ The hardness values are only applicable for each piece of small batch-tested forgings.

5.7.5.2 In case of forgings designed for use at temperatures of more than 200℃, a tensile test at elevated temperatures is to be made on the forgings. The test specimen is to be taken from material adjacent to that used for tests at ambient temperature, and the test procedure and results are to be in accordance with the relevant recognized standards.

5.7.6 Non-destructive testing

5.7.6.1 Forged shells and headers are to be subjected to ultrasonic test. On shells and drums with dish ends, the area of the dished ends is to be subjected to magnetic particle or dye penetrant testing.

5.7.7 Pressure tests

5.7.7.1 Hollow forgings are to be subjected to pressure tests.

Section 8 STEEL FORGINGS FOR LOW TEMPERATURE SERVICE

5.8.1 Application

5.8.1.1 The requirements of this Section are applicable to the forgings made of carbon-manganese steels and nickel alloy steels and intended for the construction of cargo tanks, pressure vessels and piping systems for ships carrying liquefied gases where the design temperature is less than 0℃.

5.8.1.2 The requirements of this Section are also applicable to other forgings where the use of steels with guaranteed impact properties at low-temperature is required.
5.8.1.3 In all cases, details of the proposed chemical composition, heat treatment and mechanical properties are to be submitted to CCS for approval.

5.8.2 Chemical composition
5.8.2.1 The chemical composition of ladle samples is, in general, to comply with the requirements given in Table 3.7.2.2 and Table 3.7.2.3, Chapter 3 of this PART.
5.8.2.2 For carbon or carbon-manganese steel containing suitable grain refining elements Nb, V, Ti, either singly or in any combination, the composition is to comply with the following provisions:

Nb 0.01%~0.05%
V 0.02%~0.10%
Ti ≤0.02%.

5.8.3 Heat treatment
5.8.3.1 All forgings are to be heat treated as follows:
(1) normalized; or
(2) normalized and tempered; or
(3) quenched and tempered.

5.8.4 Test specimens and mechanical properties
5.8.4.1 At least one tensile and one set of three Charpy V-notch impact test specimens are to be taken from each forging or each batch of forgings in the longitudinal direction.
5.8.4.2 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 carrying liquefied gases, the test temperature is to be in accordance with the requirements given in Table 3.7.3.1 and Table 3.7.3.2, Chapter 3 of this PART.
5.8.4.3 The results of all tensile tests and the average energy values for impact tests are in general to comply with the requirements given in Table 3.7.3.1 and Table 3.7.3.2, Chapter 3 of this PART.
5.8.4.4 For forgings accepted in batches, the Surveyor may require a hardness test to be carried out for each forging. There are not to be excessive differences in hardness of each forging.

5.8.5 Non-destructive testing
5.8.5.1 Where the wall thickness of forgings exceeds 100 mm, the magnetic particle testing and ultrasonic examination of forgings are to be carried out in accordance with the relevant recognized standards.

Section 9 AUSTENITIC STAINLESS STEEL FORGINGS

5.9.1 General requirements
5.9.1.1 This Section applies to austenitic stainless steel forgings for cargo tanks and piping systems used at low temperature service in liquefied gas carriers and for cargo tanks and piping systems used at corrosion-resisting service in bulk chemical tankers.
5.9.1.2 This Section also applies to stainless steel forgings for propeller shafts.
5.9.1.3 The austenitic steel forgings specified in this Section may also be used for elevated temperature service of boilers.
5.9.1.4 For all austenitic stainless steel forgings, details of the chemical composition, heat treatment and mechanical properties are to be submitted to CCS for approval.

5.9.2 Chemical composition
5.9.2.1 The chemical composition of ladle samples of the austenitic stainless steel forgings is, in general, to comply with the requirements given in Table 5.9.2.1.

Chemical Composition of Austenitic Stainless Steel Forgings Table 5.9.2.1

Grade	Uniform number code	Chemical composition (%)									
		C	Si	Mn	P	S	Cr	Ni	Mo	Other elements	Note
06Cr19Ni10	S30408	0.08	1.00	2.00	0.045	0.030	18.0~20.0	8.0~11.0	–	–	1
022Cr19Ni10	S30403	0.03	1.00	2.00	0.045	0.030	18.0~20.0	8.0~12.0	–	–	
06Cr17Ni12Mo2	S31608	0.08	1.00	2.00	0.045	0.030	16.0~18.0	10.0~14.0	2.0~3.0	–	1
022Cr17Ni12Mo2	S31603	0.03	1.00	2.00	0.045	0.030	16.0~18.0	10.0~14.0	2.0~3.0	–	
06Cr19Ni13Mo3	S31708	0.08	1.00	2.00	0.045	0.030	18.0~20.0	11.0~15.0	3.0~4.0	–	1
022Cr19Ni13Mo3	S31703	0.03	1.00	2.00	0.045	0.030	18.0~20.0	11.0~15.0	3.0~4.0	–	
06Cr23Ni13	S30908	0.08	1.00	2.00	0.045	0.030	22.0~24.0	12.0~15.0	–	–	2
06Cr25Ni20	S31008	0.08	1.00	2.00	0.045	0.030	24.0~26.0	19.0~22.0	–	–	2
06Cr18Ni10Ti	S32168	0.08	1.00	2.00	0.045	0.030	17.0~19.0	9.0~12.0	–	5C≤Ti≤0.80	
06Cr18Ni11Nb	S34778	0.08	1.00	2.00	0.045	0.030	17.0~19.0	9.0~12.0	–	10C≤Nb≤1.10	

Notes: ① Not recommended for structural components in cargo tanks of liquefied natural gas carriers.
② Recommended for service at elevated temperatures in severe corrosive environment.
③ Data in the Table, except for those with indication of limits, are maximum limits.

5.9.3 Heat treatment

5.9.3.1 All austenitic stainless steel forgings are to receive a solid solution treatment.

5.9.3.2 Shaft forgings which are subjected to an excessive degree of straightening are to be stress relieved accordingly and heat treated again when necessary.

5.9.4 Mechanical properties

5.9.4.1 Stainless steel forgings are to be sampled according to the following requirements:

(1) Sampling of shaft forgings is to meet the requirements of 5.3.4.1 and 5.3.4.2 of Section 3 of this Chapter;

(2) For pipe and valve forgings, at least one tensile specimen is to be taken for each heat treatment batch from each cast, with each batch weighing up to 5 t.

5.9.4.2 The results of the tensile test for the austenitic stainless steel forgings are to comply with the requirements of Table 5.9.4.2.

Mechanical Properties of Austenitic Stainless Steel Forgings Table 5.9.4.2

Grade	Uniform number code	Yield stress $R_{P0.2}$ N/mm^2	Tensile strength R_m N/mm^2	Elongation A_5 %	Reduction of area Z %	Hardness		
						HBW	HRB	HVW
06Cr19Ni10	S30408	≥205	≥520	≥40	≥60	≤187	≤90	≤200
022Cr19Ni10	S30403	≥175	≥480	≥40	≥60			
06Cr17Ni12Mo2	S31608	≥205	≥520	≥40	≥60			
022Cr17Ni12Mo2	S31603	≥175	≥480	≥40	≥60			
06Cr19Ni13Mo3	S31708	≥205	≥520	≥40	≥60			
022Cr19Ni13Mo3	S31703	≥175	≥480	≥40	≥60			
06Cr23Ni13	S30908	≥205	≥520	≥40	≥60			
06Cr25Ni20	S31008	≥205	≥520	≥40	≥50			
06Cr18Ni10Ti	S32168	≥205	≥520	≥40	≥50			
06Cr18Ni11Nb	S34778	≥205	≥520	≥40	≥50			

Note: The hardness criteria in the Table may be determined by any method and are only for reference in acceptance.

5.9.4.3 Unless otherwise agreed, impact test is generally not required for austenitic forgings. When austenitic stainless steel is used at temperatures equal to or lower than -100℃, Charpy V-notch impact test at -196℃ may be required. The average value of test results is not to be lower than 41 J (axes of specimens parallel to the final direction of rolling).

5.9.5 Non-destructive testing

5.9.5.1 Austenitic stainless steel forgings used for propeller shafts with diameters greater than 250 mm are generally to be subjected to ultrasonic testing.

5.9.5.2 Austenitic stainless steel forgings other than shaft forgings are to be subjected to non-destructive testing according to the requirements of approved plans, standards, contracts or agreements.

5.9.5.3 The stainless steel forgings are to be subjected to ultrasonic test after heat treatment or at an appropriate stage during the manufacturing process.

5.9.5.4 Operators engaged in the ultrasonic test are to have sufficient technique and experience for the testing of austenitic stainless steel forgings.

5.9.5.5 The important parts of the stainless steel forgings are to be subjected to liquid penetrant test on completion of or at an appropriate stage of the manufacturing process.

5.9.6 Intergranular corrosion tests

5.9.6.1 When austenitic stainless steels are intended for use in a corrosive environment, specimens are to be taken after heat treatment and subjected to the intergranular corrosion test in accordance with Section 7, Chapter 2 of this PART.

CHAPTER 6 STEEL CASTINGS

Section 1 GENERAL PROVISIONS

6.1.1 Application

6.1.1.1 This Chapter applies to steel castings intended for use in the construction of ships, machinery, boilers, pressure vessels and piping systems.

6.1.1.2 Impact tests for the steel castings of polar ship which are exposed to low air temperature environments are to satisfy the relevant requirements of Chapter 23, PART EIGHT of Rules for Classification of Sea-going Steel Ships.

6.1.1.3 Unless provided otherwise in Section 6 to Section 8, the provisions of this Chapter are applicable only to steel castings where the design and acceptance tests are related to mechanical properties at ambient temperature. Where required by designs and applications, necessary additional tests may be required, especially when the castings are intended for service at low or elevated temperatures.

6.1.1.4 Where it is proposed to use carbon or carbon-manganese steels or alloy steels other than those specified in this Chapter, details of the chemical composition, heat treatment process and mechanical properties, etc., when agreed by CCS, may be accepted in accordance with the relevant recognized standards.

6.1.1.5 Small castings less than 1 t in mass and made from the same cast with the similar size and heat treated in the same furnace charge may be submitted for testing in batches of not greater than 6 t, subject to agreement of CCS.

6.1.2 Manufacture

6.1.2.1 Castings are to be made at foundries approved by CCS in accordance with the manufacturer process approved by CCS.

6.1.2.2 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 casting. If necessary, the affected areas are to be either machined or ground smooth.

6.1.2.3 Where two or more castings are joined by welding to form a composite item, details of the proposed welding procedure specification are to be submitted to CCS for approval. Welding approval procedure tests may be required when necessary.

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

6.1.3 Quality of castings

6.1.3.1 Castings are to be free from surface or internal defects such as cracks, shrinkage cavities, cold shuts and scabs, and free from other defects which would be prejudicial to their proper application in service, such as pores, etc.

6.1.3.2 Castings are to be surface finished in accordance with the specific requirements of the approved plan.

6.1.3.3 The surfaces of castings are not to be hammered, peened nor treated in any way which may obscure defects.

6.1.4 Chemical composition

6.1.4.1 All castings are to be made from killed steel. The chemical composition of the ladle sample is to be within the limits given in the relevant Sections of this Chapter.

6.1.4.2 The content of grain refining elements adopted by the manufacturer is to be reported in the ladle analysis.

6.1.5 Heat treatment

6.1.5.1 All castings are to be heat treated to refine the grain structure. The type of heat treatment is to be in accordance with the requirements of the relevant Sections of this Chapter.

6.1.5.2 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.

6.1.5.3 Castings for components, 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℃ followed by furnace cooling to 300℃ or lower.

6.1.6 Test material and test specimens

6.1.6.1 Test material sufficient for the required tests and for possible re-test purposes is to be provided for each casting or batch of castings. The test samples are to be either integrally cast or gated to the casting and are to have a thickness of not less than 30 mm. In the case of quenched and tempered thin-walled steel castings, the thickness of the test sample is to be at least 20 mm, and is to be appropriate to the thickness of the casting.

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

6.1.6.3 For a number of small castings submitted for batch testing as specified in 6.1.1.5 of this Section, the test samples may be separately made from the same cast. The size of test samples is to be determined in accordance with a recognized standard (e.g. ISO 4990) and at least to be 28 mm in thickness. Test samples are to be properly identified and heat treated together with the castings they represent.

6.1.6.4 The test specimens are to be taken where the axis is at 1/4 of thickness of test samples. Where the thickness of test samples is less than 56 mm, the axis of test specimens is to be taken at 14 mm from the surface. All test specimens are to be prepared in accordance with the requirements of Chapter 2 of this PART. Tensile test specimens are to have a cross-sectional area of greater than150 mm^2.

6.1.7 Mechanical properties

6.1.7.1 The mechanical properties of castings are to comply with the relevant requirements of subsequent Sections of this Chapter.

6.1.8 Visual and non-destructive testing

6.1.8.1 All castings are to be cleaned and adequately prepared for inspection; suitable methods include pickling, 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.

6.1.8.2 All castings are to be presented to the Surveyor for visual examination. Where applicable, the internal surface examination is to be included. Unless otherwise agreed, the accuracy and verification of dimensions is the responsibility of the manufacturer.

6.1.8.3 The following areas are usually subject to magnetic particle or liquid penetrant testing:

(1) at positions indicated on the approved plan;

(2) at all fillets and changes of section;

(3) at positions where surplus metal has been removed by flame cutting, scarfing or arc-air gouging;

(4) in way of fabrication weld preparations;

(5) at areas which may be subjected to high stress in service.

For the above examinations, the dry powder method is not acceptable and the tests are to be made in the presence of the Surveyor.

6.1.8.4 Ultrasonic examination is to be carried out on the steel castings in the following areas:

(1) at positions indicated on the approved plan;

(2) in way of fabrication weld preparations;

(3) at positions where experience shows that significant internal defects may occur.

6.1.8.5 Non-destructive testing of steel castings is generally to be carried out in accordance with recognized methods of examination, and to comply with the requirements of Appendix 7B, Chapter 7 of CCS Guidelines for Inspection of Hull Welds or recognized acceptance criteria.

6.1.8.6 Where radiographic examination is carried out in areas as indicated for ultrasonic examination in 6.1.8.4 of this Section, the details of radiographic technique are to be submitted to CCS for approval. The results are to satisfy the relevant recognized standards.

6.1.9 Pressure testing

6.1.9.1 Where required by the relevant Sections of this Chapter or other relevant documents, castings are to be pressure tested before final acceptance. These tests are to be carried out in the presence of the Surveyor.

6.1.10 Rectification of defective castings

6.1.10.1 The defects of castings may be classified based on the extent of weld repairs:
(1) Major repairs are those where the depth is greater than 25% of the wall thickness or 25 mm, whichever is less, or where the total weld area on a casting exceeds 2% of the casting surface noting that where a distance between two welds is less than their average width, they are to be considered as one weld.
(2) Minor repairs are those where the total weld area (length × width) exceeds 500 mm^2.
(3) Cosmetic repairs are all other welds not included in (1) and (2) above.
(4) Castings subject to the removal of defects may be supplied without welding on un-machined surfaces where the depth of defect removal is not over 15 mm or 10% of wall thickness, whichever is less, and the length of the removed part is not over 100 mm.
6.1.10.2 Defects found in castings are to be removed by one of the following methods:
(1) grinding, machining;
(2) chipping and grinding;
(3) flame-cutting or arc-air gouging and grinding.
Thermal methods of metal removal are only to be allowed before the final heat treatment.
6.1.10.3 Complete elimination of the defective material is to be verified by non-destructive testing. Where the defective area is not required to be repaired by welding, the shallow grooves or excavations resulting from the removal of defects are to be blended by grinding and to be smoothly blended to the surface area with a finish equal to that of the adjacent surface, subject to the inspection and acceptance by the Surveyor. Where the defective area is required to be repaired by welding, the excavations are to be suitably shaped to allow good access for welding. All grooves are to have a bottom radius of approximately three times the groove depth.
6.1.10.4 Where defects are removed by flame cutting or arc-air gouging, the castings may be required to be preheated depending on their chemical composition, the dimensions and nature of defects.
6.1.10.5 Where it is proposed to repair defective castings by welding, the welding procedure specification is to be submitted to CCS for approval. Major repairs are to be subject to prior approval of the Surveyor .
6.1.10.6 Welding repairs are to be carried out in accordance with the approved procedure specification by qualified welders in the down hand position or a position in which a good welding quality is assured. Welding is to be done in positions free from adverse weather conditions.
6.1.10.7 The welding consumables used are to be of an approved low hydrogen type, giving a weld deposit with mechanical properties similar and in no way inferior to those of the parent castings.
6.1.10.8 All castings in alloy steels and crankshaft castings are to be suitably preheated prior to welding. Castings in carbon and carbon-manganese steels may also be required to be preheated, depending on their chemical composition, the dimensions and positions of the defects. Where the repair of major defects is required, a grain refining heat treatment is to be given prior to carrying out weld repairs.
6.1.10.9 After completion of welding, the castings are to be given a stress relieving heat treatment at a temperature of not less than 550℃,or given heat treatment as appropriate according to the chemical composition of castings, repair size, position and feature.
6.1.10.10 For small defects found during finish machining, heat treatment may be waived or local heat treatment may be carried out after repair subject to agreement by CCS.
6.1.10.11 On completion of post-weld heat treatment, the weld repairs and adjacent material are to be ground smooth and further examined by the existing non-destructive method dependent on the dimensions, number and position of the defects as shown on a sketch, so as to ensure that the quality of the repaired area is satisfactory.
6.1.10.12 Weld repair of defective steel castings for crankshafts is to comply with the requirements of Section 4 of this Chapter.
6.1.10.13 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 as well as subsequent survey reports. These documents are to be available to the Surveyor and copies provided on request.

6.1.11 Identification of castings

6.1.11.1 All castings which have been satisfactorily inspected by CCS are to be clearly marked by the manufacturer in at least one place with the following:
(1) CCS logo;
(2) cast number or other marking which will enable the full history of the casting to be traced;
(3) test pressure (where applicable);
(4) brand or grade of casting material;
(5) certificate number.

When the area is not enough for all marks, at least (1) to (3) of the above items are to be marked.
Any mark is to be encircled with paint for easy recognition.
6.1.11.2 Where small castings are manufactured in large numbers, modified arrangements for identification may be submitted by the manufacturer to CCS for information.

6.1.12 Certification
6.1.12.1 The manufacturer is to provide a certificate giving the following particulars for each casting or batch of castings which has been accepted:
(1) purchaser's name and order number;
(2) description of castings and steel quality;
(3) cast number and chemical analysis of ladle samples;
(4) details of heat treatment, including temperatures and holding times;
(5) results of mechanical tests;
(6) test pressure, where applicable;
(7) methods and results of non-destructive testing.

Section 2 CASTINGS FOR HULL STRUCTURES

6.2.1 Application
6.2.1.1 The requirements of this Section apply to carbon or carbon-manganese steel castings intended for use in the construction of hull structures.

6.2.2 Chemical composition
6.2.2.1 The chemical composition of ladle samples is to comply with the requirements given in Table 6.2.2.1.

Chemical Composition of Castings for Hull Structures **Table 6.2.2.1**

C	Mn①	Si	P	S	Residual elements②			
					Cu	Cr	Ni	Mo
≤ 0.23	≤ 1.60	≤ 0.60	≤ 0.04	≤ 0.04	≤ 0.30	≤ 0.30	≤ 0.40	≤ 0.15

Notes: ① The manganese content is not to be less than 3 times the actual carbon content.
② The total content of residual elements is to be not more than 0.80%.
③ If carbon equivalent C_{eq} calculated according to following formula is not more than 0.41%, the carbon content of castings may exceed the limit of 0.23%.

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

6.2.3 Heat treatment
6.2.3.1 Castings are to be heat treated as follows:
(1) fully annealed; or
(2) normalized; or
(3) normalized and tempered at a temperature of not less than 550℃; or
(4) quenched and tempered at a temperature of not less than 550℃.

6.2.4 Mechanical properties
6.2.4.1 The test specimens for castings are to be prepared as follows:
(1) The test samples are to be poured from the same cast as the castings. They are to be either integrally cast at locations as widely separated as possible or gated to the casting.
(2) At least one tensile test specimen is to be made on at least one test sample representing each casting or batch of castings.
(3) Where the casting is of complex design, or where the finished mass exceeds 10 t, 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 required corresponding to the number of casts involved. These are to be integrally cast at locations as widely separated as possible.
(4) Where impact tests are to be carried out in accordance with the requirements of 6.2.4.3, a set of three Charpy V-notch impact specimens is to be taken from the test samples.
6.2.4.2 The mechanical properties of castings are to comply with the requirements of Table 6.2.4.2.

Mechanical Properties of Castings for Hull Structures Table 6.2.4.2

Tensile strength① R_m min. (N/mm^2)	Yield strength R_{eH} min. (N/mm^2)	Elongation A_5 min. (%)	Reduction of area Z min. (%)
400	200	25	40
440	220	22	30
480	240	20	27

Notes: ① The tensile strength is not to exceed that required in the Table plus 150 N/mm^2.
② For intermediate values of tensile strength, the minimum values of R_{eH}, A_5 and Z may be obtained by interpolation.

6.2.4.3 The castings of primary hull structures (i.e. stem, stern frame, rudder bearing, propeller shaft bracket, rudder horn, stern tube shaft, etc.) are to be subject to Charpy V-notch impact tests. The test specimens are to taken at t/4 from the surface of the sample. The test temperature is to be 0℃. The impact energy is to be not less than 27 J.
6.2.4.4 For castings where the method of manufacture has been specially approved by CCS in accordance with 6.1.2.4, the number and position of test samples is to be agreed with CCS having regard to the method of manufacture employed.

6.2.5 Non-destructive testing
6.2.5.1 Castings which are to be used in the construction of the stern frame, rudder and propeller shaft supports are to be examined by ultrasonic and magnetic particle methods, and the results are to comply with the relevant recognized standards. For other steel castings the examination is to be carried out in accordance with the requirements indicated on the approved plans.

Section 3 CASTINGS FOR MACHINERY CONSTRUCTION

6.3.1 Application
6.3.1.1 The requirements of this Section apply to carbon and carbon-manganese steel castings intended for use in machinery construction.

6.3.2 Chemical composition
6.3.2.1 The chemical composition of ladle samples is to comply with the requirements of Table 6.3.2.1.

Chemical Composition of Castings for Machinery Construction Table 6.3.2.1

Application	C	Mn	Si	P	S	Residual elements①			
						Cu	Cr	Ni	Mo
Used for welded structures	≤ 0.23	≤ 1.60	≤ 0.60	≤ 0.04	≤ 0.04	≤ 0.30	≤ 0.30	≤ 0.40	≤ 0.15
Used for non-welded structures	≤ 0.40	0.50~1.60	≤ 0.60	≤ 0.04	≤ 0.04	≤ 0.30	≤ 0.30	≤ 0.40	≤ 0.15

Note: ① The total content of residual elements is to be not more than 0.80%.

6.3.3 Heat treatment
6.3.3.1 Castings are to be heat treated as follows:
(1) fully annealed; or
(2) normalized; or
(3) normalized and tempered at a temperature of not less than 550℃; or
(4) quenched and tempered.
6.3.3.2 Engine bedplate castings, turbine castings and any other castings where dimensional stability and freedom from internal stresses are important are to be given a stress relief heat treatment as follows:
(1) the casting is to be heated to a temperature not lower than 550℃, followed by furnace cooling to 300℃ or lower; or
(2) fully annealed, and followed by furnace cooling to 300℃ or lower.

6.3.4 Mechanical properties
6.3.4.1 At least one tensile test specimen is to be made on at least one test sample representing each casting or batch of castings from the same cast.
6.3.4.2 Where the casting is of complex design, or where the finished mass exceeds 10 t, 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 required corresponding to the number of casts involved. The test samples are to be integrally cast at locations as widely separated as possible.

6.3.4.3 For carbon or carbon-manganese steel castings, the mechanical properties are to comply with the requirements of Table 6.3.4.3.

Mechanical Properties of Castings for Machinery Construction Table 6.3.4.3

Tensile strength① R_m min. (N/mm^2)	Yield strength① R_{eH} min. (N/mm^2)	Elongation① A_5 min. (%)	Reduction of area Z 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

Notes: ① For intermediate values of tensile strength, the minimum values of R_{eH}, A_5 and Z may be obtained by interpolation.
② For all grades of castings in the Table, the tensile strength range is 150 N/mm^2.

6.3.5 Non-destructive testing

6.3.5.1 Castings for important machinery constructions are to be subjected to non-destructive testing as follows:

(1) Castings of engine bedplates, piston crowns and cylinder covers are to be examined by magnetic particle and ultrasonic testing.

(2) Turbine castings are to be examined by magnetic particle testing. In addition, an ultrasonic or radiographic examination is to be made in way of fabrication weld preparations.

(3) Other castings are to be examined by non-destructive methods where indicated on the approved plan or specially required by CCS.

Section 4 CASTINGS FOR CRANKSHAFTS

6.4.1 Application

6.4.1.1 The requirements of this Section apply to carbon and carbon-manganese steel castings for semi-built and fully built crankshafts. For alloy steels, the tensile strength is not to exceed 700 N/mm^2.

6.4.2 Manufacture

6.4.2.1 The method of producing combined web and pin castings is to be approved by CCS. For this purpose, the manufacturer is required to carry out necessary procedure verification tests to demonstrate the soundness of the casting and the properties at important locations.

6.4.3 Chemical composition

6.4.3.1 The chemical composition of ladle samples for crankshaft castings is to comply with the requirements of Table 6.3.2.1 of this Chapter.

6.4.4 Heat treatment

6.4.4.1 Crankshaft castings are to be heat treated as follows:

(1) fully annealed and cooled in the furnace to a temperature of 300℃ or lower; or

(2) normalized and tempered at a temperature of not less than 550℃, and cooled in the furnace to a temperature of 300℃ or lower.

6.4.5 Mechanical properties

6.4.5.1 Test material for crankshaft castings is to be gated to the castings. Proposals for the number of tests and the location of test material on the casting are to be submitted by the manufacturer to CCS for approval.

6.4.5.2 The test material for each casting is to be sufficient for at least one group of test specimens and for possible re-test purposes. Each group of test specimens is to consist of one tensile specimen and one set of three impact specimens.

6.4.5.3 For carbon or carbon-manganese crankshaft castings, their mechanical properties are to comply

with the requirements of Table 6.4.5.3.

Mechanical Properties of Castings for Crankshafts **Table 6.4.5.3**

Tensile strength① R_m min. (N/mm^2)	Yield strength② R_{eH} min. (N/mm^2)	Elongation② A_5 min. (%)	Reduction of area② Z min. (%)	Average energy for Charpy V-notch impact test min. (J)
400	200	28	45	32
440	220	26	45	28
480	240	24	40	25
520	260	22	40	20
550	275	20	35	18

Notes: ① For all grades of castings in the Table, the tensile strength range is 120 N/mm^2.

② For intermediate values of tensile strength, the minimum values of R_{eH}, A_5 and Z as well as average impact energy may be obtained by interpolation.

③ Impact tests are to be carried out at an ambient temperature of 18℃ ~ 25℃.

6.4.6 Non-destructive testing

6.4.6.1 Each casting is to be examined by ultrasonic testing.

6.4.6.2 Magnetic particle examination is to be carried out over all surfaces of the crankshaft castings. It is recommended that magnetic particle testing be carried out before the final heat treatment, followed by a re-examination of all machined surfaces in the finished condition.

6.4.7 Rectification of defective castings

6.4.7.1 Where castings have shallow surface defects, consideration is first to be given to removing such defects by grinding and blending or by machining. Shadow grooves or depressions resulting from the removal of defects are not to exceed 0.01d (d being the diameter of crankpin or pin hole).Shallow surface defects may be removed by machining the surface where there is excess metal.

6.4.7.2 Generally, approval for repairs by welding will be given to rectify areas only where accidental defects arise, subject to prior approval of CCS.

6.4.7.3 Approval for weld repairs will not be given in the following circumstances:

(1) for the rectification of repetitive defects caused by improper foundry technique or practice;

(2) for the building up by welding of surfaces or large shallow depressions;

(3) where the carbon content of the steel exceeds 0.30%;

(4) where the carbon equivalent of the steel exceeds 0.65%, given by:

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

6.4.7.4 Where necessary and provided that agreement of CCS has been obtained, the surface defects of crankshaft castings may be repaired by welding:

(1) To the surfaces of crank webs:

① the volume of the largest groove which is to be welded is not to exceed 3.2 t (cm^3); the total volume of all grooves which are to be welded is not to exceed 9.6 t (cm^3) per crank web, where t is the web axial thickness, in cm (as shown in Figures 6.4.7.4(1) and (2));

② the welds do not extend within the cross-hatched zones marked on Figures 6.4.7.4(1) and (2) for fully built and semi-built crank throws, respectively;

③ more weld repairs on balance weights may be permitted at the discretion of the Surveyor, provided that such repairs are wholly contained within the balance weight and do not affect the strength of the crank web.

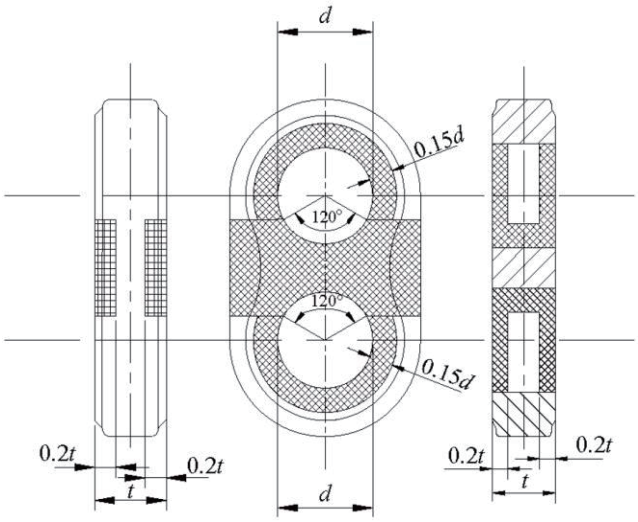


Figure 6.4.7.4(1)

(2) In the surface of the bore for the journal:

① the weld areas are not to be less than 125 mm apart;

② the welds are not to be located within circumferential bands of $t/5$ from the edges of the bores, nor at any position within the inner 120° arc of the bores, as show in Figures 6.4.7.4(1) and (2);

③ the volume of the largest weld is to be not more than 1.1 t (cm^3), where t is the web axial thickness at the bore, in cm, and not more than three welds are to be made in any one bore surface.

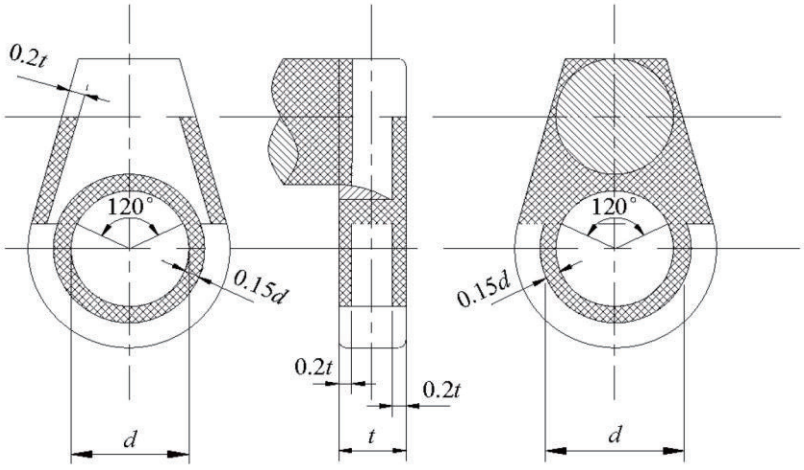


Figure 6.4.7.4(2)

6.4.7.5 After all defective material has been removed from a region, this is to be proven by magnetic particle examination or other suitable method, and the excavation is to be suitably shaped to allow good access for welding.

6.4.7.6 Weld repairs are to be carried out by qualified welders. The welds are to be made in the downhand position using low hydrogen type consumables which will produce a deposited metal in no way inferior in properties to the parent metal.

6.4.7.7 All castings are to be given a preliminary refining heat treatment prior to the commencement of weld repairs. Before welding, the material is to be preheated to a temperature of not less than 200℃. It is recommended that this preheating be carried out in a furnace. The preheating temperature is to be maintained until welding repair and post-weld heat treatment are completed.

6.4.8 Post-weld heat treatment and inspection

6.4.8.1 On completion of the repairs, the casting is to be given a post-weld heat treatment, either:

(1) fully annealed; or

(2) normalized and tempered.

Where small isolated defects are revealed after completion of the above post-weld heat treatment, weld repairs followed by a stress relieving treatment at a temperature of not less than 550℃ may be permitted.

6.4.8.2 Welds are to be dressed smooth by grinding, and proven by magnetic particle inspection. The surfaces of the welds and adjacent parent steel are to be free from harmful defects.

Section 5 STEEL CASTINGS FOR PROPELLERS

6.5.1 Application

6.5.1.1 The requirements of this Section apply to propellers (including blades and bosses) in carbon, carbon-manganese, low alloy or stainless steel castings.

6.5.1.2 The steel castings for propellers and their components are to be manufactured in accordance with the relevant requirements in Section 1 of this Chapter.

6.5.2 Chemical composition

6.5.2.1 The chemical composition of ladle samples for castings for carbon and carbon-manganese steel propellers is to be in accordance with the requirements given in Table 6.5.2.1 of this Section.

Chemical Composition of Castings for Carbon and Carbon-Manganese Steel Propellers

Table 6.5.2.1

Steel type	Chemical composition (%)								
	C	Si	Mn	P	S	Residual elements①			
						Ni	Cr	Mo	Cu
Carbon and carbon-manganese steel	≤ 0.25	≤ 0.60	0.50~1.60	≤ 0.04	≤ 0.04	≤ 0.40	≤ 0.30	≤ 0.15	≤ 0.30

Note: ① The total content of residual elements is to be not more than 0.80%.

6.5.2.2 The chemical composition of ladle samples for castings for stainless steel propellers is to be in accordance with the requirements given in Table 6.5.2.2 of this Section.

Chemical Composition of Castings for Carbon and Carbon-Manganese Steel Propellers

Table 6.5.2.2

Steel type	Alloy type①	Chemical composition (%)							
		C	Si	Mn	P	S	Ni	Cr	Mo②
1Cr12NiMo	M/F	≤ 0.15	≤ 1.5	≤ 2.0	≤ 0.035	≤ 0.030	≤ 2.0	11.5 ~ 17.0	≤ 0.5
0Cr13Ni4Mo	M/F	≤ 0.06	≤ 1.0	≤ 2.0	≤ 0.035	≤ 0.030	3.5 ~ 5.0	11.5 ~ 17.0	≤ 1.0
0Cr16Ni5Mo	M/F	≤ 0.06	≤ 1.5	≤ 2.0	≤ 0.035	≤ 0.030	3.5 ~ 6.0	15.0 ~ 17.5	≤ 1.5
1Cr18Ni12Mo	A	≤ 0.12	≤ 1.5	≤ 1.6	≤ 0.035	≤ 0.030	8.0 ~ 13.0	16.0 ~ 21.0	≤ 4.0

Notes: ① M – Martensitic; F – Ferritic; A – Austenitic.

② Minimum values are to be in accordance with international or national standards.

6.5.3 Heat treatment

6.5.3.1 The castings for carbon and carbon-manganese steel propellers are to be heat treated as follows:

(1) fully annealed; or

(2) normalized; or

(3) normalized and tempered at a temperature of not less than 550℃.

6.5.3.2 The castings for stainless steel propellers are to be heat treated in accordance with their steel type as follows:

(1) Martensitic castings are to be austenitized and annealed;

(2) Austenitic castings are to be solution heated.

6.5.4 Mechanical properties

6.5.4.1 At least one test sample is to be taken from material representing each casting. Where a number of propeller castings of the same size, and less than 1 m in diameter are made from one cast and heat treated in the same furnace charge, at least one test sample of suitable dimensions is to be provided for each multiple of five castings in the batch.

6.5.4.2 The test material is to be cast integral with the castings. The test material attached on blades is to be located in an area between 0.5 and 0.6 times the radius of the propeller. Separately cast test bars from the same ladle on the castings may be used subject to prior approval of CCS.

6.5.4.3 The test material is to be heat treated together with the castings in the same furnace charge. The test material is not to be removed from the casting until the final heat treatment has been carried out. Removal is to be by machining.

6.5.4.4 At least one tensile test specimen and one set of three Charpy V-notch impact test specimens are to be cut from each test sample, and such specimens are to be tested in accordance with the relevant requirements in Chapter 2 of this PART.

6.5.4.5 The mechanical properties of steel castings for propellers are to comply with the requirements of Table 6.5.4.5.

Mechanical Properties of Steel Castings for Propellers **Table 6.5.4.5**

Steel type		Tensile strength R_m min. (N/mm^2)	Yield stress R_{eH} or $R_{p0.2}$ min. (N/mm^2)	Elongation A_5 min. (%)	Reduction of area Z min. (%)	Average energy for Charpy V-notch impact test① min. (J)
Carbon and carbon-manganese steel		400	200	25	40	20
Low alloy		420	225	19	25	20
Stainless	1Cr12NiMo	590	440	15	30	20
	0Cr13Ni4Mo	750	550	15	35	30
	0Cr16Ni5Mo	760	540	15	35	30
	1Cr18Ni12Mo	440	180②	30	40	–

Notes: ① The impact tests are to be made at 0℃ on propeller castings for ships without Ice Class Notation or with Ice Class Notation B and at -10℃ on propeller castings for ships with other Ice Class Notations. The impact tests need not be required for austenitic stainless steel castings.

② Where the yield strength of austenitic stainless steel is defined as the 1.0% proof strength, $R_{p1.0}$ is to be not less than 205 N/mm^2.

6.5.5 Inspections

6.5.5.1 All finished propeller castings are to be 100% visually inspected, the surfaces of the finished castings are to be in accordance with the roughness specified in the approved drawings and free from cracks or other imperfections which will interfere with the use of the castings.

6.5.5.2 All propellers are subject to non-destructive testing. The categorization of important portions of the propellers and the corresponding non-destructive testing are to comply with the provisions given in 8.4.2 and 8.4.3, Section 4 of Chapter 8 in PART THREE of the Rules.

6.5.5.3 The dimensions of the propellers are to be the responsibility of the manufacturer and the report on the dimensional inspection is to be handed over to the Surveyor for confirmation in his presence.

6.5.5.4 Static balancing is to be carried out on all propellers in accordance with the approved drawing. Dynamic balancing may be required for propellers running above 500 r/min.

6.5.5.5 Defects found in the inspections are to be repaired in accordance with 8.4.4 and 8.4.5, Section 4 of Chapter 8 in PART THREE of the Rules. The Surveyor may require areas to be etched for the purpose of investigating weld repairs.

6.5.6 Identification and certification

6.5.6.1 Each casting is to be suitably identified by the manufacturer with the following:

a) heat number or other marking which will enable the full history of the casting to be traced;
b) CCS certificate number;
c) ice class symbol, where applicable;
d) skew angle for high skew propellers;
e) date of final inspection;
f) CCS stamp is to be put on when the casting has been accepted.

6.5.6.2 The manufacturer is to provide the Surveyor with a marine product certificate or equivalent document 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 and non-destructive testing.

Section 6 CASTINGS FOR BOILERS, PRESSURE VESSELS AND PIPING SYSTEMS

6.6.1 Application

6.6.1.1 This Section applies to carbon, carbon-manganese and alloy steel castings for boilers, pressure vessels and piping systems.

6.6.1.2 Castings which comply with the requirements of this Section may be used for liquefied gas piping systems where the design temperature is not lower than 0℃. Where the design temperature is lower than 0℃, and for other applications where guaranteed impact properties at low temperature are required, the castings are to comply with the requirements of Section 7 or 8 of this Chapter.

6.6.2 Chemical composition

6.6.2.1 The chemical composition of ladle samples is to comply with the limits specified in Table 6.6.2.1.

Chemical Composition of Castings for Boilers, Pressure Vessels and Piping Systems

Table 6.6.2.1

Steel type	Chemical composition (%)										
	C	Si	Mn	S	P	Residual elements					
						Cr	Mo	Cu	Ni	Total	
Carbon and carbon-manganese steel	≤0.25	≤0.60	0.50~1.60	≤0.04	≤0.04	≤0.25	≤0.15	≤0.30	≤0.40	≤0.80	
Alloy	C	Si	Mn	S	P	Cr	Mo	V	Residual elements		
									Cr	Cu	Ni
0.5Mo	≤0.25	≤0.60	0.50~1.0	≤0.04	≤0.04	–	0.35~0.65	–	≤0.25	≤0.30	≤0.40
1Cr0.5Mo	≤0.23	≤0.60	0.50~0.80	≤0.04	≤0.04	1.0~1.50	0.45~0.65	–	–	≤0.30	≤0.40
2.25Cr1Mo	≤0.20	≤0.60	0.40~0.80	≤0.04	≤0.04	2.0~2.75	0.90~1.20	–	–	≤0.30	≤0.40
0.5Cr0.5Mo0.25V	≤0.20	≤0.45	0.40~0.80	≤0.04	≤0.04	0.30~0.50	0.40~0.60	0.20~0.30	–	≤0.30	≤0.40

6.6.3 Heat treatment

6.6.3.1 Castings are to be heat treated as follows:

(1) fully annealed; or

(2) normalized; or

(3) normalized and tempered; or

(4) quenched and tempered.

6.6.4 Mechanical properties

6.6.4.1 From each casting at least one test sample is to be taken. Where a casting is of complex design, or where the finished mass exceeds 2.5 t, at least two test samples are to be provided. The test samples are to be integrally cast at locations as widely separated as possible. At least 1 tensile test specimen is to be cut from each test sample.

6.6.4.2 Small castings may be batch tested in accordance with the requirements of this Chapter subject to agreement of CCS.

6.6.4.3 The mechanical properties of the castings are to comply with the requirements of Table 6.6.4.3.

Mechanical Properties of Castings for Boilers, Pressure Vessels and Piping Systems

Table 6.6.4.3

Steel type	Tensile strength R_m min. (N/mm^2)	Yield strength R_{eH} min. (N/mm^2)	Elongation A_5 min. (%)	Reduction of area Z min. (%)
Carbon and carbon-manganese steel	410	205	25	40
	460	230	22	30
	490	245	20	25
0.5Mo	440	245	20	30
1Cr 0.5Mo	480	280	17	20
2.5Cr1Mo	480	280	17	20
0.5Cr0.5Mo0.25V	510	295	17	20

Note: For all grades of castings in the Table, the tensile strength range is 150 N/mm^2.

6.6.5 Non-destructive testing

6.6.5.1 The non-destructive testing of steel castings is to be carried out in accordance with the requirements indicated on the approved plans.

6.6.6 Mechanical properties at elevated temperatures

6.6.6.1 In the case of castings intended for use at elevated temperatures, details of the mechanical properties at elevated temperatures and relevant information are to be submitted to CCS for approval.

Section 7 FERRITIC STEEL CASTINGS FOR LOW TEMPERATURE SERVICE

6.7.1 Application

6.7.1.1 This Section applies to castings in carbon-manganese and nickel alloy steels intended for use in liquefied gas piping systems where the design temperature is lower than 0℃, and for other applications where guaranteed impact properties at low temperatures are required.

6.7.2 Chemical composition

6.7.2.1 The chemical composition of ladle samples is to comply with the requirements given in Table 6.7.2.1.

Chemical Composition of Ferrite Steel Castings for Low Temperature Service Table 6.7.2.1

Steel type	Chemical composition (%)						
	C	Si	Mn	S	P	Ni	Other elements
Carbon-manganese steel	≤ 25	≤ 0.60	0.70 ~ 1.60	≤ 0.035	≤ 0.035	≤ 0.80	Cr ≤ 0.25 Cu ≤ 0.30
2.25Ni	≤ 0.25	≤ 0.60	0.50 ~ 0.80	≤ 0.03	≤ 0.03	2.0 ~ 3.0	
3.5Ni	≤ 0.15	≤ 0.60	0.50 ~ 0.80	≤ 0.03	≤ 0.03	3.0 ~ 4.0	

Note: Carbon-manganese steels are to be made by fine grain practice.

6.7.3 Heat treatment

6.7.3.1 Castings are to be heat treated as follows:
(1) normalized; or
(2) normalized and tempered; or
(3) quenched and tempered.

6.7.4 Mechanical properties

6.7.4.1 At least one group of test specimens is to be prepared from each casting or batch of castings.
6.7.4.2 One group of test specimens consists of one tensile test specimen and one set of three Charpy V-notch impact test specimens.
6.7.4.3 The mechanical properties of castings are to comply with the requirements given in Table 6.7.4.3.

Mechanical Properties of Ferrite Steel Castings for Low Temperature Service Table 6.7.4.3

Steel Type	Tensile strength① R_m min. (N/mm^2)	Yield strength R_{eH} min. (N/mm^2)	Elongation A_5 min. (%)	Reduction of area Z min. (%)	Charpy V-notch impact test	
					Test temp. (℃)	Average energy min. (J)
Carbon-manganese steel	400	200	25	40	②	27
	430	215	23	35		
	460	230	22	30		
2.25Ni	490	275	20	35	-70	34
3.5Ni	490	275	20	35	-95	34

Note: ①For castings with specified minimum a tensile strength < 430 N/mm^2, the tensile strength range is 100 N/mm^2. For all grades of castings with specified minimum tensile strength ≥ 430 N/mm^2, the tensile strength range is l50 N/mm^2.
② Test temperature is to be 5℃ lower than design temperature, or -20℃, whichever is lower. The specific test temperature is to be determined when the order is placed.

6.7.5 Non-destructive testing

6.7.5.1 The non-destructive testing of castings is to be carried out in accordance with the requirements indicated on the approved plans.

Section 8 AUSTENITIC STAINLESS STEEL CASTINGS

6.8.1 Application

6.8.1.1 This Section applies to castings in austenitic stainless steels for piping systems used in low-temperature environment (where the design temperature is not lower than -165℃, such as liquefied gas carriers) and required for corrosion resistance (such as bulk chemical tankers).

6.8.2 Chemical composition

6.8.2.1 The chemical composition of ladle samples of castings is to comply with the requirements given in Table 6.8.2.1.

Chemical Composition of Austenitic Stainless Steel Castings **Table 6.8.2.1**

Steel grade	Chemical composition (%)								
	C	Si	Mn	S	P	Cr	Mo	Ni	Other elements
00Cr18Ni10	≤0.03	0.20~1.50	0.50~2.0	≤0.04	≤0.04	16.0~21.0	–	8.0~12.0	–
0Cr18Ni9	≤0.08						–	8.0~12.0	–
00Cr17Ni14Mo3	≤0.03						2.0~3.0	9.0~13.0	–
0Cr18Ni9Ti	≤0.08						–	8.0~12.0	5C≤Ti≤0.70
1Cr18Ni11Nb①	≤0.06						–	8.0~12.0	8C≤Nb≤0.90

Note: ①When guaranteed impact values at low temperature are not required, the maximum carbon content may be 0.080% and the maximum niobium content may be 1.0%.

6.8.3 Heat treatment

6.8.3.1 All castings are to be solution treated at a temperature of not less than 1,000℃ and cooled rapidly in a proper medium.

6.8.4 Mechanical properties

6.8.4.1 At least one test sample is to be prepared from each casting or batch of castings. At least 1 tensile test specimen is to be cut from each test sample.

6.8.4.2 Where the castings are intended for liquefied gas applications and the design temperature is lower than -55℃, one set of three Charpy V-notch impact test specimens is also to be taken, if required by CCS.

6.8.4.3 The mechanical properties of the castings are to comply with the requirements given in Table 6.8.4.3.

Mechanical Properties of Austenitic Stainless Steel Castings **Table 6.8.4.3**

Steel grade	Tensile strength R_m min. (N/mm^2)	Yield strength $R_{p1.0}$ min. (N/mm^2)	Elongation A_5 min. (%)	Reduction of area Z min. (%)	Charpy V-notch impact test	
					Test temp. (℃)	Average energy min. (J)
00Cr18Ni10	400	200	26	40	-196	41
0Cr18Ni9	440	220				
00Cr17Ni14Mo3	430	215	26	40	-196	41
0Cr18Ni9Ti 1Cr18Ni11Nb	480	240	22	35	-196	41

6.8.5 Intergranular corrosion tests

6.8.5.1 Where an intergranular corrosion test is specified, it is to be carried out in accordance with the provisions given in Section 7, Chapter 2 of this PART.

6.8.6 Non-destructive testing

6.8.6.1 The non-destructive testing of castings is to be carried out in accordance with the requirements indicated on the approved plans.

CHAPTER 7 IRON CASTINGS

Section 1 GENERAL PROVISIONS

7.1.1 Application

7.1.1.1 This Chapter applies to both grey and spheroidal or nodular graphite iron castings or other higher tensile strength iron castings intended for use in the construction of ships, machinery, boilers, pressure vessels and piping systems.

7.1.1.2 Where it is proposed to use iron castings other than those specified in this Chapter, details of the chemical composition, heat treatment process and mechanical properties, etc., are to be submitted to CCS for examination, and such castings, subject to agreement of CCS, may be accepted in accordance with the relevant recognized standards.

7.1.1.3 Iron castings are to be manufactured and tested in accordance with the relevant requirements of this Chapter and Chapters 1 and 2 of this PART.

7.1.1.4 Small castings made from the same cast with the similar size and heat treated in the same furnace charge may be submitted for batch testing, subject to agreement of CCS.

7.1.2 Manufacture

7.1.2.1 Iron castings are to be made at foundries approved by CCS.

7.1.2.2 Suitable mechanical methods are to be employed for the removal of runners and other surplus material from castings. Where it is proposed to use thermal cutting processes, sufficient machining allowance is to be made so as to remove the cutting face that has been affected by heat.

7.1.2.3 Where iron castings of the same type are produced in regular quantities, the manufacturer is to make procedure confirmation tests to prove that the procedure can guarantee a sound and stable quality of the castings.

7.1.3 Quality of castings

7.1.3.1 Iron castings are to be free from defects such as cracks, pores, shrinkage cavities, porosities, sand and slag cavities and cold shuts, which would be prejudicial to their proper application in service and to subsequent machining.

7.1.3.2 The surface finish of iron castings is to be in accordance with the requirements indicated on the approved plans.

7.1.4 Chemical composition

7.1.4.1 Unless otherwise specified, 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 dimensions of the castings and their mechanical properties specified in the subsequent Sections of this Chapter.

7.1.5 Heat treatment

7.1.5.1 Unless otherwise specified, iron castings may be supplied in either the as cast or properly heat treated condition.

7.1.6 Test material

7.1.6.1 Sufficient test material is to be provided for each casting or batch of castings for the required tests and for possible re-test purposes. For large castings, where more than one ladle of metal is used, one test sample is to be provided, from each ladle used.

7.1.6.2 Where separately cast test samples are used, they are to be cast from the same ladle as the castings in moulds of the same type of material as the moulds for the castings. The test samples are not to be stripped from the moulds until the metal temperature is below 500℃.

7.1.6.3 All test samples are to be suitably marked to identify them with the castings which they represent.

7.1.6.4 Where castings are supplied in the heat treated condition, the test samples are to be heat treated together with the castings which they represent.

7.1.6.5 Preparation of test specimens and methods of tests are to comply with the requirements of Chapter 2 of this PART.

7.1.7 Mechanical properties

7.1.7.1 The mechanical properties of iron castings are to comply with the relevant requirements of this Chapter.

7.1.8 Visual and non-destructive testing

7.1.8.1 All iron castings are to be cleaned and adequately prepared for visual examination of the internal and external surfaces. The surfaces are not to be hammered, peened or treated in any way which may obscure defects.
7.1.8.2 Unless otherwise stated in the approved plans or where there is reason to suspect the soundness of the casting, the non-destructive testing of iron castings is generally not required.
7.1.8.3 The manufacturer is to ensure an adequate accuracy of the dimensions of the castings.
7.1.8.4 Where necessary, pressure tests for iron castings may be required before the final acceptance.

7.1.9 Rectification of defective castings

7.1.9.1 Minor surface blemishes may be removed by a proper method.
7.1.9.2 Repairs of surface defects by welding are generally not permitted. If deemed necessary, full details of the proposed repair procedure are to be submitted for approval of CCS prior to the commencement of the proposed rectification.
7.1.9.3 Subject to prior approval of the Surveyor, castings containing local porosity may be rectified by impregnation with a suitable plastic filler, provided that the extent of the porosity is such that it does not adversely affect the strength of the casting.

7.1.10 Identification of castings

7.1.10.1 All castings which have been satisfactorily inspected by CCS are to be clearly marked by the manufacturer in at least one place with the following:
(1) CCS logo;
(2) cast number or other marking which will enable the full history of the casting to be traced;
(3) test pressure (where applicable);
(4) brand or grade of casting material;
(5) certificate number.
When the area is not enough for all marks, at least (1) to (3) of the above items are to be marked.
Any mark is to be encircled with paint for easy recognition.

7.1.11 Certification

7.1.11.1 The manufacturer is to provide a certificate giving the following particulars for each iron casting or batch of iron castings which has been accepted:
(1) purchaser’s name and order number;
(2) description of castings and quality of cast iron;
(3) identification number (or cast number);
(4) chemical composition (when specially required);
(5) details of heat treatment, where applicable;
(6) results of mechanical tests;
(7) test pressure, where applicable.

Section 2 GREY IRON CASTINGS

7.2.1 Application

7.2.1.1 The requirements of this Section apply to grey iron castings intended for use in the construction of machinery and pipe fittings.

7.2.2 Test material

7.2.2.1 Separately cast test samples are to be used unless otherwise agreed between the manufacturer and purchaser. The test samples are to be in the form of cylindrical bars 30 mm in diameter and of a suitable length. Where two or more test samples are cast simultaneously in a single mould, the bars are to be at least 50 mm apart (as shown in Figure 7.2.2.1).

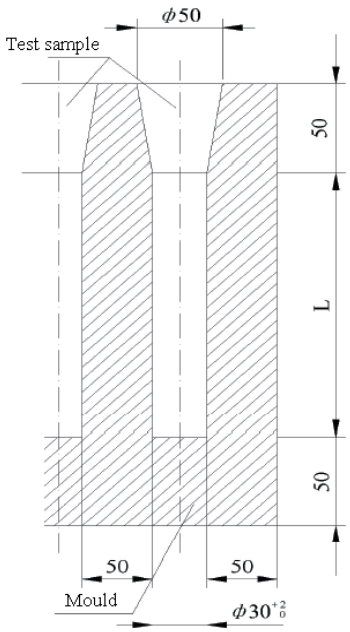


Figure 7.2.2.1 Test Sample for Grey Cast Iron

7.2.2.2 Integral cast samples may be used when a casting is more than 20 mm in thickness and its mass exceeds 200 kg, subject to an agreement between the manufacturer and the purchaser. The type and location of the samples are to be such as to provide approximately the same cooling conditions as for the casting it represents and to be agreed by CCS.

7.2.2.3 Unless provided otherwise in 7.2.2.4, iron castings may be tested in batch in accordance with the following principles. At least one test sample is to be cast with each batch.

(1) A batch testing procedure may be adopted for castings in a batch of similar type and dimensions, the total mass of which does not exceed 2 t, and cast from the same ladle of metal.

(2) A single casting will constitute a batch if its mass is 2 t or more.

(3) For continuous melting and casting of the same grade of cast iron in large tonnages the mass of a batch may be increased to the output of 2 h of pouring.

7.2.2.4 Where one grade of cast iron is melted continuously in large tonnages and 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 as agreed by CCS.

7.2.2.5 Integral cast samples are to be heat treated together with the iron castings.

7.2.2.6 Where castings are supplied in the heat treated condition, the test samples are to be heat treated together with the castings which they represent. For cast-on-test samples the sample is not to be cut off from the casting until after the heat treatment.

7.2.2.7 All test samples are to be suitably marked to identify them with the castings which they represent. One tensile test specimen is to be prepared from each test sample. For samples with 30 mm diameter, the diameter of the test specimens is to be 20 mm.

7.2.3 Heat treatment

7.2.3.1 For service at elevated temperatures or where geometrical and dimensional stability is required, the castings are to be given a suitable tempering or stress relieving heat treatment.

7.2.4 Mechanical properties

7.2.4.1 The mechanical properties of grey iron castings are to comply with the requirements of Table 7.2.4.1.

Mechanical Properties of Grey Iron Castings **Table 7.2.4.1**

Tensile strength R_m min. (N/mm^2)	Brinell hardness① (HB)
200	150 ~ 225
250	168 ~ 251
300	185 ~ 278
350	203 ~ 304

Notes:① Hardness test only applies to castings to which wear resistance is important, e.g. for propellers and cylinder blocks, cylinder liners, pistons, piston rings, guide plates of diesel engines.
② Where attached test samples are employed, the mechanical properties of grey iron castings may be accepted according to recognized national/international standards.

7.2.4.2 The minimum tensile strength of castings is not to be less than 200 N/mm^2. The fractured surfaces of all tensile test specimens are to be granular and entirely grey in appearance.

Section 3 SPHEROIDAL OR NODULAR GRAPHITE IRON CASTINGS

7.3.1 Application

7.3.1.1 The requirements of this Section apply to spheroidal or nodular graphite iron castings intended for use in the construction of machinery and pipe fittings.

7.3.1.2 This Section is applicable to spheroidal or nodular graphite iron castings for use at ambient temperatures. If the castings are intended for use at low or elevated temperatures, prior approval of CCS is to be obtained.

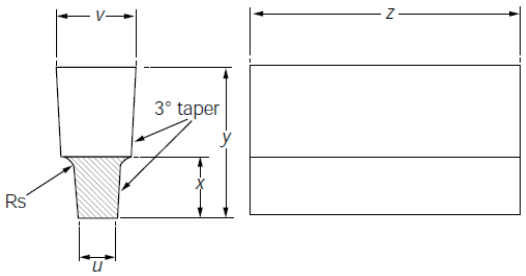
7.3.2 Heat treatment

7.3.2.1 For service at elevated temperatures or where geometrical and dimensional stability is required, the castings are to be given a suitable stress relieving heat treatment before machining or after any refining heat treatment. Where special qualities with a tensile strength of 350 N/mm^2 or 400 N/mm^2 and impact tests are required, the castings are to be given a ferritizing heat treatment.

7.3.2.2 Where castings are to be surface hardened, details of the procedure are to be submitted to CCS for approval.

7.3.3 Test material

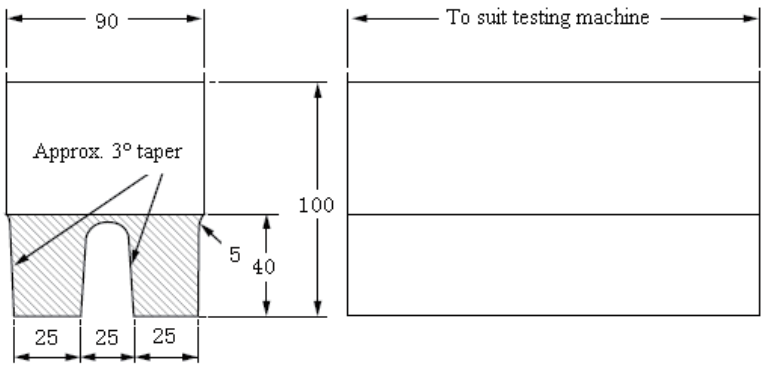
7.3.3.1 The test samples are generally to be one of the three standard types as detailed in Figure 7.3.3.1 with a thickness of 25 mm. Test samples of other dimensions, as detailed in Figure 7.3.3.1 may, however, be specially required for some components.



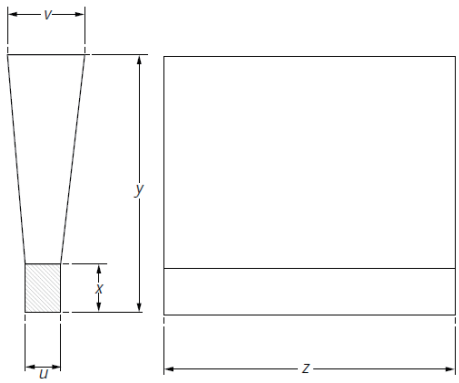
Dimensions of Type A test samples (mm)

Dimensions	Standard sample	Alternative samples when specially required		
u	25	12	50	75
v	55	40	90	125
x	40	30	60	65
y	100	80	150	165
z	To suit testing machine			
R	Approximately 5			

(1) Type A test samples (U-type)



(2) Type B test samples (double U-type)



Dimensions of Type C test samples (mm)

Dimensions	Standard sample	Alternative samples when specially required		
u	25	12	50	75
v	55	40	100	125
x	40	25	50	65
y	140	135	150	175
z	To suit testing machine			
Thickness of mould surrounding test sample	≥40	≥40	≥80	≥80

(3) Type C test samples (Y-type)

Figure 7.3.3.1 Test Samples for Spheroidal or Nodular Graphite Iron Castings

7.3.3.2 Test samples are to be prepared as follows:
(1) At least one test sample is to be provided for each casting and unless otherwise required may be either gated to the casting or separately cast. Alternatively test material of other suitable dimensions may be provided integral with the casting.
(2) For large castings where more than one ladle of treated metal is used, additional test samples are to be provided so as to be representative of each ladle used.
(3) A batch testing procedure may be adopted for castings with a fettled mass of 1 t or less. All castings in a batch are to be of similar type and dimensions, cast from the same ladle of treated metal. One separately cast test sample is to be provided for each multiple of 2 t of fettled castings in the batch.
(4) Where heat treatments are required for castings, the integrally cast samples are to be removed from the casting only after the heat treatment and the separately cast samples are to be heat treated together with the castings which they represent.
7.3.3.3 One tensile test specimen is to be prepared from each test sample.

7.3.4 Mechanical properties

7.3.4.1 The mechanical properties of spheroidal or nodular graphite iron castings are to comply with the requirements of Table 7.3.4.1.

Mechanical Properties of Spheroidal or Nodular Graphite Iron Castings Table 7.3.4.1

Tensile strength R_m min. (N/mm^2)		Proof strength $R_{p0.2}$ min. (N/mm^2)	Elongation A_5 min. (%)	Hardness (HB)	Charpy V-notch impact test		Typical structure of matrix
					Test temp. (℃)	Impact energy (J)	
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/Tempered structure
Special qualities	350	220	22④	110 ~ 170	20	17(14)	Ferrite
	400	250	18④	140 ~ 200	20	14(11)	Ferrite

Notes: ① Intermediate values may be obtained by interpolation.
② Generally, the tensile strength and elongation are used as the acceptance criteria. However, if required in the design plan, the yield strength and hardness are also to be used as the acceptance criteria.
③ The average impact energy is to be not less than the value specified in the Table, and the single value is to be not less than the value specified in the parentheses.
④ For integral cast samples, the elongation may be 2% less.

7.3.4.2 Where the result of any tensile test does not comply with the requirements, two additional specimens are to be taken from the same casting or batch of castings for re-tests. If both additional tests comply with the requirements, the said casting or batch of castings may be accepted. If one or both additional tests fail, the said casting or batch of castings is to be rejected.

7.3.4.3 Where necessary, impact tests may be required by CCS. One set of three Charpy V-notch impact test specimens is to be taken from each test sample, the dimension of the specimens and the test procedure are to comply with the relevant requirements of Chapter 2 of this PART.

7.3.5 Metallographic examination

7.3.5.1 The metallographic examination is mandatory for nodular graphite iron castings.
7.3.5.2 When required, a representative sample from each ladle of treated metal is to be prepared for metallographic examination. These samples may be taken either from the tensile test specimens, or towards the end of the pour.
7.3.5.3 Examination of the samples is to show that at least 90% of the graphite is in a dispersed spheroidal or nodular form. Details of typical matrix structures are given in Table 7.3.4.1 and are intended for information purposes.

Section 4 IRON CASTINGS FOR CRANKSHAFTS

7.4.1 Application

7.4.1.1 This Section gives additional requirements for cast iron crankshafts intended for diesel engines and compressors for refrigerants. Grey iron castings for crankshafts only apply to refrigerating compressors.

7.4.2 Heat treatment

7.4.2.1 The crankshaft castings other than those which are fully annealed, normalized or oil quenched and tempered, are to receive a suitable stress relief heat treatment before machining.
7.4.2.2 Where it is proposed to harden the surfaces of machined pins and/or journals of cast iron crankshafts, details of the process are to be submitted to CCS for approval. Before such a process is applied to a crankshaft, procedure tests are to be made to the satisfaction of CCS.

7.4.3 Test material

7.4.3.1 The dimensions of the test samples are to be such as to ensure that they have mechanical properties representative of those of the average section of the crankshaft casting.
7.4.3.2 For large crankshaft castings, the test samples are to be cast integral with, or gated from each casting.
7.4.3.3 For small crankshaft castings having a mass not exceeding 100 kg each and produced in batches, the test samples are to be cast in accordance with the requirements of 7.3.3 of this Chapter.

7.4.4 Mechanical properties

7.4.4.1 For crankshaft castings in grey iron, the tensile strength is to be not less than 300 N/mm^2. For crankshaft castings in spheroidal or nodular graphite iron, the tensile strength is to be not less than 490 N/mm^2 and the mechanical properties are to comply with the requirements given in Table 7.3.4.1 of this Chapter.
7.4.4.2 In addition to tensile tests, hardness tests are to be carried out on each casting. For spheroidal or nodular graphite iron castings, the hardness values are to comply with the requirements given in Table 7.3.4.1 of this Chapter and for grey iron castings, the hardness test results are to comply with the relevant recognized standards.

7.4.5 Rectification of defective castings

7.4.5.1 Cast iron crankshafts are not to be repaired by welding, and blemishes are not to be plugged with a filler.

7.4.6 Non-destructive testing

7.4.6.1 Cast crankshafts are to be subjected to a magnetic examination after final machining. The surfaces for examination are to be of necessary roughness. The results of the magnetic particle examination are to be submitted to CCS for approval.

CHAPTER 8 ALUMINIUM ALLOYS

Section 1 GENERAL PROVISIONS

8.1.1 Application

8.1.1.1 This Chapter applies to seawater corrosion resistant aluminum sheets, sections (including bars and pipes), aluminum alloy rivets and pistons intended for use in the construction of hull and equipment of ships. Where the aluminum alloy is intended for the construction of cargo tanks or storage for low-temperature liquefied gases, the relevant test data are to be submitted to CCS for examination.

8.1.1.2 Other aluminum alloy castings and forgings may be accepted in accordance with the relevant recognized standards.

8.1.2 Manufacture

8.1.2.1 In addition to the requirements of this Chapter, the manufacture and acceptance of aluminum alloys are to comply with the relevant requirements of Chapters 1 and 2 of this PART.

8.1.2.2 Aluminum alloys may be manufactured by an approved continuous or semi-continuous casting process. Plates and sheets are to be formed by hot or cold rolling according to the mechanical properties required. Sections may be formed by extrusion, and pipes may be formed by extrusion or drawing.

8.1.2.3 Unless otherwise agreed, non-destructive testing is not required for the acceptance of aluminum alloys. Manufacturers are expected, however, to employ suitable methods for the general maintenance of quality standards.

8.1.3 Chemical composition

8.1.3.1 The chemical composition of aluminum alloys is to comply with the relevant requirements of Sections of this Chapter. Special tests such as corrosion resistance test and weldability test or relative details may be required by CCS as deemed necessary. Other aluminum alloys or those not fully complying with the requirements of this Chapter cannot be used until the agreement of CCS is obtained.

8.1.4 Test

8.1.4.1 Products are to be presented for test individually or in batches according to the types of aluminum alloys and the relevant requirements of Sections of this Chapter. Where products are presented for test in one batch, they are to be from the same cast, having the same chemical composition, of the same type (e. g. plates, sections or bars), in the same condition of supply and of similar dimensions (the same thickness for plates). Where the products are supplied in the heat treated condition, each batch is to be heat treated in the same furnace charge or subjected to the same finishing treatment when a continuous furnace is used.

8.1.5 Surface quality and dimensions

8.1.5.1 The surface of aluminum alloy products is to be free from harmful defects that will impair further processing and proposed applications, such as cracks, laminations, corrosion, oxide inclusions, oxide skins, blisters, nitrate spots and serious mechanical damages, etc. The defects are to be determined according to the relevant recognized specifications.

8.1.5.2 The edges of aluminum alloy products are to be flush, and free from burrs. The external dimensions and tolerances are to be in accordance with the relevant specifications acceptable to CCS.

8.1.6 Rectification of defects

8.1.6.1 Slight surface imperfections may be removed by mechanical means or grinding, provided that the prior agreement of the Surveyor is obtained. The depth of any rectification is not to exceed the allowable minus deviation from the thickness, and no unfavorable effects to the material are allowed. Unless otherwise agreed, all such rectifications are to be carried out in the presence of CCS Surveyor.

8.1.6.2 Defects which cannot be removed in accordance with 8.1.6.1 are generally not allowed to be repaired by welding unless it can be demonstrated that such repair will not impair the strength and application of the aluminum alloy products.

8.1.7 Identification

8.1.7.1 All aluminum alloy products accepted by CCS are to be clearly marked, at least at one position, by the manufacturer with CCS stamp and the following particulars:

(1) name or trade mark of the manufacturer;

(2) alloy grade and temper condition;
(3) "M" showing that products are corrosion tested, if applicable;
(4) identification mark which will enable the full history of the item to be traced.
8.1.7.2 Where the products are bundled together or packed in crates for delivery, the marking specified in 8.1.7.1 may be affixed by a securely fastened tag or label at a position accessible for inspection.

8.1.8 Certification
8.1.8.1 The manufacturer is to provide a certificate giving the following particulars for all the products accepted by CCS:
(1) name of the purchaser and order number;
(2) ship name or structural project number, if known;
(3) number, dimensions and weight of the product;
(4) designation of the aluminum alloy (grade) and of its delivery condition;
(5) chemical composition;
(6) manufacturing batch number or identification mark which will enable the full history of the item to be traced;
(7) mechanical test results;
(8) corrosion test results, if applicable.

Section 2 ALUMINIUM ALLOY PLATES AND SECTIONS

8.2.1 Application
8.2.1.1 The requirements of this Section apply to aluminum alloy plates and sections with a thickness of 3 mm to 50 mm and intended for use in the construction of hull structures, superstructures and other maritime structures. However, the requirements of this Section are generally not applicable to the use of aluminum alloys for structures at a working temperature of below -100℃.
8.2.1.2 Aluminum alloys other than those specified in this Section may be used for the construction of ships and offshore engineering installations only when their chemical composition, delivery condition and mechanical properties are found satisfactory by CCS.

8.2.2 General requirements
8.2.2.1 Aluminium alloy plates and sections and their part-processed products are to be made at works approved by CCS.
8.2.2.2 Aluminium alloys used are to be of satisfactory seawater corrosion resistance and weldability.
8.2.2.3 AlSiMg series alloys (6000 series) are generally not allowed to be used in direct contact with seawater, unless effective protection measures (such as cathodic protection and/or being well coated) are taken.

8.2.3 Chemical composition
8.2.3.1 The chemical composition of aluminium alloys is to comply with the requirements of Table 8.2.3.1.

Chemical Composition of Aluminum Alloys (%) **Table 8.2.3.1**

Designation	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al	Other elements①	
										Each	Total
5A01	Si+Fe≤0.40		≤0.10	0.30~0.70	6.0~7.0	0.10~0.20	≤0.20	≤0.15	Residual	≤0.05	≤0.15
5454	≤0.25	≤0.40	≤0.10	0.50~1.0	2.4~3.0	0.05~0.20	≤0.25	≤0.20	Residual	≤0.05	≤0.15
5083	≤0.40	≤0.40	≤0.10	0.40~1.0	4.0~4.9	0.05~0.25	≤0.25	≤0.15	Residual	≤0.05	≤0.15
5383	≤0.25	≤0.25	≤0.20	0.7~1.0	4.0~5.2	≤0.25	≤0.40	≤0.15	Residual	≤0.05④	≤0.15④
5059	≤0.45	≤0.50	≤0.25	0.6~1.2	5.0~6.0	≤0.25	0.40~0.90	≤0.20	Residual	≤0.05⑤	≤0.15⑤
5086	≤0.40	≤0.50	≤0.10	0.20~0.70	3.5~4.5	0.05~0.25	≤0.25	≤0.15	Residual	≤0.05	≤0.15
5456	≤0.25	≤0.40	≤0.10	0.50~1.0	4.7~5.5	0.05~0.20	≤0.25	≤0.20	Residual	≤0.05	≤0.15
5754	≤0.40	≤0.40	≤0.10	≤0.50②	2.6~3.6	≤0.30②	≤0.20	≤0.15	Residual	≤0.05	≤0.15
6005A	0.50~0.90	≤0.35	≤0.30	≤0.50③	0.4~0.7	≤0.30③	≤0.20	≤0.10	Residual	≤0.05	≤0.15
6061	0.40~0.80	≤0.7	0.15~0.40	≤0.15	0.8~1.2	0.04~0.35	≤0.25	≤0.15	Residual	≤0.05	≤0.15
6082	0.7~1.3	≤0.50	≤0.10	0.40~1.0	0.6~1.2	≤0.25	≤0.20	≤0.10	Residual	≤0.05	≤0.15

Notes: ① Other elements include Ni, Ga, V and listed elements for which no specific limit is shown. Regular analysis need

not be made.

② 0.10% ≤ Mn + Cr ≤ 0.60%.

③ 0.12% ≤ Mn + Cr ≤ 0.50%.

④ Zr ≤ 0.20. The total for other elements does not include zirconium (Zr).

⑤ 0.05% ≤ Zr ≤ 0.25%. The total for other elements does not include zirconium.

8.2.3.2 Forges and foundries intending to supply semi-finished products are to issue to the Surveyor a certificate indicating the cast number and chemical composition.

8.2.4 Conditions of supply

8.2.4.1 Aluminum alloy plates, bars, sections and pipes may be formed by rolling or extrusion.

8.2.4.2 Aluminium alloys are generally to be supplied in any of the following conditions:

O — annealed

H111 — annealed and slightly hardened (e.g. straightening)

H112 — strain hardened from working at elevated temperatures

H116 — with specified resistance to corrosion for aluminium alloys where the magnesium content not less than 3.0%

H32 — deformation hardened and stabilization processed

H321 —for aluminium alloys with a magnesium content not less than 3.0%, deformation hardened and stabilization processed

T5 — hot worked and artificially aged

T6 — solution heat treated and artificially aged

8.2.4.3 Rolled aluminium magnesium alloys are generally to be supplied in the condition of H111, H112, H116, H32, H321 or O.

8.2.4.4 Extruded aluminium magnesium alloys are generally to be supplied in the condition of H111, H112 or O.

8.2.4.5 Extruded AlSiMg alloys are generally to be supplied in the condition of T5 or T6.

8.2.5 Testing and inspections

8.2.5.1 The manufacturer is to determine the chemical composition of each cast. The chemical composition of aluminium alloys is to be in accordance with the requirements given in 8.2.3.1 of this Section.

8.2.5.2 All finished material is to have the specified surface roughness without internal or external defects which will interfere with the use. Slight surface imperfections may be removed by grinding or machining as long as the thickness of the material remains within the tolerances given in 8.2.5.3.

8.2.5.3 The manufacturer is to determine the dimensional tolerances of each batch of aluminium alloy products. The underthickness tolerances for rolled products are to be in accordance with the requirements of Table 8.2.5.3. The underthickness tolerances for extruded products are to be in accordance with the requirements of recognized national or international standards. The dimensional tolerances other than underthickness ones are to be in accordance with the requirements of recognized national or international standards.

Underthickness Tolerances for Rolled Products **Table 8.2.5.3**

Nominal width B (mm) / Nominal thickness t (mm)	$B \le 1500$	$1500 < B \le 2000$	$2000 < B \le 3500$
$3 \le t < 4$	0.10	0.15	0.15
$4 \le t < 8$	0.20	0.20	0.25
$8 \le t < 12$	0.25	0.25	0.35
$12 \le t < 20$	0.35	0.40	0.50
$20 \le t < 50$	0.45	0.50	0.65

8.2.5.4 Mechanical test samples are to be taken from each batch of aluminium alloy products. Each batch is to be made up of products of the same alloy grade and from the same cast, of the same product form and similar dimensions (the same thickness for plates), manufactured by the same process. The number of test samples is to be in accordance with the requirements of 8.2.5.5 to 8.2.5.7 below.

8.2.5.5 One tensile specimen is to be taken from each batch of rolled products. If the weight of each batch exceeds 2,000 kg, one extra tensile specimen is to be taken from every 2,000 kg of the product or fraction thereof, in each batch. Where the weight of a single piece (plate or coil) is greater than 2,000 kg, only one tensile specimen is required.

8.2.5.6 For extruded products, samples are to be taken for tests in accordance with Table 8.2.5.6.

Sampling Number of Extruded Products Table 8.2.5.6

Nominal weight of products	Weight of each batch	Sampling number
< 1 kg/m	1000 kg and fraction thereof	One sample
1 ~ 5 kg/m	2000 kg and fraction thereof	One sample
> 5 kg/m	3000 kg and fraction thereof	One sample

8.2.5.7 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. Drift expansion tests may be carried out in accordance with the following requirements:
(1) Every fifth profile is to be sampled after final heat treatment. Batches of five profiles or less are to be sampled one profile. Profiles with lengths exceeding 6 m are to be sampled every profile in the start of the production. The number of tests may be reduced to every fifth profile if the results from the first 3~5 profiles are found acceptable.
(2) Each profile sampled is to have two samples cut from the front and back end of the production profile.
(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.
(4) The length of the specimen is to be in accordance with 2.6.2, Chapter 2 of this PART.
(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 60º.
(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.
8.2.5.8 Tests are to be carried out in accordance with the relevant requirements given in Chapter 2 of this PART. The test results are to be in accordance with the requirements given in 8.2.7 of this Section.
8.2.5.9 Where the results of any tensile test are not in accordance with the requirements, re-tests for acceptance may be carried out in accordance with the requirements given in 1.2.5 of Chapter 1 of this PART.
8.2.5.10 Each batch of aluminium manganese alloys of type 5083, 5383, 5059, 5086 and 5456 in the H116 and H321 tempers intended for use in marine hull construction or in marine applications where frequent direct contact with seawater is expected are to be corrosion tested or examined with respect to exfoliation and intergranular corrosion resistance in accordance with paragraphs 8.2.5.11 to 8.2.5.13.
8.2.5.11 The manufacturers are in general to establish the relationship between microstructure and resistance to corrosion when the above alloys are approved. A reference photomicrograph taken at 500x, under the conditions specified in ASTM B928, Section 9.4.1, is to be established for each of the alloy-tempers and thickness ranges relevant. The reference photographs are to be taken from samples which have exhibited no evidence of exfoliation corrosion and a pitting rating of PB or better, when subjected to the test described in ASTM G66 (ASSET).The samples are also to have exhibited resistance to intergranular corrosion at a mass loss no greater than 15 mg/cm^2, when subjected to the test described in ASTM G67 (NAMLT). Upon satisfactory establishment of the relationship between microstructure and resistance to corrosion, the master photomicrographs and the results of the corrosion tests are to be approved by CCS. Production practices are not to be changed after approval of the reference micrographs.
8.2.5.12 For batch acceptance of aluminium alloy (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, under the conditions specified in ASTM B928, Section 9.6.1. If the microstructure shows evidence of continuous grain boundary network of aluminium-magnesium precipitate in excess of the reference photomicrographs of acceptable material, the batch is either to be rejected or tested for exfoliation corrosion resistance and intergranular corrosion resistance subject to agreement of the Surveyor. The corrosion tests are to be in accordance with ASTM G66 and G67 or equivalent standards. Acceptance criteria are that the sample is to exhibit no evidence of exfoliation corrosion and a pitting rating of PB or better when subjected to ASTM G66 ASSET test, and the sample is to exhibit resistance to intergranular corrosion at a mass loss no greater than 15 mg/cm^2 when subjected to ASTM G67 NAMLT test. If the results from testing satisfy the acceptance criteria stated in paragraph 8.2.5.11, the batch is accepted, else it is to be rejected.

8.2.5.13 As an alternative to metallographic examination, each batch may be tested for exfoliation corrosion resistance and intergranular corrosion resistance, in accordance with ASTM G66 and G67 under the conditions specified in ASTM B928. If this alternative is used, then the results of the test are to satisfy the acceptance criteria stated in paragraph 8.2.5.12.

8.2.6 Test samples and specimens

8.2.6.1 Tensile samples are to be taken at 1/3 width from a longitudinal edge of rolled products; tensile specimens are to be taken in the range 1/3 to 1/2 of the distance from the edge to the centre of the thickest part of extruded products.

8.2.6.2 Test samples are to be taken so that the orientation of test specimens is as follows:

(1) Normally for rolled products, tests in the transverse direction are required. If the width is insufficient for obtaining transverse test specimens, or in the case of strain hardening alloys, tests in the longitudinal direction will be permitted.

(2) The extruded products are normally to be tested in the longitudinal direction.

8.2.6.3 After removal of test samples, each test specimen is to be marked in order that its original identity, location and orientation is maintained.

8.2.6.4 Test specimens are to be cut from test samples in accordance with the following requirements:

(1) For thicknesses up to and including 12.5 mm, flat tensile test specimens are to be used in accordance with the second non-proportional test specimen of item 1 in Table 2.2.2.1 of this PART. The tensile test specimen is to be prepared so that both rolled surfaces are maintained.

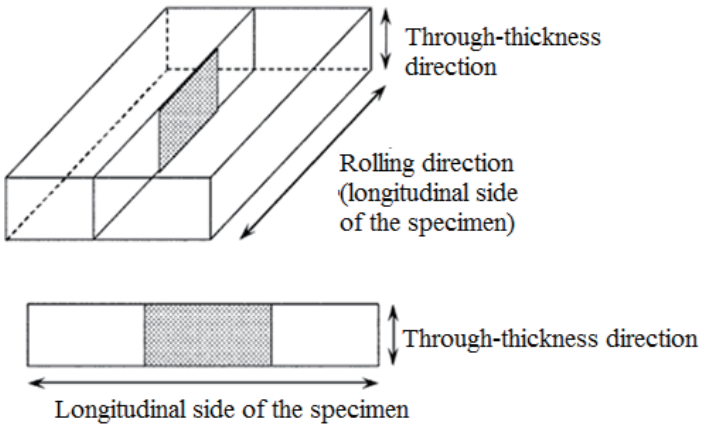
(2) For thicknesses exceeding 12.5 mm, round tensile test specimens are to be used in accordance with Item 2 of Table 2.2.2.1 of this PART. For thicknesses up to and including 40 mm, the longitudinal axis of the round tensile test specimen is to be located at a distance from the surface equal to half the thickness. For thicknesses over 40 mm, the longitudinal axis of the round tensile test specimen is to be located at a distance from one of the surfaces equal to one quarter of the thickness.

8.2.6.5 For corrosion test or metallographic examination, a longitudinal section perpendicular to the rolled surface is to be prepared as follows:

(1) from mid width at one end of a coil;

(2) from mid width at one end of a random sheet or plate.

The sampling direction and evaluation areas of intergranular corrosion specimen are shown in Figure 8.2.6.5.



The dash areas in the Figure are the evaluation areas of intergranular corrosion specimen

Figure 8.2.6.5 Sampling Direction and Evaluation Areas of Intergranular Corrosion Specimen

8.2.7 Mechanical properties

8.2.7.1 Mechanical properties of rolled products in various temper conditions are to be in accordance with the requirements given in Table 8.2.7.1.

Mechanical Properties of Rolled Aluminium Alloys (3 mm ≤ t ≤ 50 mm) Table 8.2.7.1

Designation	Temper condition	Thickness t (mm)	Proof strength $R_{p0.2}$ (N/mm^2)	Tensile strength R_m (N/mm^2)	Minimum elongation A① (%)	
					50 mm	5d
5A01	O	3 ≤ t ≤ 50	≥165	≥325	10	
	H112	3 ≤ t ≤ 0	≥165	≥325	10	
	H32	3 ≤ t ≤ 50	≥245	≥365	8	
5454	O	3 ≤ t ≤ 50	≥85	215 ~ 285	17	16
	H112	6 ≤ t ≤ 12.5	≥125	≥220	8	–
		12.5 < t ≤ 50	≥85	≥215	–	9
	H32	3 ≤ t ≤ 6.3	≥180	250 ~ 305	8	–
		6.3 < t ≤50	≥180	250 ~ 305	–	10
5083	O	3 ≤ t ≤ 50	≥125	275 ~ 350	16	14
	H111	3 ≤ t ≤ 50	≥125	275 ~ 350	16	14
	H112	3 ≤ t ≤ 50	≥125	≥275	12	10
	H116	3 ≤ t ≤ 50	≥215	≥305	10	10
	H321	3 ≤ t ≤ 50	215 ~ 295	305 ~ 385	12	10
5383	O	3 ≤ t ≤ 50	≥145	≥290	–	17
	H111	3 ≤ t ≤ 50	≥145	≥290	–	17
	H116	3 ≤ t ≤ 50	≥220	≥305	10	10
	H321	3 ≤ t ≤ 50	≥220	≥305	10	10
5059	O	3 ≤ t ≤ 50	≥160	≥330	24	24
	H111	3 ≤ t ≤ 50	≥160	≥330	24	24
	H116	3 ≤ t ≤ 20	≥270	≥370	10	10
		20 < t ≤ 50	≥260	≥360	–	10
	H321	3 ≤ t ≤ 20	≥270	≥370	10	10
		20 < t ≤ 50	≥260	≥360	–	10
5086	O	3 ≤ t ≤ 50	≥95	240 ~ 305	16	14
	H111	3 ≤ t ≤ 50	≥95	240 ~ 305	16	14
	H112	3 ≤ t ≤ 12.5	≥125	≥250	8	–
		12.5 < t ≤ 50	≥105	≥240	–	9
	H116	3 ≤ t ≤ 50	≥195	≥275	10②	9
5456	O	3 ≤ t ≤ 6.3	130~205	290 ~ 365	16	–
		6.3 < t ≤ 50	125~205	285 ~ 360	16	14
	H116	3 ≤ t ≤ 30	≥230	≥315	10	10
		30 < t ≤ 40	≥215	≥305	–	10
		40 < t ≤ 50	≥200	≥285	–	10
	H321	3 ≤ t ≤ 12.5	230~315	315 ~ 405	12	–
		12.5 < t ≤ 40	215~305	305 ~ 385	–	10
		40 < t ≤ 50	200~295	285 ~ 370	–	10
5754	O	3 ≤ t ≤ 50	≥80	190 ~ 240	18	17
	H111	3 ≤ t ≤ 50	≥80	190 ~ 240	18	17

Notes: ① Elongation in 50 mm applies to thicknesses up to and including 12.5 mm and in 5d to thicknesses over 12.5 mm.
② 8 % for thicknesses up to and including 6.3 mm.
③ The mechanical properties for the O and H111 tempers are the same. However, they are separated to discourage dual certification as these tempers represent different processing.

8.2.7.2 Mechanical properties for extruded products in various temper conditions are to be in accordance with the requirements given in Table 8.2.7.2.

Mechanical Properties for Extruded Aluminum Alloy Products Table 8.2.7.2

Designation	Temper condition	Thickness t mm	Proof strength $R_{p0.2}$ (N/mm^2)	Tensile strength R_m (N/mm^2)	Minimum elongation A①② (%)	
					50 mm	5d
5A01	H112	3 ≤ t ≤ 50	≥170	≥330	10	
5454	H112	3 ≤ t ≤ 50	≥100	≥230	10	
5083	O	3 ≤ t ≤ 50	≥110	270 ~ 350	14	12
	H111	3 ≤ t ≤ 50	≥165	≥275	12	10
	H112	3 ≤ t ≤ 50	≥110	≥270	12	10
5383	O	3 ≤ t ≤ 50	≥145	≥290	17	17
	H111	3 ≤ t ≤ 50	≥145	≥290	17	17

Designation	Temper condition	Thickness t mm	Proof strength $R_{p0.2}$ (N/mm^2)	Tensile strength R_m (N/mm^2)	Minimum elongation $A^{①②}$ (%)	
					50 mm	$5d$
	H112	$3 \le t \le 50$	≥190	≥310		13
5059	H112	$3 \le t \le 50$	≥200	≥330		10
5086	O	$3 \le t \le 50$	≥95	240 ~315	14	12
	H111	$3 \le t \le 50$	≥145	≥250	12	10
	H112	$3 \le t \le 50$	≥95	≥240	12	10
5456	H112	$3 \le t \le 50$	≥130	≥300	10	
5754	H112	$3 \le t \le 50$	≥80	≥180	10	
6005A	T5	$3 \le t \le 50$	≥215	≥260	9	8
	T6	$3 \le t \le 10$	≥215	≥260	8	6
		$10 < t \le 50$	≥200	≥250	8	6
6061	T6	$3 \le t \le 50$	≥240	≥260	10	8
6082	T5	$3 \le t \le 50$	≥230	≥270	8	6
	T6	$3 \le t \le 5$	≥250	≥290	6	
		$5 < t \le 50$	≥260	≥310	10	8

Notes: ① Elongation in 50 mm applies to thicknesses up to and including 12.5 mm and in $5d$ to thicknesses over 12.5 mm.
② The values are applicable to both longitudinal and transverse tensile test specimens.

Section 3 ALUMINIUM ALLOY RIVETS

8.3.1 Application

8.3.1.1 The requirements of this Section apply to aluminum alloy rivets used for the construction of marine structures.

8.3.2 Chemical composition

8.3.2.1 The chemical composition of bars used for the manufacture of rivets is to comply with the requirements in Table 8.3.2.1.

Chemical Composition of Aluminum Alloy Rivets **Table 8.3.2.1**

Designation	Original designation	Chemical composition (%)										
		Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti[①]	Al	Other elements	Miscellaneous[①]
5052	AlMg2.5	≤0.25	≤0.40	≤0.10	≤010	2.2~2.8	0.15~0.35	≤0.10	–	Remainder	$0.10 \le Zr \le 0.20$	Each ≤ 0.05 Total ≤ 0.15
5754	AlMg3	≤0.40	≤0.40	≤0.10	≤0.50[②]	2.6~3.6	≤0.30[②]	≤0.20	≤0.15	Remainder		
5154A	AlMg3.5	≤0.50	≤0.50	≤0.10	≤0.50[③]	3.1~3.9	≤0.25[③]	≤0.20	≤0.20	Remainder		
5086	AlMg4	≤0.40	≤0.50	≤0.10	0.20~0.70	3.5~4.5	0.05~0.25	≤0.25	≤0.15	Remainder		
6082	AlSi1Mg	0.7~1.3	≤0.50	≤0.10	0.40~1.0	0.6~1.2	≤0.25	≤0.20	≤0.10	Remainder		

Notes: ① Ti can be replaced totally or partially by other grain refining elements.
② $0.10\% \le Mn + Cr \le 0.60\%$.
③ $0.10\% \le Mn + Cr \le 0.50\%$.

8.3.3 Heat treatment

8.3.3.1 Bars used for the manufacture of rivets or finished rivets are to be supplied for inspection in one of the following conditions:
(1) annealed;
(2) solution heat treated and naturally aged.

8.3.4 Test specimens and tests

8.3.4.1 Bars intended for the manufacture of rivets may be presented for test in batches. Where the weight of a batch exceeds 250 kg, one tensile test specimen and one dump test specimen are to be taken from each

250 kg or fraction thereof.
8.3.4.2 Where necessary, the shear test of bars used for the manufacture of rivets may be required by CCS. The results of the test are to comply with the relevant recognized standards.
8.3.4.3 Each batch of bars presented for test is to be from the same melt, having the same chemical composition and the same diameter, and each batch is to be heat treated in full cross section and in a manner simulating the heat treatment applied to the finished rivets in the same furnace charge.
8.3.4.4 The test specimens are to be taken in the direction and position specified in 8.2.6.2 of this Chapter. The preparation and dimensions of tensile test specimens are to comply with the appropriate requirements of Chapter 2 of this PART. The dump test specimen is to consist of a section cut from the bar with the ends perpendicular to the axis, and the length of this section is to be equal to the diameter of the bar.

8.3.5 Mechanical properties
8.3.5.1 The results of tensile tests are to comply with the requirements of Table 8.3.5.1.

Mechanical Properties for Aluminum Alloy Rivets **Table 8.3.5.1**

Designation	Temper condition	Proof stress $R_{p0.2}$ min. (N/mm^2)	Tensile strength R_m min. (N/mm^2)	Elongation A_5 min. (%)
5052	O	70	170	16
5754	O	80	190	16
5154A	O	90	210	16
5086	O	100	230	16
6082	T6	115	200	16

Note: Values in the Table are applicable to all thicknesses or diameters.

8.3.5.2 The dump test is to be carried out at ambient temperature, and is to consist of compressing the specimen until the diameter is increased to 1.6 times the original diameter. After compression, the specimen is to be free from cracks.

8.3.6 Tests for finished rivets
8.3.6.1 For finished rivets, one dump test specimen is to be taken from every 100 kg or fraction thereof, and the test is to be carried out in accordance with the requirements in 8.3.5.2 of this Section.
If the test fails, twice the number of rivets may be re-tested. If there is still an unsatisfactory result, the batch is to be rejected.

Section 4 ALUMINIUM ALLOY PISTONS

8.4.1 Manufacture
8.4.1.1 Aluminum alloy pistons for diesel engines may be made of aluminum alloy castings. The castings are to be manufactured and tested in accordance with the requirements of this Section and of Chapters 1 and 2 of this PART. Where it is proposed to use other types of aluminum alloys, their chemical composition and mechanical properties are to be in accordance with the design requirements and to be submitted to CCS for information.

8.4.2 Inspection items
8.4.2.1 Inspection items for aluminum alloy castings for pistons are to be as follows:
(1) chemical composition: specimens from each cast;
(2) tensile test: one tensile test specimen representative of each cast, the dimensions of the test specimens are to comply with the requirements in Table 2.2.2.1 of Chapter 2 of this PART;
(3) hardness test;
(4) macro-examination: to be carried out on each casting.

8.4.3 Chemical composition and mechanical properties
8.4.3.1 The chemical composition and mechanical properties of aluminum alloy pistons are to comply with the requirements of Tables 8.4.3.1(1) and (2).

Chemical Composition of Aluminum Alloy Piston **Table 8.4.3.1(1)**

Designation	Alloy code	Chemical composition (%)					
		Si	Cu	Mn	Mg	Ni	Al
ZAlSi12Cu2Mgl	ZL108	11~13	1~2	0.3~0.9	0.4~1.0	-	Residual
ZAlSi12CulMglNil	ZL109	11~13	0.5~1.5	-	0.8~1.3	0.8~1.5	Residual
ZAlSi5Cu6Mg	ZL110	4~6	5~8	-	0.2~0.5	-	Residual

Mechanical Properties of Aluminum Alloy Pistons **Table 8.4.3.1(2)**

Designation	Alloy code	Tensile Strength R_m min. (N/mm^2)	Hardness HBW min.	Delivery condition
ZAlSil2Cu2Mgl	ZL108	200	85	Artificial ageing (T5)
	ZL108	260	90	Solution treated & complete artificial ageing (T6)
ZAlSil2Cu1MglNil	ZL109	195	90	Artificial ageing (T5)
	ZL109	245	100	Solution treated & complete artificial ageing (T6)
ZAlSi5Cu6Mg	ZL110	170	90	Artificial ageing (T5)

8.4.4 Macro-examination

8.4.4.1 The surfaces of the piston castings are to be free from blow holes, cracks, etc.

Section 5 ALUMINIUM-STEEL TRANSITION JOINTS

8.5.1 Application

8.5.1.1 This Section applies to transition joints used for connecting aluminium alloy structures to steel plating.

8.5.2 General requirements

8.5.2.1 Aluminium/steel transition joints are to be produced by a manufacturer approved by CCS.

8.5.2.2 The manufacturer is to submit a specification which is to include the maximum temperature allowable at the interface during welding.

8.5.2.3 Aluminium/steel transition joints are composed of two or three layers of metal, with steel base being covered by aluminium alloy. For three-layer transition joints, the intermediate layer may be titanium or aluminium.

8.5.2.4 The base material is generally to be normal strength hull structural steels which comply with the relevant requirements of Section 2, Chapter 3 of this PART.

8.5.2.5 The cover material is generally to be marine aluminium alloys which comply with the relevant requirements of Section 2 of this Chapter.

8.5.2.6 The industrially pure titanium or aluminium used as the intermediate layer is to comply with recognized standards.

8.5.3 Manufacture

8.5.3.1 Composite plates are to be manufactured by explosion bonding.

8.5.3.2 Transition joints in the form of strips, blocks or in other shapes are made from such composite plates by machining.

8.5.4 Visual and ultrasonic examination

8.5.4.1 Each composite plate is to be subjected to 100 percent visual and ultrasonic examination to determine the extent of any unbonded areas. Unbonded areas plus 25 mm of surrounding sound material is to be discarded.

8.5.4.2 Ultrasonic examination is to comply with a recognized standard.

8.5.5 Mechanical tests

8.5.5.1 Each batch of composite plates is to be sampled for mechanical testing. A batch is to consist of three or less composite plates produced at one time and with same materials, dimension and explosion

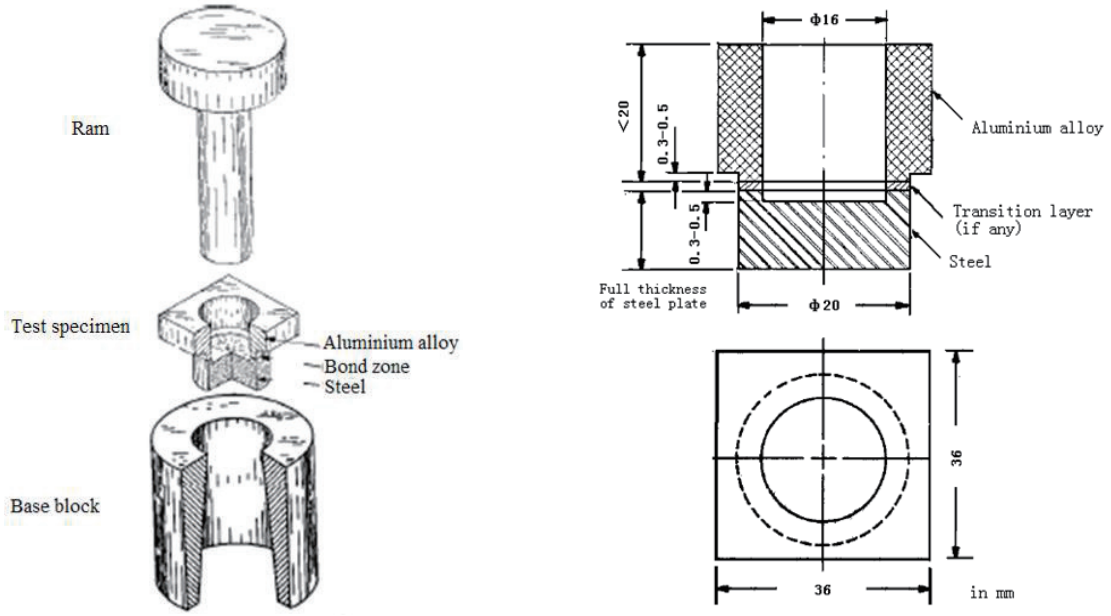
bonding technology. One set of test specimens is to be taken from each end of one of the composite plates.

8.5.5.2 The following specimens are included in each set:

(1) two tensile test specimens: Tensile tests may be made across the interface by welding extension pieces to each surface or by the ram method shown in Figure 8.5.5.2. One specimen is to be tested at ambient temperature after heating to the maximum allowable interface temperature for 15 min;

(2) two shear test specimens: Measuring shear strength of the interface. One specimen is to be tested at ambient temperature after heating to the maximum allowable interface temperature for 15 min. If the intermediate transition layer is titanium, two specimens are to be added to measure the shear strength at both interfaces under the above conditions;

(3) one bend test specimen: The ram diameter is to be 6 *t* (*t* being the thickness of the specimen) and the specimen is to be bent to 90°.



(a) Ram tensile test setup **(b) Recommended dimension for ram test specimen**

Figure 8.5.5.2 Ram Test

8.5.5.3 Methods for the above tests are to comply with recognized standards.

8.5.5.4 Test results are to comply with the manufacturer's specifications.

8.5.5.5 Where the result of any mechanical test does not comply with the requirements, two additional specimens may be taken from the same plate for retests. If retest results comply with the requirements, the said batch may be accepted. If the retests fail, each composite plate of the batch is to be examined.

CHAPTER 9 OTHER NON-FERROUS MATERIALS

Section 1 COPPER ALLOY PROPELLERS

9.1.1 Application

9.1.1.1 The requirements of this Section apply to cast copper alloy propellers (including blades and bosses).

9.1.1.2 Cast copper alloy propellers and their components are to be manufactured and tested in accordance with the relevant requirements given in this Section and Chapters 1 and 2 of this PART.

9.1.2 Approval

9.1.2.1 Manufacturers (including foundries and machining works) are to apply for works approval in accordance with the relevant requirements of CCS.

9.1.2.2 The approved works are to be subject to periodical verification by CCS, covering the quality assurance system and the technical conditions and accuracy of production, testing and inspection facilities. The manufacturers not frequently engaged in producing such castings are to be checked in accordance with the details of the approval test, in addition to the fore-mentioned requirements.

9.1.3 Chemical composition

9.1.3.1 The chemical composition of copper alloy propellers and their components is generally to be as given in Table 9.1.3.1. For chemical composition of alloys other than those given in Table 9.1.3.1, the related information (including chemical composition, heat treatment procedure, mechanical properties and seawater corrosion resistance) is to be submitted, which may be accepted in accordance with relevant recognized standards subject to agreement of CCS.

Typical Chemical Composition of Copper Alloy Propellers **Table 9.1.3.1**

Copper alloy	Chemical composition (%)							
Type	Cu	Al	Mn	Zn	Fe	Ni	Sn	Pb
Grade 1 manganese bronze (Cu1)	52 ~ 62	0.5 ~ 3.0	0.5 ~ 4.0	35 ~ 40	0.5 ~ 2.5	≤ 1.0	≤ 1.5	≤ 0.5
Grade 2 Ni-manganese bronze (Cu2)	50 ~ 57	0.5 ~ 2.0	1.0 ~ 4.0	33 ~ 38	0.5 ~ 2.5	3.0 ~ 8.0	≤ 1.5	≤ 0.5
Grade 3 Ni-aluminum bronze (Cu3)	77 ~ 82	7.0 ~ 11.0	0.5 ~ 4.0	≤ 1.0	2.0 ~ 6.0	3.0 ~ 6.0	≤ 0.1	≤ 0.03
Grade 4 Mn-aluminum bronze (Cu4)	70 ~ 80	6.5 ~ 9.0	8.0 ~ 20.0	≤ 6.0	2.0 ~ 5.0	1.5 ~ 3.0	≤ 1.0	≤ 0.05

9.1.3.2 For alloys Grades Cu1 and Cu2, the proportions of α and β phases are to be determined by the manufacturer. The proportion of α phase is to be not less than 25% and that of β phase is to be kept low so as to ensure adequate cold ductility and corrosion fatigue resistance.

9.1.3.3 In order to ensure the proportions of α phase in microstructure of Cu1 and Cu2, zinc equivalent of copper alloy is not to exceed 45%. Zinc equivalent is to be defined by the following formula:

$$\text{Zinc equivalent} = 100 - \frac{100 \times \text{Cu}\%}{100 + A} \quad (\%)$$

where: $A = 1\times\text{Sn}\% + 5\times\text{Al}\% - 0.5\times\text{Mn}\% - 0.1\times\text{Fe}\% - 2.3\times\text{Ni}\%$.

Where the proportion of α phase is or above 25%, the zinc equivalent may not be required.

9.1.4 Manufacture and heat treatment

9.1.4.1 The pouring is to be carried out into dried moulds using degassed liquid metal. The pouring is to be controlled to avoid turbulent flow. Special devices are to be used to prevent slag flowing into the mould.

9.1.4.2 Casting defects which may impair the serviceability of the castings, e.g. major non-metallic inclusions, shrinkage cavities, blow holes and cracks are not permitted.

9.1.4.3 Where specimens are taken from separately cast sample pieces, the samples are to be cast in moulds made of the same material as the mould for the propeller and they are to be cooled down under the same conditions as the propeller.

9.1.4.4 For castings of propellers or their components, subsequent stress relieving heat treatment may be performed to reduce the residual stresses. A specification containing the details of the heat treatment is to be submitted to CCS for examination. For stress relieving temperatures and soaking time, see Table 9.1.4.4.

Soaking Times for Stress Relief Heat Treatment of Copper Alloy Propellers Table 9.1.4.4

Alloy grade / Soaking time / Stress relief temperature (℃)	Cu1 and Cu2		Cu3 and Cu4	
	Hours per 25 mm thickness (h)	Max. recommended total time hours (h)	Hours per 25 mm thickness (h)	Max. recommended total time hours (h)
350	5	15	-	-
400	1	5	-	-
450	1/2	2	5	15
500	1/4	1	1	5
550	1/4①	1/2①	1/2②	2②
600	–	–	1/4②	1②

Notes: ① Applicable to Cu2 alloys.
② Applicable to Cu4 alloys only.

9.1.4.5 Castings may be supplied in either the as-cast or properly heat treated condition.

9.1.5 Test samples

9.1.5.1 For cast copper alloy propellers, separately cast keel block type test samples as given in Figure 9.1.5.1 are generally used. Where possible, test bars attached on blades are to be located in an area between 0.5 *R* and 0.6 *R* (*R* being the radius of the propeller). Separately cast test samples in accordance with other recognized standards may be used.

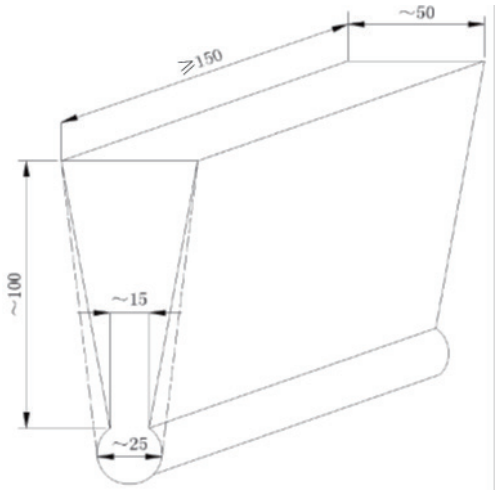


Figure 9.1.5.1 Keel Type Test Sample

9.1.5.2 Usually at least 1 mechanical test sample is to be taken from each ladle of liquid metal and the sample is usually to be cast towards the end of pouring process.

9.1.5.3 Where a batch of propellers made and heat treated from one cast with same shape and dimensions, at least one sample is to be provided for each multiple of five casings in the batch provided that the following conditions are met:

(1) integrally cast propeller with a diameter not greater than 1 m;

(2) for controllable pitch propeller, the weight of each blade or propeller hub not more than 200 kg.

9.1.5.4 Where propellers are subjected to a heat treatment, the test samples are to be heat treated together with them. The test sample material is to be removed from the casting by non-thermal procedures.

9.1.5.5 Round proportional tensile test specimens are to be cut from each test sample in accordance with the requirements given in Item 2 of Table 2.2.2.1 of this PART.

9.1.6 Testing and inspections

9.1.6.1 Analysis of the chemical composition is required on each cast of copper alloy propellers and their components, and the results of the analysis are to comply with the relevant requirements of 9.1.3 of this Section.

9.1.6.2 Samples for metallographic examination are to be prepared from every melt of Grades Cu1 and Cu2 alloys. The proportion of α phase determined from the average of 5 counts is to comply with the

requirements of 9.1.3.2.

9.1.6.3 The tensile strength, 0.2% proof strength and elongation are to be determined by mechanical tests. Test results of test specimens taken from separately cast samples are to comply with the values given in Table 9.1.6.3. For integrally cast test specimens the mechanical characteristics are to be specially agreed with CCS.

Mechanical Properties of Copper Propeller Castings **Table 9.1.6.3**

Type of coppery alloy	Proof strength $R_{p0.2}$ N/mm^2	Tensile strength R_m N/mm^2	Elongation A_5 (%)
Grade 1 manganese bronze (Cu1)	≥ 175	≥ 440	≥ 20
Grade 2 Ni-manganese bronze (Cu2)	≥ 175	≥ 440	≥ 20
Grade 3 Ni-aluminum bronze (Cu3)	≥ 245	≥ 590	≥ 16
Grade 4 Mn-aluminium bronze (Cu4)	≥ 275	≥ 630	≥ 18

9.1.6.4 Propeller castings are to be visually examined at all stages of manufacture and the whole surface is to be subjected to a comprehensive visual examination in the finished condition by the Surveyor. This examination is also to include the bore.

9.1.6.5 The dimensions, geometrical tolerances and surface roughness are to be checked by the manufacturer and the report on the dimensional inspection is to be handed over to the Surveyor, who may require checks to be made in his presence. The inspection results are to be in accordance with the approved drawings.

9.1.6.6 Minor casting defects such as small sand and slag inclusions, small cold shuts and scabs are to be trimmed. Casting defects which may impair the serviceability of the castings, e.g. major non-metallic inclusions, shrinkage cavities, blow holes and cracks are to be removed by a proper method and repaired in accordance with the relevant requirements in Section 4, Chapter 8 of PART THREE of the Rules.

9.1.6.7 Each propeller and its components are to be subject to a non-destructive testing in accordance with the relevant requirements in Section 4, Chapter 8 of PART THREE of the Rules and a report of the non-destructive testing is to be provided.

9.1.6.8 Where any defect to be repaired are found, the repair is to be carried out in accordance with the relevant requirements in Section 4, Chapter 8 of PART THREE of the Rules. And the repaired portion is to be subject to NDT for certifying that the product is as required.

9.1.6.9 The Surveyor may require areas to be etched (e.g. by iron chloride) for the purpose of investigating weld repairs.

9.1.6.10 Static balancing is to be carried out on all propellers in accordance with the approved drawing. Dynamic balancing is to be carried out for propellers running above 500 r/min.

9.1.7 Marking and certification

9.1.7.1 Each propeller casting is to be marked by the manufacturer at least with the following:

a) grade of cast material or corresponding abbreviated designation;
b) manufacturer’s mark;
c) heat number or other marking which will enable the full history of the casting to be traced;
d) specimen number;
e) number of CCS certificate;
f) ice class notation, where applicable;
g) skew angle for high skew propellers;
h) date of final inspection;
i) CCS stamp, where the casting is found satisfactory.

9.1.7.2 Each satisfactorily inspected propeller casting is to be provided with a marine product certificate or equivalent document containing the following details:

a) purchaser’s name and order number;
b) ship’s name, if 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 weight;
g) alloy type, heat number and chemical composition;
h) heat or casting number;
i) casting identification number;
j) method and results of non-destructive testing;
k) results of mechanical tests;

l) proportion of α phase in metallographic examination (for Cu1 and Cu2 alloys only).

Section 2 CAST COPPER ALLOYS

9.2.1 Application

9.2.1.1 The requirements of this Section apply to cast copper alloys for the manufacture of valves, pump housings, shaft liners, bushes and other fittings.

9.2.1.2 Copper alloy castings are to be manufactured and tested in accordance with the requirements of this Section and of Chapters 1 and 2 of this PART. Where it is proposed to use cast copper alloys other than those specified in this Section, subject to agreement of CCS, these cast copper alloys may be accepted in accordance with the relevant recognized standards.

9.2.2 Manufacture

9.2.2.1 All castings are to be manufactured at foundries approved by CCS.

9.2.2.2 Castings may be made by sand casting, chill casting, centrifugal casting or continuous casting, etc., depending on the shape of the casting.

9.2.3 Quality of castings

9.2.3.1 All castings are to be supplied in a clean and fettled condition. They are to be free from shrinkage cavities, pores, blow holes, cracks, inclusions and other surface or internal defects which would be prejudicial to their proper application in service.

9.2.4 Chemical composition

9.2.4.1 The chemical composition of the cast copper alloys is to comply with the requirements given in Table 9.2.4.1.

Chemical Composition of Cast Copper Alloys **Table 9.2.4.1**

Designation	Chemical composition (%)								Recommended application
	Cu	Sn	Zn	Pb	Ni	Mn	P	Fe	
90/10 Cu-Sn phosphor bronze	Remainder	9.0 ~ 11.0	≤ 0.50	≤ 0.75	≤ 0.5	–	≤ 0.50	–	Shaft liners, bushes, valves, pump housings and fittings
88/10/2 gunmetal	Remainder	8.5 ~ 11.0	1.0 ~ 3.0	≤ 1.5	≤ 1.0	–	–	–	Shaft liners, valves and fittings
83/7/4/6 gunmetal	Remainder	6.0 ~ 8.0	3.0 ~ 5.0	5.0 ~ 7.0	≤ 2.0	–	–	–	Shaft liners and bushes
85/5/5/5 Lead gunmetal	Remainder	4.0 ~ 6.0	4.0 ~ 6.0	4.0 ~ 6.0	≤ 2.0	–	–	–	Bushes, valves and fittings
90/10 Cu-Ni-Fe	Remainder	–	–		9.0 ~ 11.0	0.50 ~ 1.0	–	1.0 ~ 1.8	Valves, pump housings and fittings
70/30 Cu-Ni-Fe	Remainder	–	–	–	29.0 ~ 32.0	0.50 ~ 1.50	–	0.40 ~ 1.0	Shaft liners, valves, pump housings and fittings

Note: The manufacturer is to ensure that the content of other elements is within the acceptable limits approved by CCS.

9.2.4.2 The chemical analysis by the ingot maker is to comply with the requirements of 9.1.3.1 of this Chapter.

9.2.5 Heat treatment

9.2.5.1 Castings may be supplied in the as cast or properly heat treated condition.

9.2.6 Mechanical properties

9.2.6.1 Small castings of cast copper alloy may be sampled for test with similar dimensions and same cast number in batches not greater than 1 t. Test samples for mechanical properties may be separately cast as keel block type ones in accordance with Figure 9.1.5.1 of this Chapter or may be sampled directly from the product.

9.2.6.2 Where castings are supplied in a heat treated condition, the test samples are to be similarly heat treated.

9.2.6.3 From each test sample, a tensile test specimen is to be prepared, the dimensions of which are to comply with those given in Table 2.2.2.1 of this PART.

9.2.6.4 The results of tensile tests are to comply with the requirements given in Table 9.2.6.4.

Mechanical Properties of Cast Copper Alloys **Table 9.2.6.4**

Designation	Tensile strength R_m (N/mm^2)	Proof strength $R_{p0.2}$ (N/mm^2)	Elongation A_5 (%)
90/10 Cu-Sn phosphor bronze	≥ 250	≥ 120	≥ 15
88/10/2 gunmetal	≥ 270	≥ 130	≥ 13
83/7/4/6 gunmetal	≥ 270	≥ 130	≥ 16
85/5/5/5 lead gunmetal	≥ 200	≥ 100	≥ 16
90/10 Cu-Ni-Fe	≥ 320	≥ 160	≥ 20
70/30 Cu-Ni-Fe	≥ 420	≥ 220	≥ 20

9.2.7 Visual examination

9.2.7.1 All castings are to be cleaned and presented to the Surveyor for visual examination of internal and external surfaces.

9.2.8 Rectification of defective castings

9.2.8.1 Subject to the prior approval of the Surveyor, castings containing local porosity may be rectified by impregnation with a suitable plastic filler provided that the extent of the porosity is such that it does not adversely affect the strength of the casting.

9.2.8.2 Proposals to repair a defective casting by welding are to be submitted to the Surveyor before this work is commenced. And the number, size, and position of the defects as well as the weld repair procedures are to be submitted to CCS for information. The welding of liners in copper alloys containing more than 0.5% lead is not permitted.

9.2.9 Pressure testing

9.2.9.1 Where pressure test is required for castings, the tests are to be carried out in the presence of the Surveyor.

9.2.10 Identification

9.2.10.1 All castings which have been satisfactorily inspected by CCS are to be clearly marked by the manufacturer in at least one place with the following:

(1) CCS logo;

(2) cast number or other marking which will enable the full history of the casting to be traced;

(3) test pressure (where applicable);

(4) brand or grade of casting material;

(5) certificate number.

When the area is not enough for all marks, at least (1) to (3) of the above items are to be marked.

Any mark is to be encircled with paint for easy recognition.

9.2.11 Certification

9.2.11.1 The manufacturer is to provide a certificate giving the following particulars for each casting:

(1) purchaser's name and order number;

(2) description of castings;

(3) cast number;

(4) ingot or cast analysis;

(5) details of heat treatment;

(6) description of repairs by welding, where applicable.

Section 3 COPPER TUBES

9.3.1 Application

9.3.1.1 The requirements of this Section apply to copper alloy tubes intended for use in condensers, heat exchangers and pressure piping systems.

9.3.1.2 Except for Class III pressure tubes, all tubes are to be manufactured and tested in accordance with the requirements of this Section and of Chapters 1 and 2 of this PART.

9.3.2 Manufacture

9.3.2.1 All tubes are to be made at works approved by CCS.
9.3.2.2 Tubes are generally to be made by a seamless process. Where it is proposed to use welded tubes, details of the method of manufacture and the properties are to be submitted to CCS for approval.

9.3.3 Quality
9.3.3.1 The quality of tubes is to comply with the appropriate requirements of Chapter 4 of this PART.

9.3.4 Chemical composition
9.3.4.1 The chemical composition of tubes is to comply with the requirements of Table 9.3.4.1.

Chemical Composition of Copper Tubes **Table 9.3.4.1**

Designation	Chemical composition (%)							
	Cu	As	Fe	Pb	Ni	Al	Mn	Zn
Aluminium brass	76.0~79.0	0.02~0.06	≤ 0.06	≤ 0.07	–	1.8~2.5		Remainder
90/10 Cu-Ni-Fe	Remainder	–	1.0~2.0	–	9.0~11.0	–	0.50~1.0	–
70/30 Cu-Ni-Fe	Remainder	–	0.4~1.0	–	29.0~33.0	–	0.50~1.5	–

Note: In addition to the content of principal elements listed in the Table, the manufacturer is to ensure that the content of other elements is within acceptable limits approved by CCS.

9.3.5 Heat treatment
9.3.5.1 All tubes are to be supplied in the annealed condition. Aluminum brass tubes are required to be given a stress relieving heat treatment when subjected to a cold straightening operation after annealing.

9.3.6 Mechanical and technical properties
9.3.6.1 Tubes may be presented for test in batches of 300 lengths. Each batch is to consist of the tubes of the same size, manufactured from the same material grade and subjected to the same heat treatment process.
9.3.6.2 The tests and number of test specimens for each batch are to be as follows:
(1) Tensile test: at least one specimen from each batch;
(2) Flattening test: at least one specimen from each batch;
(3) Drift expanding test: at least one specimen from each batch.
Where the tubes are supplied in reels, at least one reel is to be selected from each batch. One test sample is to be taken from every ten circles of tubes or fraction thereof.
9.3.6.3 The methods for mechanical tests and the dimensions of the test specimens are to be in accordance with Chapter 2 of this PART. The flattening test is to be continued until the interior surfaces of the tube meet. After flattening, the specimens are to be free from cracks and flaws. The drift expanding test is to be carried out with a mandrel having an included angle of 45°, and the outside diameter of the end of the test length is to be expanded by 30%. The expanded portion of the tube is to be free from cracks and flaws.
9.3.6.4 The mechanical properties of tubes are to comply with the requirements given in Table 9.3.6.4.

Mechanical Properties of Copper Tubes **Table 9.3.6.4**

Designation	Tensile strength R_m min. (N/mm^2)	Proof strength $R_{p0.2}$ min. (N/mm^2)	Elongation A_5 min. (%)
Aluminium brass	320	110	35
90/10 Cu-Ni-Fe	270	100	30
70/30 Cu-Ni-Fe	360	120	30

9.3.7 Stress corrosion cracking test
9.3.7.1 Stress corrosion cracking test is to be carried out on aluminum brass tubes in batches. The method of test is as follows:
(1) one test specimen having a length of 150 mm is to be cut from one tube selected at random from each batch;
(2) the specimen is to be immersed in a mercurous nitrate solution for a period of 2 h;
(3) after being removed from the solution, the internal and external surfaces of the specimen are to be examined by the aid of a five to ten-fold magnifying glass, and no cracks are allowable;
(4) should any specimen fail to meet the requirements of this test, then all tubes represented by that specimen are to be withdrawn. The tubes may be re-submitted after a stress relieving treatment for full testing.

9.3.8 Hydraulic test

9.3.8.1 Each tube is to be subjected to a hydraulic test, and the test pressure is to be 1.5 times the design pressure, but need not exceed 7.0 MPa maximum. The test pressure is to be maintained for a period of time sufficient for verification and inspection. The tested tubes are not permitted to show any sign of leakage, deformation or crack. An eddy current test may be accepted in lieu of the hydraulic test subject to agreement of CCS.

9.3.9 Visual examination and rectification of defects

9.3.9.1 All tubes are to be presented for visual examination of internal and external surfaces and for verification of dimensions. The surfaces of all tubes are to be smooth and clean and free from blow holes, cracks, blisters, laminations and verdigris.

9.3.9.2 The repair of surface defects by welding is not permitted. Surface defects may be removed by grinding provided that the dressed area is to be blended into the contour of the tube and that the dimensional tolerances are not exceeded.

9.3.10 Identification

9.3.10.1 Tubes are to be clearly marked by the manufacturer with CCS stamp and the following particulars:

(1) manufacturer's name or trade mark;

(2) grade of material or designation code.

9.3.10.2 No hard stamping on tubes is permitted for identification marks.

9.3.11 Certification

9.3.11.1 The manufacturer is to provide a certificate giving the following particulars for each batch of tubes:

(1) purchaser's name and order number;

(2) specification or grade of material;

(3) description and dimensions;

(4) cast number and chemical composition;

(5) results of mechanical and technological tests;

(6) results of stress corrosion cracking test;

(7) results of hydraulic test.

Section 4 TITANIUM ALLOY PLATES

9.4.1 Application

9.4.1.1 This Section applies to titanium alloy plates with thicknesses more than 3 mm and intended for use in the construction of ships and offshore installations.

9.4.1.2 Where it is proposed to use titanium alloy plates other than those specified in this Section, details of the chemical composition, mechanical properties and applications are to be submitted to CCS for approval and may be accepted in accordance with relevant recognized standards subject to agreement of CCS.

9.4.2 Manufacture

9.4.2.1 Titanium alloy plates are to be manufactured by works which have been approved by CCS.

9.4.2.2 In addition to the requirements of this Section, the manufacture and test of titanium alloys are to comply with the relevant requirements of Chapters 1 and 2 of this PART.

9.4.2.3 The melting and casting of titanium alloys are to be carried out under vacuum conditions. If melting in a vacuum self-consuming remelting furnace is adopted, argon-shielded tungsten arc welding is prohibited for self-consuming electrodes. Melting is to be carried out at least twice to ensure chemical homogeneity of material.

9.4.2.4 Titanium alloy plates are usually to be manufactured by means of rolling.

9.4.2.5 Unless otherwise specified in the contract, titanium alloy plates are usually to be supplied in the annealed condition.

9.4.3 Surface quality

9.4.3.1 The surface of plates is to be free from defects that will impair their use, such as cracks, flakes, scale, laps, metallic or non-metallic inclusions, traces of alkali cleaning, etc.

9.4.3.2 The edges of titanium alloy products are to be flush and free from burrs. The dimensions and tolerances are to be in accordance with the relevant specifications acceptable to CCS.

9.4.3.3 Slight surface imperfections may be removed by grinding. Grinding is generally to be carried out in the rolling direction. The ground surface is to leave a gentle transition to the surrounding surface and the thickness is not to be less than the minimum thickness required by technical specifications. Repair by welding is not allowed for rectifying surface defects.

9.4.4 Chemical composition

9.4.4.1 The chemical composition of ladle samples of titanium alloy ingots is to be analyzed by the manufacturer to each heat, and is to meet the requirements of Table 9.4.4.1.

Chemical Composition of Titanium Alloys (%) **Table 9.4.4.1**

Grade	Nominal chemical composition	Al	Mo	Sn	Zr	V	Si	Nb	N	C	H	Fe	O	Other elements		Ti
														Single	Total	
TA7	Ti-5Al-2.5Sn	4.0~6.0	—	**2.0~3.0**	—	—	—		0.05	0.08	0.015	0.50	0.20	0.10	0.40	Remainder
TA18	Ti-3Al-2.5V	2.0~3.5	—	—	—	1.5~3.0	—		0.05	0.08	0.015	0.25	0.12	0.10	0.30	Remainder
TC4	Ti-6Al-4V	5.5~6.75	—	—	—	3.5~4.5	—		0.05	0.08	0.015	0.30	0.20	0.10	0.40	Remainder
TC4 ELI	Ti-6Al-4V ELI	5.5~6.5	—	—	—	3.5~4.5	—		0.03	0.08	0.012	0.25	0.13	0.10	0.40	Remainder
TA31(Ti80)	Ti-6Al-3Nb-2Zr-Mo	5.5~6.5	0.6~1.5	—	1.5~2.5	—	0.15	2.5~3.5	0.05	0.10	0.015	0.25	0.15	0.10	0.30	Remainder

Note: Data in the Table, except for those with indication of limits, are maximum limits.

9.4.5 Mechanical properties

9.4.5.1 For each batch of plates (the same cast, the same manufacturing process, the same thickness and heat treatment in the same furnace charge), at least one plate (two plates for a batch of more than four plates) is to be taken, and a sample is to be cut at approximately 1/4 of the width from an edge.

9.4.5.2 A tensile specimen and a set of 3 Charpy impact specimens (for plate thicknesses of more than 10 mm) and 2 bend test specimens are to be taken from each sample according to the following requirements:

(1) The tensile specimen is to be the flat proportional specimen specified in item 1 of Table 2.2.2.1, Chapter 2 of this PART (specimen may be P7 specimen with width of 12.5 mm). For a plate thickness of more than 40 mm, a round bar specimen specified in Item 2 may also be used (but specimen diameter may be 5 mm), with the axis of the specimen located at 1/4 of the thickness of the plate.

(2) If the plate thickness is not more than 40 mm, the impact specimens are to be such that their edges are within 2 mm from the rolled surface; if the plate thickness is more than 40 mm, the axis of the specimen is to be located at 1/4 of the thickness of the plate. The axis of the specimen is to be perpendicular to the rolling direction and the notch of the specimen is to be perpendicular to the rolled surface.

(3) For each of the two bend test specimens, at least one tension face is to be kept as the original rolled surface and the axis is to be perpendicular to the rolling direction. If specimens of plates with a thickness of more than 5 mm are 15 mm in width, their thickness may be reduced to 5 mm on one side.

9.4.5.3 Specimens are to be prepared and tested for mechanical properties in accordance with the relevant requirements of Chapter 2 of this PART. The bend test is to be such that both rolled surfaces of the plate are tested.

9.4.5.4 Mechanical properties of titanium alloys are to meet the requirements of Table 9.4.5.4.

Mechanical Properties of Titanium Alloys **Table 9.4.5.4**

Grade	Nominal chemical composition	Plate thickness mm	Proof strength $R_{p0.2}$ N/mm^2	Tensile strength R_m N/mm^2	Elongation A %	Charpy impact energy Cv① J	Bend test②	
							Diameter D	Bend angle α
TA7	Ti-5Al-2.5Sn	≤10	≥685	735~930	≥12	–	9t	105°
TA18	Ti-3Al-2.5V	≤10	≥485	590~735	≥15	–	6t	105°
TC4	Ti-6Al-4V	≤80	≥825	≥895	≥10	≥20	10t	105°
TC4 ELI	Ti-6Al-4V ELI	≤100	≥795	≥860	≥10	≥24	10t	105°
TA31(Ti80)	Ti-6Al-3Nb-2Zr-Mo	≤25	≥785	≥880	≥12	≥47	8t	105°
		>25~100	≥740	≥810	≥10	≥40	8t	105°

Notes: ① Test is carried out under normal temperature. Impact values of TA7 and TA18 alloys may be specified in the contract.
② The tension face of bend specimens is to be free from visible cracks.

9.4.6 Non-destructive testing

9.4.6.1 The non-destructive testing, if specified in the contract, is to be carried out according to the requirements of the contract.

9.4.7 Identification and certification of materials

9.4.7.1 Every finished item (thin plates may be stacked and packaged) is to be clearly marked at the same position by the manufacturer with the CCS stamp and the following particulars:
(1) the manufacturer's name;
(2) material grade and delivery condition;
(3) identification number or initials which will enable the full history of the item to be traced;
(4) if required by the purchaser, his order number or other identification mark.

9.4.7.2 Each batch of plates is to be accompanied by a certificate of conformity which is to include the following particulars:
(1) purchaser's name and order number;
(2) grade, cast number and delivery condition of material;
(3) specification and quantity of material;
(4) chemical composition and mechanical properties of material.

Section 5 TITANIUM AND TITANIUM ALLOY PIPES

9.5.1 General requirements

9.5.1.1 This Section applies to titanium and titanium alloy pipes intended for general use in the construction of ships and offshore installations.

9.5.1.2 Where it is proposed to use titanium and titanium alloy pipes other than those specified in this Section, details of the chemical composition, mechanical properties and applications are to be submitted to CCS for approval and may be accepted in accordance with relevant recognized standards subject to agreement of CCS.

9.5.2 Manufacture

9.5.2.1 Titanium and titanium alloy pipes are to be manufactured by works which have been approved by CCS.

9.5.2.2 In addition to the requirements of this Section, the manufacture and test of titanium and titanium alloy pipes are to comply with the relevant requirements of Chapters 1, 2 and 4 of this PART.

9.5.2.3 The melting and casting of titanium and titanium alloys are to be carried out under vacuum conditions. If melting in a vacuum self-consuming remelting furnace is adopted, remelting is to be carried out at least twice to ensure chemical homogeneity and heterogeneous grain structure of material and to reduce oxidation and oxide inclusions.

9.5.2.4 Titanium alloy pipes may be manufactured by means of rolling, welding or welding plus rolling.

9.5.2.5 Welded pipes may be welded by means of TIG or MIG from rolled band plates in the annealed condition. Any filler material, if needed, is to match the parent material.

9.5.2.6 The manufacturing quality of titanium and titanium alloy pipes is to comply with the relevant requirements of 4.1.3, Chapter 4 of this PART.

9.5.3 Heat treatment

9.5.3.1 Unless otherwise specified in the contract, titanium and titanium alloy pipes are to be supplied in the annealed condition.

9.5.3.2 Cold-rolled pipes are usually to be supplied in the annealed condition with temperatures not lower than 540℃. Hot-rolled pipes need not be subject to further heat treatment if the temperature at termination of the processing is not lower than 760℃.

9.5.4 Chemical composition

9.5.4.1 The chemical composition of ladle samples of titanium alloy ingots is to be analyzed by the manufacturer to each heat and is to meet the requirements of Table 9.5.4.1.

Chemical Composition of Titanium and Titanium Alloy Pipes (%) **Table 9.5.4.1**

Grade	Nominal chemical composition	Ti	Mo	Pd	Ni	Fe	C	N	H	O	Other elements	
											Single	Total
TA2	Industrially pure titanium	Remainder	–	–	–	0.30	0.08	0.03	0.015	0.25	0.10	0.40
TA3	Industrially pure titanium	Remainder	–	–	–	0.30	0.08	0.05	0.015	0.35	0.10	0.40
TA9	Ti-0.2Pd	Remainder	–	0.12~0.25	–	0.30	0.08	0.03	0.015	0.25	0.10	0.40
TA9-1	Ti-0.2Pd	Remainder	–	0.12~0.25	–	0.20	0.08	0.03	0.015	0.18	0.10	0.40
TA10	Ti-0.3Mo-0.8Ni	Remainder	0.2~0.4	–	0.6~0.9	0.30	0.08	0.03	0.015	0.25	0.10	0.40

Note: Data in the Table, except for those with indication of limits, are maximum limits.

9.5.5 Mechanical properties

9.5.5.1 Titanium and titanium alloy pipes may be presented inspection and testing in batches. Each batch is to consist of titanium pipes of the same cast, the same manufacturing process, the same size and heat treatment in the same furnace charge.

9.5.5.2 Pipes (not less than 2 pipes) are to be selected randomly from each batch in the proportion of 2%, and specimens are to be taken from them for test according to the following requirements:

(1) One tensile specimen and one flattening test specimen are to be taken from each pipe;

(2) If required by the purchaser, one bend test specimen is to be taken from each pipe.

9.5.5.3 Tensile and flattening tests and their specimens are to comply with the relevant requirements of Chapter 2 of this PART. During the flattening test, if pipe diameter is not more than 25.4 mm, the flattening coefficient is to be taken as 0.04; if pipe diameter is more than 25.4 mm, the flattening coefficient is to be taken as 0.06. For TA10 alloys, the flattening coefficient is to be taken as 0.04.

9.5.5.4 Mechanical properties of titanium and titanium alloy pipes are to meet the requirements of Table 9.5.5.4.

Mechanical Properties of Titanium and Titanium Alloy Pipes **Table 9.5.5.4**

Grade	Nominal chemical composition	Delivery condition	Proof strength $R_{p0.2}$ N/mm^2	Tensile strength R_m N/mm^2	Elongation A_{50} %
TA2	Industrially pure titanium	Annealed	275 ~ 450	≥ 345	≥ 20
TA3	Industrially pure titanium	Annealed	380 ~ 550	≥ 500	≥ 18
TA9	Ti-0.2Pd	Annealed	275 ~ 450	≥ 400	≥ 20
TA9-1	Ti-0.2Pd	Annealed	140 ~ 310	≥ 240	≥ 24
TA10	Ti-0.3Mo-0.8Ni	Annealed	≥ 300	≥ 460	≥ 18

9.5.6 Non-destructive testing and hydraulic test

9.5.6.1 All titanium and titanium alloy pipes are to be subject to non-destructive testing or hydraulic test at the manufacturer.

9.5.6.2 For non-destructive testing, eddy current or ultrasonic testing may be carried out in accordance with recognized standards (such as GB/T 12969).

9.5.6.3 If not required in the contract, the hydraulic test pressure may be determined by the following formula, but for pipes with diameter not exceeding 76 mm, the test pressure need not exceed 17.2 MPa; for pipes with diameter exceeding 76 mm, the test pressure need not exceed 19.3 MPa.

$$P = \frac{kSt}{\frac{D}{2} - 0.4t}$$

where: P — test pressure, in MPa;

K — coefficient of test pressure, taken as 1 for seamless pipes and 0.85 for welded pipes;

S — allowable stress of pipes, generally taken as 50% of minimum proof strength of material, in MPa;

t — thickness of pipe wall, in mm;

D — nominal outside diameter of pipe material, in mm.

9.5.6.4 During hydraulic test, the test pressure is to be kept for at least 5s, and no distortion or leakage is allowed for pipes.

9.5.7 Identification and certification of materials

9.5.7.1 Every finished titanium pipe or titanium alloy pipe is to be clearly marked by the manufacturer with the CCS stamp and the following particulars:
(1) the manufacturer's name or trade mark;
(2) material grade and specification;
(3) identification number or initials which will enable the full history of the item to be traced;
9.5.7.2 Each batch of pipes is to be accompanied by a material certificate of conformity which is at least to include the following particulars:
(1) purchaser's name and order number;
(2) grade, cast number and delivery condition of material;
(3) specification and quantity of material;
(4) chemical composition and mechanical properties of material.

Section 6 BEARING METALS

9.6.1 Manufacture

9.6.1.1 The bearings intended to be used for ship machinery may be made from tin-base bearing alloys, lead-base bearing alloy, aluminum-base bearing alloy or copper-lead alloy.

9.6.2 Inspections

9.6.2.1 The inspections for bearing metals are to be as follows:
(1) Chemical analysis: samples from each cast;
(2) Macro-examination: to be carried out on each piece;
(3) Adhesion examination: to be carried out on each piece;
(4) Microscopic examination and hardness test: the white metal used for the manufacture of main bearings, connecting rod top and bottom end bearings and thrust bearings of diesel engines, if necessary, is to be subjected to a microscopic examination (×100 magnification) and hardness test. But the metal of each bearing for turbine engines is to be subjected to a microscopic examination and hardness test;
(5) Metallographic examination: only applicable to copper-lead alloy.

9.6.3 Chemical composition

9.6.3.1 The chemical composition of bearing metals is to comply with the requirements given in Table 9.6.3.1.

Chemical Composition of Bearing Metals **Table 9.6.3.1**

Designation	Chemical composition (%)				
	Sn	Cu	Sb	Fb	Al
ChSnSb11- 6	Remainder	5.5 ~ 6.5	10 ~ 12		–
ChPbSb7.5 - 3	Remainder	3 ~ 4	7 ~ 8		–
ChPbSb16-16-1.8	15 ~ 17	1.5 ~ 2	15 ~ 17	Remainder	–
ChPbSb15 - 5.5 - 2.8	5 ~ 6	2.5 ~ 3	14 ~ 16	Remainder	–
QPb30	–	Remainder	–	27 ~ 33	–
(201) SnCuAl-steel bimetal strip	20	1	–	–	Remainder

9.6.4 Miscellaneous

9.6.4.1 The surfaces of the bearing metal of each bearing are to be smooth and clean and free from slags and non-metallic inclusions.
9.6.4.2 The bearing metal is to be tightly adhered to bearing shells.
9.6.4.3 At the metallographic examination, it is required that lead in the copper-lead alloy is to be shown in medium size grains and in the form of globules or detached networks evenly distributed in the copper matrix, and no segregation of lead in blocks is allowable.

CHAPTER 10 EQUIPMENT

Section 1 ANCHORS

10.1.1 General requirements

10.1.1.1 The requirements of this Section apply to the materials, manufacture, testing and certification of anchor heads, shanks and shackles manufactured by casting, forging and welding processes.

10.1.1.2 All anchor designs are to be approved. Any changes to the design made during manufacture are to have prior agreement from CCS.

10.1.1.3 Ordinary anchors of 'stockless' type are to be generally adopted and they are to be designed and manufactured in compliance with the standards accepted by CCS.

10.1.1.4 High holding power anchors specified in this Section are anchors of which the holding power is at least twice that of an ordinary stockless anchor having the same mass.

10.1.1.5 Super high holding power anchors specified in this Section are anchors of which the holding power is at least four times that of an ordinary stockless anchor of the same mass or twice that of a high holding power anchor of the same mass. The mass of super high holding power anchors is generally not to be greater than 1,500 kg.

10.1.2 Material

10.1.2.1 All materials for anchors and main parts are to be made by the processes approved by CCS.

10.1.2.2 Cast steel anchors are to be of steel castings fine grain treated with aluminum for welded construction, and manufactured and tested in accordance with the relevant requirements of Sections 1 and 2, Chapter 6 of this PART.

For steel castings for super high holding power anchors, a set of 3 Charpy impact specimens is to be additionally taken in each batch and tested at the temperature of 0℃. The average value of their impact energy is not to be less than 27 J.

10.1.2.3 Forged steel anchors are to be of carbon and carbon-manganese steels for welded construction, and manufactured and tested in accordance with the relevant requirements of Sections 1 and 2, Chapter 5 of this PART.

10.1.2.4 Plates or bars used in fabricated steel anchor heads are to be in accordance with the relevant requirements of Sections 2 and 3 of Chapter 3 of this PART.

10.1.2.5 The base steel grades in welded Super high holding power anchors are to be selected with respect to the material grade requirements for Class II in CCS Rules for Classification of Sea-going Steel Ships, PART TWO, Chapter 1, Table 1.3.2.2(7). The toughness of the anchor shackles for SHHP anchors is to meet that for Grade 3 accessories in accordance with Table 10.2.8.4 of Section 2 of this Chapter of the Rules.

10.1.2.6 Rolled bars intended for pins, swivels and shackles are to be in accordance with the relevant requirements of Chapters 3 and 5 of this PART.

10.1.2.7 The welding consumables used in the manufacturing process are to be compatible with the parent metals and in accordance with the relevant requirements of Chapter 2 of PART THREE of the Rules.

10.1.3 Manufacture

10.1.3.1 Anchors are to be made at works which have been approved by CCS.

10.1.3.2 The assembly welding of fabricated anchors is to be in accordance with approved welding procedures, using approved consumables and carried out by the welders holding a Qualification Certificate of Welder.

10.1.3.3 Components for cast or forged anchors are to properly heat treated in accordance with the requirements of Chapter 6 or Chapter 5 of the Rules. Fabricated anchors may require stress relief after welding in accordance with the requirements of approved procedures.

10.1.3.4 Non-destructive test may be required for components of cast or forged anchors when necessary.

10.1.3.5 Surface defects of cast or forged anchors that would not impair their use may be repaired, subject to agreement by the Surveyor. Repairs to fabricated anchors are to be agreed by the Surveyor and carried out by qualified welders in accordance with approved weld procedures.

10.1.3.6 Anchor assembly and fitting are to be done in accordance with the design details. Securing of anchor pins, shackle pins or swivel nuts by welding is to be done in accordance with an approved procedure.

If not otherwise specified in accepted standards or not indicated on approved drawings, the following assembly and fitting tolerances are to be applied:
(1) The clearance either side of the shank within the shackle jaws is to comply with the requirements in Table 10.1.3.3(1).

Clearance of Shank within Shackle Jaws Table 10.1.3.3(1)

Anchor weight T (t)	Clearance (mm)
$T \leq 3$	≤ 3
$3 < T \leq 5$	≤ 4
$5 < T \leq 7$	≤ 6
$T > 7$	≤ 12

(2) The shackle pin is to be a push fit in the eyes of the shackle, which are to be chamfered on the outside to ensure a good tightness when the pin is clenched over on fitting. The shackle pin to hole tolerance is to comply with the following requirements:
≤ 0.5 mm for pins of up to 57 mm in diameter;
≤ 1.0 mm for pins of larger than 57 mm in diameter.
(3) The trunnion pin is to be a snug fit within the chamber and be long enough to prevent horizontal movement. The gap is to be no more than 1% of the chamber length.
(4) The lateral movement of the shank is not to exceed 3º, see Figure 10.1.3.6(3).

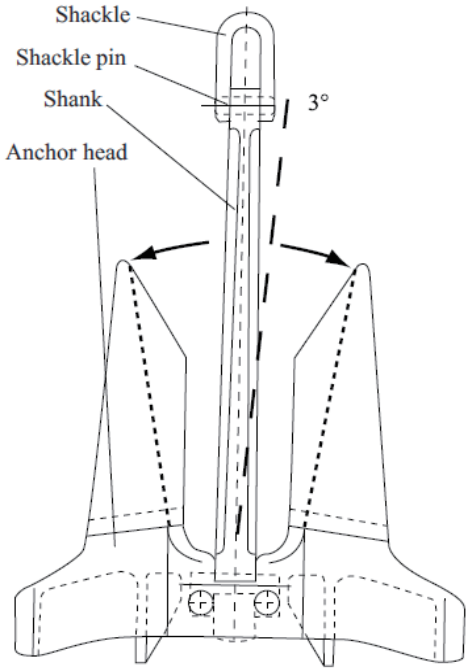


Figure 10.1.3.6(3) Lateral Movement of Shank

10.1.4 Inspection of finished anchors

10.1.4.1 Anchors are not to be painted until visual examinations, weighing and tests have been completed.
10.1.4.2 The surfaces of all parts are to be free from scale and sand. All parts are to have a clean surface consistent with the method of manufacture and be free from cracks, notches, inclusions and other defects that would be detrimental to service performance.
10.1.4.3 The mass of anchors is to comply with following requirements:
(1) The mass of the head of an ordinary stockless anchor including pins and fittings is not to be less than 60% of the total mass of the anchor.
(2) The deviation of the actual mass of anchors from their nominal mass is to be within the range of +7% to -3%.
10.1.4.4 Ordinary anchors having a nominal mass of 75 kg or more inclusive of stock or 56 kg high holding power ones or 38 kg super high holding power ones are to be subject to proof load tests in

accordance with the requirements in 10.1.5 of this Section.

10.1.4.5 Each cast anchor fluke or shank is to be subjected to drop test and hammering test in accordance with the following requirements:

(1) Each anchor fluke or shank is raised to a height of 4 m (usually shank suspended horizontally and anchor crown downward) and dropped freely.

(2) Each cast anchor component is to be dropped on to a steel slab without fracturing. The steel slab is to be suitable to resist the impact of the dropped component.

(3) After the drop test, hammering tests are carried out on each anchor fluke and shank, which is slung clear of the ground, using a non-metallic sling, and hammered to check the soundness of the component. A hammer of 3 kg to 7 kg mass is to be used.

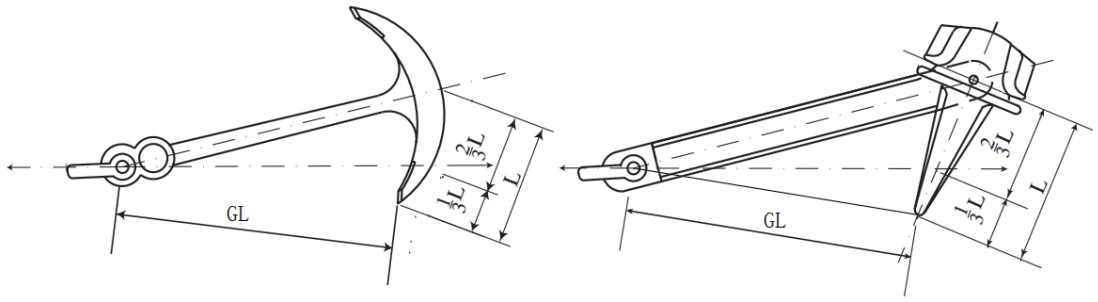
10.1.4.6 Fitting of anchors is to comply with the relevant requirements in 10.1.3.6 of this Section.

10.1.5 Proof load tests of anchors

10.1.5.1 Anchors of all sizes are to be proof load tested. Prior to the proof load test, examination and confirmation is to be made that no harmful surface defects are found on anchors. The testing machines are to be calibrated.

10.1.5.2 The anchors are to be proof-load tested as follows:

(1) The proof load is to be applied to two points, one at the anchor shackle and the other at a point which, measured from the extremity of the bill, is 1/3 of the distance between it and the center of the crown, as shown in Figure 10.1.5.2(1).



Where: L-- the distance between the extremity of the bill and the center of the crown; GL—Gauge length

Figure 10.1.5.2(1)

(2) For stockless anchors, both arms are to be tested at the same time, first on one side of the shank, then reversed and tested on the other.

(3) For stocked anchors, each arm is to be tested individually.

(4) Prior to the load test, a gauge mark (punched or cut) is to be made for each anchor respectively on the shank adjacent to the shackle and near each fluke tip, and gauge length (L) between the two points are to be measured.

(5) During the test, the anchor is first to be subjected to 10% of the required load for a period of 5 min, and then the gauge length is to be measured and recorded. After that, the applied load is to be slowly increased to the required proof load and kept for 5 min, then the load is to be gradually decreased to 10% of the required load, then again the gauge length is to be measured.

10.1.5.3 The proof test loads for anchors are to be determined in accordance with mass of anchor and comply with Table 10.1.5.3. For anchors of different types, the mass of anchors m_a given in the Table is to be taken as follows:

(1) for stockless anchors, the actual total mass;

(2) for stocked anchors, the actual mass of anchor excluding the stock;

(3) for high holding power anchors, 1.33 times the actual mass is to be taken. Unless specifically agreed otherwise, the same applied to the mass of mooring anchors;

(4) for super high holding power anchors, twice the actual mass is to be taken.

Proof Test Load of Anchors **Table 10.1.5.3**

Mass of anchor m_a (kg)	Proof test load Q (kN)	Mass of anchor m_a (kg)	Proof test load Q (kN)	Mass of anchor m_a (kg)	Proof test load Q (kN)	Mass of anchor m_a (kg)	Proof test load Q (kN)
50	23.2	1200	231.0	4800	645.0	11000	1070.0
55	25.2	1250	239.0	4900	653.0	11500	1090.0
60	27.1	1300	247.0	5000	661.0	12000	1110.0
65	28.9	1350	255.0	5100	669.0	12500	1130.0
70	30.7	1400	262.0	5200	677.0	13000	1160.0
75	32.4	1450	270.0	5300	685.0	13500	1180.0
80	33.9	1500	278.0	5400	691.0	14000	1210.0
90	36.3	1600	292.0	5500	699.0	14500	1230.0
100	39.1	1700	307.0	5600	706.0	15000	1260.0
120	44.3	1800	321.0	5700	712.0	15500	1270.0
140	49.0	1900	335.0	5800	721.0	16000	1300.0
160	53.3	2000	349.0	5900	728.0	16500	1330.0
180	57.4	2100	362.0	6000	735.0	17000	1360.0
200	61.3	2000	376.0	6100	740.0	17500	1390.0
225	65.8	2300	388.0	6200	747.0	18000	1410.0
250	70.4	2400	401.0	6300	754.0	18500	1440.0
275	74.9	2500	414.0	6400	760.0	19000	1470.0
300	79.5	2600	427.0	6500	767.0	19500	1490.0
325	84.1	2700	438.0	6600	773.0	20000	1520.0
350	88.8	2800	450.0	6700	779.0	21000	1570.0
375	93.4	2900	462.0	6800	786.0	22000	1620.0
400	97.9	3000	474.0	6900	794.0	23000	1670.0
425	103.0	3100	484.0	7000	804.0	24000	1720.0
450	107.0	3200	495.0	7200	818.0	25000	1770.0
475	112.0	3300	506.0	7400	832.0	26000	1800.0
500	116.0	3400	517.0	7600	845.0	27000	1850.0
550	125.0	3500	528.0	7800	861.0	28000	1900.0
600	132.0	3600	537.0	8000	877.0	29000	1940.0
650	140.0	3700	547.0	8200	892.0	30000	1990.0
700	149.0	3800	557.0	8400	908.0	31000	2030.0
750	158.0	3900	567.0	8600	922.0	32000	2070.0
800	166.0	4000	577.0	8800	936.0	34000	2160.0
850	175.0	4100	586.0	9000	949.0	36000	2250.0
900	182.0	4200	595.0	9200	961.0	38000	2330.0
950	191.0	4300	604.0	9400	975.0	40000	2410.0
1000	199.0	4400	613.0	9600	987.0	42000	2490.0
1050	208.0	4500	622.0	9800	998.0	44000	2570.0
1100	216.0	4600	631.0	10000	1010.0	46000	2650.0
1150	224.0	4700	638.0	10500	1040.0	48000	2730.0

Notes: ① Proof loads for intermediate mass are to be determined by linear interpolation.

② Where ordinary anchors have a mass exceeding 48,000 kg, the proof load Q is to be calculated as follows:

$Q = 2.059\, m_a^{2/3}$ kN.

③ Where high holding power anchors have a mass exceeding 36,000 kg, the proof load Q is to be calculated as follows:

$Q = 2.452\, m_a^{2/3}$ kN.

10.1.5.4 After proof testing, anchors are to be inspected as follows:

(1) Visual inspection and non-destructive testing: after proof testing, finished anchors are to be subjected to visual inspection and nondestructive testing in accordance with the requirements given in Table 10.1.5.4(1).

(2) Measurement of permanent set (i.e. variation in gauge length): no obvious permanent deformation for stocked anchors, and no permanent set exceeding 1% of the gauge length for stockless anchors.

(3) Free rotation of anchor: fabricated anchors are to be capable of free rotation of their heads over the

complete design angle. If the anchor head cannot rotate freely or over the complete angle, such defect is to be rectified and the anchor in question is to be re-tested. If the re-test fails, the anchor is to be rejected.

Visual Inspection and Non-Destructive Testing of Anchors after Proof Load Test

Table 10.1.5.4(1)

Method \ Type		Ordinary anchor	High holding power anchor	Super high holding power anchor
Visual inspection		No cracks or other obvious defects allowable for all stressed parts	No cracks or other obvious defects allowable for all stressed parts	No cracks or other obvious defects allowable for all stressed parts
Non-destructive test*	Magnetic particle or dye penetrant test	Feeders and risers of castings; Welds of fabricated anchors; Repairs by welding of all anchors	Feeders and risers of castings; Welds of fabricated anchors; Repairs by welding of all anchors; Highly stressed areas (if deemed necessary by the Surveyor)	All surfaces of castings; Welds of fabricated anchors; Highly stressed areas (if deemed necessary by the Surveyor)
	Ultrasonic test	Not required	Welds of fabricated steel anchors (if deemed necessary by the Surveyor)	Welds of fabricated steel anchors; Feeders and risers of castings; Repairs by welding of all anchors; Highly stressed areas (if deemed necessary by the Surveyor)

Note: Non-destructive tests for steel castings are to be in accordance with the requirements in Sections 1 and 2, Chapter 5 of this PART. Non-destructive tests for steel forgings are to be in accordance with the requirements in Sections 1 and 2, Chapter 6 of this PART. Welds of fabricated steel anchors are to be in accordance with the relevant quality requirements.

10.1.6 Holding power tests

10.1.6.1 For approval of anchors designed as high holding power ones or super high holding power ones, they are to be tested in full scale at sea on various types of bottom (normally, soft mud or silt, sand or gravel and hard clay or similar compounded material) for their holding powers in accordance with the following requirements.

10.1.6.2 The tests are to be applied to anchors of mass which are as far as possible representative of the full range of sizes proposed. Normally the following requirements are to be complied with:

(1) For approval and/or acceptance for a range of HHP anchor sizes, tests at sea are to be carried out for at least two anchor sizes. The larger of the two anchors tested is to have a mass not less than one-tenth of that of the largest anchor for which approval is sought, and the smaller of the two anchors is to have a mass not less than one-tenth of that of the large anchor.

(2) For approval and/or acceptance for a range of SHHP anchor sizes, at least three anchor sizes are to be tested, indicative of the bottom, middle and top of the mass range.

10.1.6.3 For a definite group within the range, the two anchors selected for testing (ordinary stockless anchor and HHP anchor, or ordinary stockless anchor and SHHP anchor, respectively) are to be of approximately the same mass. Where an ordinary stockless anchor is not available, a previously approved HHP anchor or SHHP anchor may be used in its place.

10.1.6.4 The diameter of the chain used in the test is to be appropriate for the anchor to be tested. The length of the cable with each anchor is to be such that the pull on the shank remains horizontal. For this purpose a scope of 10 is considered normal but a scope of not less than 6 may be accepted. Scope is defined as the ratio of length of cable to depth of water.

10.1.6.5 Three tests are to be taken for each anchor and each type of bottom. The stability of the anchor and ease of breaking out are to be noted where possible. Tests are to be carried out from a tug but alternatively shore based tests may be accepted. The pull is to be measured by dynamometer. Measurements of pull, based on the RPM/bollard pull curve of the tug may be accepted as an alternative to a dynamometer. The holding power test load is not to exceed the proof load of the anchor as indicated in Table 10.1.5.3.

10.1.7 Certificates and markings

10.1.7.1 Accepted anchors are to have marine product certificates or equivalent documents with the details as follows:

(1) manufacturer’s name
(2) order number, if any;
(3) fluke and shank identification numbers;
(4) type, nominal and actual mass of anchor;
(5) details of heat treatment;
(6) grade or make of anchor material;

(7) proof test load;
(8) markings on anchors.
10.1.7.2 Accepted anchors are to be stamped with CCS approval and other markings as follows on the fluke and the shank:
(1) manufacturer's mark;
(2) number of the product certificate;
(3) total mass of anchor;
(4) mass of the shank;
(5) the designation HHP or SHHP when approved as high holding power or super high holding power anchors;
(6) unique cast identification number (the number is to be cast on the shank and the fluke).
On the fluke, these markings are to be approximately at a distance of two thirds from the tip of the bill to the center line of the crown on the right hand fluke looking from the crown towards the shank. The markings on the shank are to be approximately level with the fluke tips.

Section 2 MARINE ANCHOR CHAIN CABLES AND ACCESSORIES

10.2.1 Application

10.2.1.1 The requirements of this Section apply to the materials, design, manufacture and testing of the marine stud link chain cables and accessories made of rolled steel bars and forged steels.
10.2.1.2 The marine chain cables specified in this Section include common links, enlarged links, end links, Kenter shackles, joining shackles, end shackles, swivels and swivel shackles.
10.2.1.3 Studless short link chain cables are to be manufactured and tested in accordance with the relevant standards acceptable to CCS.
10.2.1.4 Chain cables are to be subdivided into three grades, i.e. 1, 2 and 3, depending on the nominal tensile strength.

10.2.2 Materials for chain cables

10.2.2.1 The rolled steel bars used for chain cables are to be in accordance with the relevant requirements of Section 12, Chapter 3 of this PART.
10.2.2.2 The steel forgings used in the manufacture of accessories are to comply with the relevant requirements of Section 1, Chapter 5 of this PART and, in addition, the following requirements:
(1) The chemical composition is to comply with the specifications acceptable to CCS. The steel manufacturer is to determine and certify the chemical composition for each heat.
(2) Billets for forging chain cables are to be sampled for mechanical test in accordance with the requirements of 3.12.5 of Chapter 3 of this PART.
10.2.2.3 Cast steels used for the manufacture of accessories are to comply with the relevant requirements of Section 1, Chapter 6 of this PART, unless otherwise specified as follows:
(1) The chemical composition is to comply with the specifications acceptable to CCS. The foundry is to determine and certify the chemical composition of every heat.
(2) All castings are to be properly heat treated as specified for the relevant steel grade in Table 10.2.6.1.
10.2.2.4 The studs are to be made of weldable material corresponding to steel used for the chain cables such as rolled or forged steels with low carbon content. The use of other materials, e.g. grey or nodular cast iron is not permitted.
10.2.2.5 The brand, steel grade and the identification enabling traceability of the material to the original cast are to be clearly marked at the end of material by the manufacturer. For steel bars having diameters of up to and including 40 mm and bundled together for delivery, the marking is to be affixed by a securely fastened tag or label.

10.2.3 Design and manufacture of chain cables and accessories

10.2.3.1 The works manufacturing chain cables and accessories are to be approved by CCS.
10.2.3.2 The chain cables and accessories are to be designed and manufactured in accordance with recognized standards, and their typical designs are shown in Figures 10.2.3.2(1) to (7). The numbers in the Figures represent multiples of the nominal diameter *d*. A length of chain cable is to comprise an odd number of links. Where accessories are of a construction and produced by a welding process other than those required in these Figures, the whole set of drawings giving details of dimensions, manufacturing process and heat treatment together with technological specifications are to be submitted to CCS for approval.

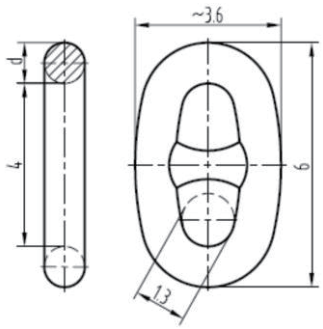


Figure 10.2.3.2(1) Common link

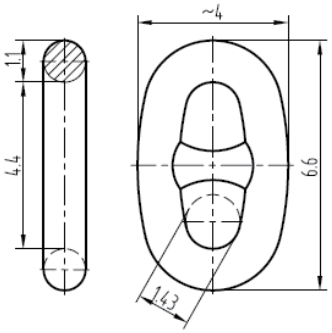


Figure 10.2.3.2(2) Enlarged link

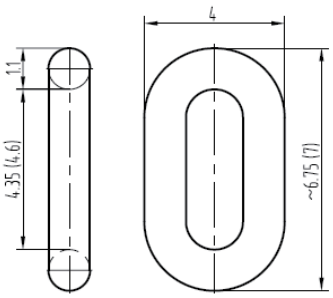


Figure 10.2.3.2(3) End link

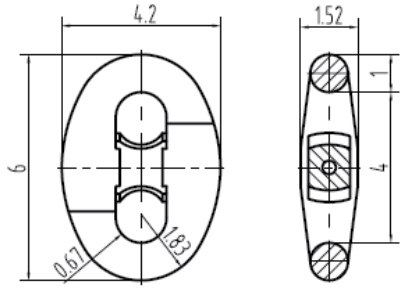


Figure 10.2.3.2(4) Kenter shackle

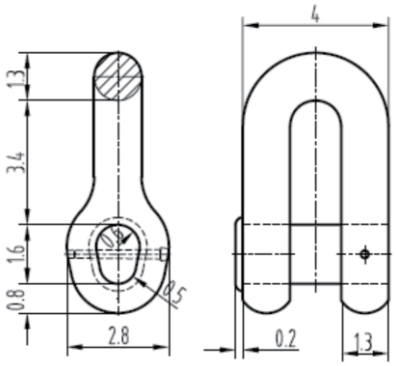


Figure 10.2.3.2(5) Joining shackle

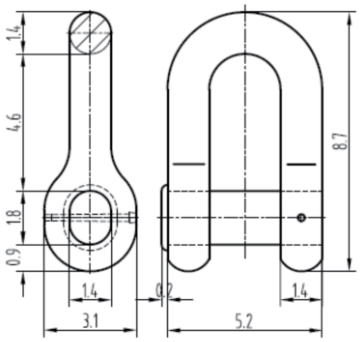


Figure 10.2.3.2(6) End shackle

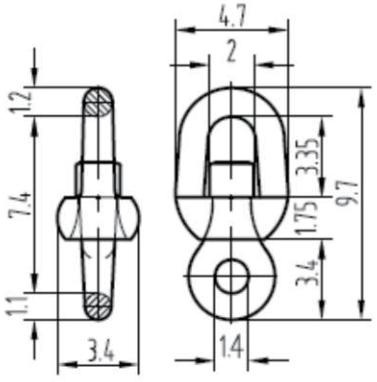


Figure 10.2.3.2(7) Swivel

10.2.3.3 Stud link chain cables are preferably to be manufactured by flash butt welding. Pressure butt welding may also be adopted for Grades 1 and 2 studless chain cables provided that the nominal diameter of the chain cable does not exceed 26 mm.

10.2.3.4 Accessories such as shackles, swivels and swivel shackles are to be forged in steel of at least grade 2. The welded construction of these parts is subject to special approval by CCS. Anchor shackles

produced from cast steel may be accepted provided that the steel grade is not lower than grade 2.

10.2.3.5 The welding of studs is to comply with the requirements as follows:

(1) The studs are to be welded at one end only, i.e., opposite to the weldment of the link. The stud ends are to fit the inside of the link without appreciable gap.

(2) The welds, preferably in the horizontal position, are to be executed by qualified welders using suitable welding consumables.

(3) All welds are to be carried out before the final heat treatment of the chain cable.

(4) The welds are to be free from defects liable to impair the proper use of the chain. Undercuts, end craters and similar defects are to be ground off.

(5) A procedure test for the welding of chain studs may be required.

10.2.4 Surface quality

10.2.4.1 All chain cables and accessories are to have a clean surface consistent with the method of manufacture and be free from cracks, notches, inclusions and other defects impairing the performance of the product. The flashes produced by drop forging or upsetting are to be properly removed.

10.2.4.2 Minor surface defects may be ground off so as to leave a gentle transition to the surrounding surface, provided that the diameter of ground links is not less than required by dimensional tolerances (see 10.2.5 of this Section). Remote from the crown, local grinding up to 5% of the nominal link diameter may be permitted.

10.2.4.3 Where the links are to be repaired by welding, the welding procedure specification is to be submitted to CCS for approval. Welding at the crown is not permitted.

10.2.5 Dimensions and tolerances

10.2.5.1 The dimensions of chain cables and accessories are to comply with the relevant recognized standards.

10.2.5.2 The following tolerances are applicable to links:

(1) The diameter measured at the crown is to be taken twice at the same location, one in the plane of the link and the other perpendicular to the plane of the link. The tolerance on the nominal diameter d is to be in compliance with the requirements of Table 10.2.5.2(1) and the cross-sectional area must have no negative tolerance.

Allowable Tolerance of Diameter at Crown **Table 10.2.5.2(1)**

Nominal diameter (mm)	$d \leq 40$	$40 < d \leq 84$	$84 < d \leq 122$	$d > 122$
Allowable tolerance (mm)	-1 ~ + 0.05 d	-2 ~ + 0.05 d	-3 ~ + 0.05 d	-4 ~ + 0.05 d

(2) The diameter measured at locations other than the crown is to have no negative tolerance. The plus tolerance may be up to 5% of the nominal diameter. The plus tolerance of the diameter at the flash-butt weld is to comply with the requirements of the approved specification.

(3) The allowable manufacturing tolerance of a length of 5 links is to be 0% to +2.5% (measured with the chain under tension after proof load test).

(4) All other dimensions are to be subjected to a manufacturing tolerance of ±2.5%, provided that all of the final link parts of the chain cable fit together properly.

(5) Studs are to be located in the links centrally and at right angles to the sides of the links. The following tolerances are acceptable provided that the stud fits snugly and its ends lie practically flush against the inside of the link (measured in accordance with Figure 10.2.5.2(5)):

1) maximum off-centre distance $X = (A - a) / 2$ is 10% of the nominal diameter;

2) maximum deviation from the 90° position is ≤ 4°.

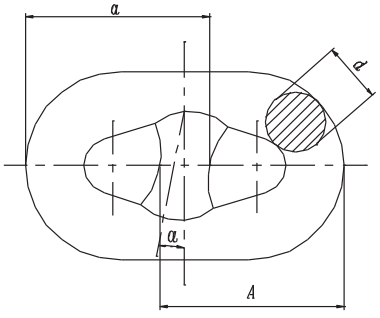


Figure 10.2.5.2(5)

The studs of enlarged links at each end of any length may be located off-centre so as to facilitate the insertion of the Kenter shackle.

10.2.5.3 The dimensional tolerances of accessories are not to be greater than the following:

nominal diameter: 0% to +5%;

other diameters: ±2.5%.

10.2.6 Heat treatment of finished chain cables and accessories

10.2.6.1 According to the grade of steel, chain cables and accessories are to be supplied in one of the conditions specified in Table 10.2.6.1. The heat treatment is to be performed before the proof load test, breaking load test and all mechanical testing.

Condition of Supply of Chain Cables and Accessories **Table 10.2.6.1**

Grade	Chain cables	Accessories
1	As welded or normalized	Not applicable
2	As welded or normalized①	Normalized
3	Normalized, normalized and tempered or quenched and tempered	Normalized, normalized and tempered or quenched and tempered

Note: ① Grade 2 chain cables made by forging are to be supplied in the normalized condition.

10.2.7 Testing of finished chain cables

10.2.7.1 Finished chain cables are to be subjected to the proof load test and the breaking load test in accordance with recognized standards in the presence of the Surveyor, and are not to fracture or exhibit cracking. Special attention is to be given to the visual inspection of the flash-butt weld, if present. For this purpose, the chain cables must be free from paint and anti-corrosion media. Where the manufacturer has a procedure to record proof loads and the adequacy of the recording system to the satisfaction of the Surveyor, the Surveyor may not witness all proof load tests, provided that he is satisfied that the testing machines are calibrated and maintained in a satisfactory condition.

10.2.7.2 Proof load test: Each length of chain cable (27.5 m) is to be subjected to a proof load test at the proof load appropriate to the particular chain cables as shown in Table 10.2.7.2 using an approved testing machine. After unloading, each length of chain cable including the dimensions is to be examined. All links are to be free from significant defects, and the permanent stretch in a length of chain cable is not to exceed 5% of the original length.

Proof and Break Test Loads of Chain Cables **Table 10.2.7.2**

Test load	1	2	3
Proof load (kN)	$0.00686d^2$ (44-0.08d)	$0.00981d^2$ (44-0.08d)	$0.01373d^2$ (44-0.08d)
Breaking load (kN)	$0.00981d^2$ (44-0.08d)	$0.01373d^2$ (44-0.08d)	$0.01961d^2$ (44-0.08d)

10.2.7.3 For the braking load test, one sample comprising of at least three links taken from every four lengths or fraction of chain cables is be regarded as the specimen by the Surveyor and tested at the breaking loads given by Table 10.2.7.2. The breaking load is to be maintained for at least 30 s. The links concerned are to be made in a single manufacturing cycle together with the chain cable and welded and heat treated together with it.

Where 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 is to be agreed.

Where the specimen is not broken after the specified load is applied, it is regarded that the specimen has passed the test.

10.2.7.4 Retest: Where a breaking load test fails to meet the requirements, an additional specimen may be taken from the same length of chain cable and tested. The test is to be considered successful if the requirements are then satisfied.

Where the retest fails, the length of chain cable concerned is to be rejected. If the manufacturer so wishes, the remaining three lengths belonging to the batch test quantity may then be individually subjected to test at the breaking load. Where one such test fails to meet the requirements, the entire batch is to be rejected.

Where a proof load test fails and subject to agreement of CCS, the defective link(s) may be replaced by new links which have been locally heat treated and the proof load test repeated. In addition, an investigation is to be made to identify the cause of the failure.

10.2.7.5 For Grades 2 and 3 chain cables, mechanical test specimens are to be taken from every four lengths of welded chain cable. For forged chain cables where the batch size is less than four lengths, the sampling frequency is to be by heat and heat treatment charge. One tensile specimen and two sets of three

Charpy V-notch impact test specimens are to be taken from each batch according to the requirements of Table 10.2.7.5. One tensile specimen and one set of three impact test specimens are to be taken from the side of the base material opposite the weld, and the other set of three impact test specimens is to be taken with the notch positioned at the centre of the weld. The specimen link is to be manufactured and heat treated together with this batch of chain cable.

Number of Mechanical Specimens for Finished Chain Cables and Accessories

Table 10.2.7.5

Grade	Manufacturing method	Condition of supply	Number of specimens		
			Tensile test for base metal	Charpy V-notch impact test	
				Base metal	Weldment
1	Flash-butt welded	As welded, normalized	Not required	Not required	Not required
2	Flash-butt welded	As welded	1	3	3
		Normalized	Not required	Not required	Not required
	Forged or Cast	Normalized	1	3①	Not applicable
3	Flash-butt welded	Normalized, normalized and tempered, quenched and tempered	1	3	3
	Forged or Cast	Normalized, normalized and tempered, quenched and tempered	1	3	Not applicable

Note: ① This only applies to accessories.

10.2.7.6 The mechanical test is to be carried out in the presence of the Surveyor. The mechanical properties are to comply with the requirements of Table 10.2.8.4 in this Section.

10.2.7.7 Where the mechanical properties of links in a length are not satisfactory, specimens may be taken again for retest in accordance with the requirements of Sections 1, 2 and 3, Chapter 2 of this PART.

10.2.7.8 Where the retest still fails, this length of chain cable may be heat treated and sampled again for an additional retest. Where the additional retest still fails, this length is to be rejected.

10.2.8 Testing of accessories

10.2.8.1 Proof load test: All the accessories are to be subjected to the proof load test at the proof load specified for the corresponding chain cable in Table 10.2.7.2 of this Section.

10.2.8.2 Breaking load test: From each manufacturing batch (the same cast, diameter and heat treatment) of 25 units or less of shackles, swivels, swivel shackles, enlarged links and end links and from each manufacturing batch of 50 units or less of Kenter shackle, one unit is to be subjected to the breaking load test at the break load specified in Table 10.2.7.2. Parts tested in this way may not be put to further use.

Enlarged links and end links need not be tested provided that they are manufactured and heat treated together with the chain cable.

10.2.8.3 CCS may waive the breaking load test if:

(1) the breaking load has been demonstrated on the occasion of the approval testing of parts of the same design;

(2) the mechanical properties and impact energy of each manufacturing batch have been proved; and

(3) the accessories have been subjected to suitable non-destructive testing.

10.2.8.4 For test sampling, forged or cast accessories of similar dimensions originating from the same heat of steel and the same heat treatment charge are to be combined into one test unit. From each test unit, at least one specimen is to be taken for mechanical test after heat treatment in accordance with the requirements of 10.2.7.5 of this Section. Test results and retest requirements are to comply with Table 10.2.8.4.

Mechanical Properties of Finished Chain Cables and Accessories **Table 10.2.8.4**

Grade	Yield strength R_{eH} (N/mm^2)	Tensile strength R_m (N/mm^2)	Elongation A_5 (%)	Reduction of area Z (%)	Charpy V-notch impact test		
					Test temperature (℃)	Impact energy (J)	
						Base metal	Weldment
2	≥ 295	490 ~ 690	≥ 22	Not required	0	≥ 27	≥ 27
3	≥ 410	≥ 690	≥ 17	≥ 40	0(-20)①	≥ 60(35)	≥ 50(27)

Note: ① In general, the impact test temperature of grade 3 finished chain cables is 0℃. Where it is required by the purchaser, -20℃ may be regarded as a supply condition.

10.2.9 Marking and certification

10.2.9.1 The chain cables and accessories accepted by CCS are to be stamped with the following marks on both ends of each length of chain cable as shown in Figure 10.2.9.1:

(1) Chain cable grade;

(2) Certificate number;

(3) CCS symbol.

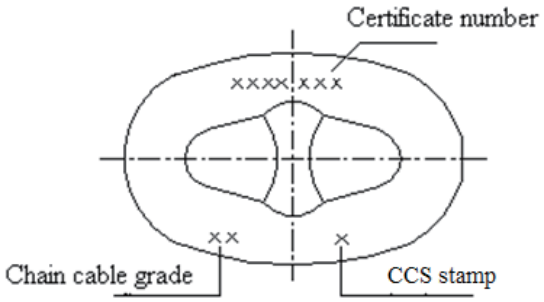


Figure 10.2.9.1

The certificate number may be an abbreviation or other equivalent marking, and is to be stated in the corresponding certificate.

10.2.9.2 Chain cables or accessories which meet the requirements are to be certified by CCS at least with the following items:

(1) name of manufacturer;

(2) grade;

(3) cast number (applicable to accessories);

(4) chemical composition (including total aluminum content);

(5) nominal diameter/weight;

(6) proof load and breaking load;

(7) heat treatment;

(8) marks on chain cables or accessories;

(9) length (applicable to chain cables);

(10) mechanical properties (where applicable).

Section 3 OFFSHORE MOORING CHAINS AND ACCESSORIES

10.3.1 Application

10.3.1.1 The requirements of this Section apply to the design, manufacture and testing of offshore mooring chains and accessories intended for offshore applications such as mooring of mobile offshore units, floating production units, offshore loading systems and gravity based structures during fabrication.

10.3.1.2 The mooring chains specified in this Section include common stud and studless links, connecting common links (splice links), enlarged links, end links, detachable connecting links (eg. shackles), end shackles, subsea connectors, swivels and swivel shackles.

10.3.1.3 Studless link chain is normally deployed only once, being intended for long-term permanent mooring systems with pre-determined design life.

10.3.1.4 Chafing chains for single point mooring arrangements are also to be manufactured according to the requirements of this Section.

10.3.2 Chain grades

10.3.2.1 Depending on the nominal tensile strength of the steels used for manufacture, chains are to be subdivided into five grades, i.e.: R3, R3S, R4, R4S and R5.

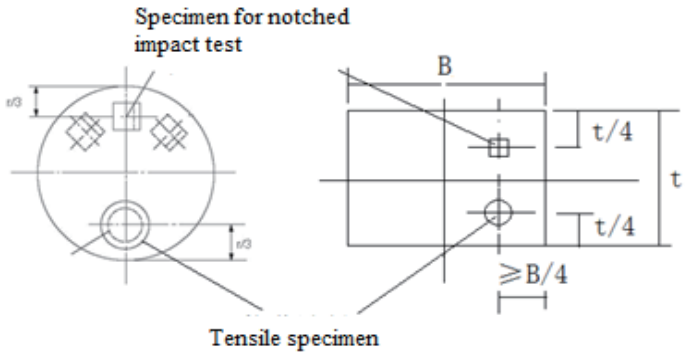
10.3.2.2 Manufacturers' propriety specifications for R4S and R5 may vary subject to design conditions and the acceptance of CCS.

10.3.3 Material

10.3.3.1 The rolled steel bars intended for welded mooring chains and accessories are to comply with the relevant requirements of Section 10, Chapter 3 of this PART.

10.3.3.2 Forged steels used for the manufacture of accessories are to comply with the relevant

requirements of Section 1, Chapter 5 of this PART, unless otherwise specified as follows:
(1) Forged steels are to comply with the approved specifications and the submitted test reports approved by CCS. Steel is to be manufactured by basic oxygen, electric furnace or such other process as may be specially approved. All steel is to be killed and fine grain treated. Steel for forgings intended for R4S and R5 chain is to be vacuum degassed.
(2) The steel manufacturer is to determine the chemical composition of every heat of material. The chemical composition is to comply with the specifications acceptable to CCS at the time of approval.
(3) Steel for forgings is to be tested for the austenitic grain size in accordance with a recognized standard (e.g. ASTM E112). The austenitic grain size is to be 6 or finer. Measurements for circular sections are to be taken at 1/3 radius. Measurements for non-circular sections are to be taken at 1/4t.
(4) For steel intended for R4S and R5 accessories, each heat is to be subject to the quantification and assessment of non-metallic inclusions in accordance with the national/international standards (e.g. ISO 4967), examination of segregation or porosity (e.g. ASTM E381) and testing of hardenability (e.g. ASTM A255). The results are to satisfy the requirements determined at the time of approval.
(5) Finished forgings are to be properly heat treated in compliance with the specifications submitted and approved.
(6) After proper heat treatment, forgings of similar dimensions (diameters do not differ by more than 25 mm) originating from the same heat treatment charge and the same heat of steel are to be combined into one test unit, and from each test unit one sample is to be taken. One tensile and three impact test specimens are to be taken from the sample at the locations as shown in Figure 3.12.5.2 of Section 12, Chapter 3 of this PART or Figure 10.3.3.2(4) of this Section for mechanical testing. The mechanical properties are not to be inferior to those required for steel bars intended for mooring chains in Section 12, Chapter 3 of this PART.



a Sampling positions of specimen with circular section b Sampling positions of specimen with rectangular section

Figure 10.3.3.2(4) Sampling Position of Specimens for Mechanical Testing

(7) Each heat of Grade R3S, R4, R4S and R5 is to be tested for hydrogen embrittlement in accordance with the requirements of 3.12.5.3, Section 12, Chapter 3 of this PART.
(8) Wet continuous magnetization technique by adopting recognized standards (e.g. EN 10228-1 or other equivalent standards) is to be used for testing of the surface of delivered steel forgings in accordance with the testing procedure submitted by the manufacturer. The forgings are to be subject to one hundred percent ultrasonic examination at an appropriate stage of manufacture in compliance with a recognized standard (e.g. ISO 13588 or other equivalent standards). The testing results are to satisfy the requirements of standards submitted at the time of approval.
(9) Defects on non-machined surfaces of forging materials intended for mooring chains may be removed by grinding to a depth of 5% of the nominal diameter. Grinding is not permitted on machined surfaces, except for slight inspection grinding on plane surfaces to a maximum depth of 0.8 mm in order to investigate spurious indications. Welding repairs are not permitted.
10.3.3.3 Cast steels used for the manufacture of accessories (anchor shackles) are to comply with the relevant requirements of Section 1, Chapter 6 of this PART, unless otherwise specified as follows:
(1) Cast steels are to comply with the approved specifications and the submitted test reports approved by CCS. Steel is to be manufactured by basic oxygen, electric furnace or such other process as may be specially approved. All steel is to be killed and fine grain treated. Steel for forgings intended for R4S and R5 chain is to be vacuum degassed.
(2) The manufacturer is to determine the chemical composition of every heat. The chemical composition is to comply with the specifications acceptable to CCS at the time of approval.

(3) Steel for castings is to be tested for the austenitic grain size in accordance with a recognized standard (e.g. ASTM E112). The austenitic grain size is to be 6 or finer. Measurements for circular sections are to be taken at 1/3 radius. Measurements for non-circular sections are to be taken at 1/4t.
(4) For steel forgings intended for R4S and R5 accessories, each heat is to be subject to the quantification and assessment of non-metallic inclusions, examination of segregation or porosity and testing of hardenability in accordance with the national/international standards (e.g. ISO 4967, ASTM E381 and ASTM A255). The results are to satisfy the requirements determined at the time of approval.
(5) All castings are to be properly heat treated in compliance with specifications submitted and approved.
(6) Castings of similar dimensions originating from the same heat treatment charge and the same heat of steel are to be combined into one test unit, and from each test unit one sample is to be taken. One tensile and three impact test specimens are to be taken from the sample at the locations as shown in Figure 3.12.5.2 of Section 12, Chapter 3 of this PART and for mechanical testing. The mechanical properties are not to be inferior to those required for steel bars intended for mooring chains in Section 12, Chapter 3 of this PART. The acceptance requirement for reduction of area is, however, reduced to 40% for grades R3 and R3S and 35% for grades R4, R4S and R5.
(7) Wet continuous magnetization technique by adopting recognized standards (e.g. ASTM E709 or other equivalent standards) is to be used for testing of the surface of delivered castings in accordance with the testing procedure submitted by the manufacturer. The forgings are to be subject to one hundred percent ultrasonic examination at an appropriate stage of manufacture in compliance with a recognized standard (e.g. ISO 13588 or other equivalent standards). The testing results are to satisfy the requirements of standards submitted at the time of approval.
(8) Defects on non-machined surfaces may be removed by grinding to a depth of 5% of the nominal diameter. Grinding is not permitted on machined surfaces, except for slight inspection grinding on plane surfaces to a maximum depth of 0.8 mm in order to investigate spurious indications. Where the repair entails removal of more than 5% of the diameter or thickness, the defective area is to be repaired by welding in accordance with the following requirements:

① 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 NDE.
② A weld repair is considered major when the depth of the groove prepared for welding exceeds 25% of the diameter/thickness or 25 mm, whichever is smaller. All other weld repairs are considered minor.
③ Major weld repairs require approval before the repair is commenced. Procedures are to be qualified according to recognized standards (e.g. ISO 15614 or equivalent) with the following additional requirements: Charpy V notch impact tests with notch locations in weld metal, fusion line and heat affected zone + 2 mm and + 5 mm from fusion line, respectively. Test results are to meet the requirements specified for the parent metal. Proposals for major repairs are to be accompanied by sketches or photographs showing the extent and positions of the repairs.
④ A grain refining heat treatment is to be given to the whole casting prior to major repairs. A post weld heat treatment or repeat of original heat treatment of castings is to be carried out.
⑤ Minor and major weld repairs must be recorded on sketches or photographs showing the extent and positions of the repairs.

10.3.3.4 For the delivery of forged and cast steels for grades R4S and R5 accessories, in addition to routine steel information, the following information is to be included in the accessory documentation: non-metallic inclusions, segregation or porosity, jominy hardenability and ultrasonic examination, results of hydrogen embrittlement test and ultrasonic examination as well as welding repair records accompanied by sketches or photographs(if any).
10.3.3.5 The studs are to be made of steel corresponding to that of the chain or in compliance with specifications submitted to and approved by CCS. In general, the carbon content is not to exceed 0.25% or the carbon equivalent is not to exceed 0.58% if the studs are to be welded in place.

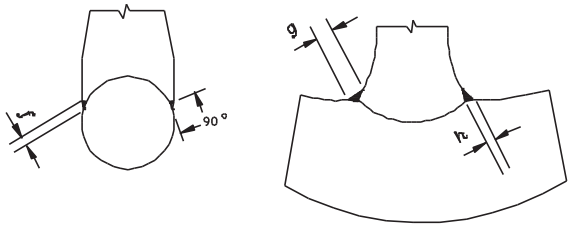
10.3.4 Design of mooring chains

10.3.4.1 Drawings accompanied by design calculations, giving detailed design of mooring chain and accessories made by or supplied through the chain manufacturer are to be submitted to CCS for approval. Typical designs of stud link chains are given in Figure 10.2.3.2. For studless chains, the shape and proportions are to comply with the requirements of 10.3.8.6(5). Other studless proportions are to be specially approved. New or non-standard designs of chain links, shackles or accessories may require a fatigue analysis and other possible performance, fatigue or corrosion fatigue testing.

10.3.4.2 In addition, for stud link chains, drawings showing the detailed design of the stud are to be submitted to CCS for information. The stud is to give an impression in the chain link which is sufficiently deep to secure the position of the stud, but the combined effect of shape and depth of the impression is not to cause any harmful notch effect or stress concentration in the chain link.
10.3.4.3 Machining of Kenter shackles is to result in fillet radius min. 3% of nominal diameter.

10.3.5 Manufacture of mooring chains
10.3.5.1 Chain manufacturers are to be approved by CCS and to purchase steel bars for mooring chains from the works approved by CCS.
10.3.5.2 Offshore mooring chains are to be manufactured in continuous lengths by flash butt welding and are to be heat treated in a continuous furnace; batch heat treatment is not permitted, except in special circumstances where short lengths of chain are delivered, such as chafing chain.
10.3.5.3 The use of connecting common links to replace defective links is subject to the written approval of the end purchaser in terms of the number and type permitted. The use of connecting common links is restricted to 3 links in each 100 m of chain.
10.3.5.4 Bar heating is to comply with the following requirements:
(1) Bars for links are to be heated by electric resistance, induction or in a furnace.
(2) For electric resistance heating or induction heating, the heating phase is to be controlled by an optical heat sensor. The controller is to be checked at least once every 8 h and records made.
(3) For furnace heating, the heat is to be controlled and the temperature continuously recorded using thermocouples in close proximity to the bars. The controls are to be checked at least once every 8 h and records made.
10.3.5.5 The welding parameters for platen motion, current as a function of time and hydraulic pressure are to be controlled during flash welding of each link. The controls are to be checked at least every 4 h and records made.
10.3.5.6 Heat treatment of mooring chains is to comply with the following requirements:
(1) Chain is to be austenitized, above the upper transformation temperature, at a combination of temperature and time within the limits established.
(2) When applicable, chain is to be tempered at a combination of temperature and time within the limits established. Cooling after tempering is to be appropriate to avoid temper embrittlement.
(3) Temperature and time or temperature and chain speed is to be controlled and continuously recorded.
10.3.5.7 Records of bar heating, flash welding and heat treatment are to be made available for inspection by the Surveyor.

10.3.6 Fitting of studs
10.3.6.1 A welded stud may be accepted for grade R3 and R3S chains. Welding of studs in grades R4, R4S and R5 chains is not permitted unless specially approved by CCS.
10.3.6.2 Where studs are welded into the links, this is to be completed before the final heat treatment of chain.
10.3.6.3 The stud ends are to be a good fit inside the link and the weld is to be confined to the stud end opposite to the flash butt weld. The full periphery of the stud end is to be welded unless otherwise approved.
10.3.6.4 Welding of the stud's both ends is not permitted unless specially approved.
10.3.6.5 The welds are to be made by qualified welders using an approved procedure and approved low-hydrogen consumables.
10.3.6.6 The size of the fillet weld is to comply with the requirements of Figure 10.3.6.6.



$f = 0.1d^{0}_{-0.01d}$, $g = 0.2d^{0}_{-0.02d}$, $h = 0.09d^{0}_{-0.01d}$

Figure 10.3.6.6

10.3.6.7 The welds are to be of good quality and free from defects such as cracks, lack of fusion, gross porosity and undercuts exceeding 1 mm.
10.3.6.8 All stud welds are to be visually examined. At least 10 per cent of all stud welds within each length of chain are to be examined by dye penetrant or magnetic particles after proof testing. If cracks or lack of fusion are found, all stud welds in that length are to be examined.

10.3.7 Connecting common links (splice links)
10.3.7.1 Single links to substitute for test links or defective links without the necessity for reheat treatment of the whole length are to be made in accordance with an approved procedure. Separate approvals are required for each grade of chain and the tests are to be made on the maximum size of chain for which approval is sought.
10.3.7.2 Manufacture and heat treatment of connecting common links is not to affect the properties of the adjoining links. The temperature reached by these links is nowhere to exceed 250℃.
10.3.7.3 Each link is to be subjected to the appropriate proof load and non-destructive testing as detailed in Tables 10.3.8.5, 10.3.8.9 and 10.3.8.10. A second link is to be made identical to the connecting common link; the link is to be tested and inspected in accordance with the requirements of 10.3.8.8 to 10.3.8.10.
10.3.7.4 Each connecting common link is to be marked either on the stud for stud link chain or, on the outer straight length on the side opposite the flash butt weld for studless chain. This marking is to be in accordance with the requirements of 10.3.10.1 plus a unique number for the link satisfying the requirements of 10.3.10 of this Section. The adjoining links are also to be marked on the studs or straight length as above.

10.3.8 Testing and inspection of mooring chains
10.3.8.1 This section applies to but is not limited to testing and inspection of finished mooring chains such as common stud and studless links, end links, enlarged end links and connecting common links (splice links).
10.3.8.2 Prior to inspection, the chain is to be free from scale, paint or other coating by sand blasting, shot blasting or other suitable means and is to have a suitably prepared surface as per the applied NDE testing standard.
10.3.8.3 Mooring chains are to have a clean surface consistent with the method of manufacture and be free from cracks, notches and other defects impairing the performance of the chain. Each link is to be examined in accordance with approved procedures. The dimensions of mooring chains and accessories are to comply with the relevant standards accepted or special design requirements approved by CCS.
10.3.8.4 All mooring chains are to be subjected to proof load tests, sample break load tests and mechanical tests in accordance with a standard acceptable to CCS after final heat treatment in the presence of the Surveyor. Where the manufacturer has a procedure to record proof loads and the Surveyor is satisfied with the adequacy of the recording system, he need not witness all proof load tests. The Surveyor is, however, to satisfy himself that the testing machines are calibrated and maintained in a satisfactory condition.
10.3.8.5 Mooring chains are to be subject to proof and break tests in accordance with the following requirements:
(1) The entire length of chain is to withstand the proof load specified in Table 10.3.8.5(1) without fracture and is not to crack in the flash weld and without obvious stud loosening. The load applied is not to exceed the proof load by more than 10% when stretching the chain. Where plastic straining is used to set studs, the applied load is not to be greater than that qualified in approval tests.

Proof and Break Test Loads, Weight and Length over 5 Links Table 10.3.8.5(1)

Stud link	R3	R3S	R4	R4S	R5
Proof test load (kN)	0.0148K	0.0180K	0.0216K	0.0240K	0.0251K
Break test load (kN)	0.0223K	0.0249K	0.0274K	0.0304K	0.0320K
Studless	R3	R3S	R4	R4S	R5
Proof test load (kN)	0.0148K	0.0174K	0.0192K	0.0213K	0.0223K
Break test load (kN)	0.0223K	0.0249K	0.0274K	0.0304K	0.0320K
Chain weight (kg/m)	Stud link = $0.0219d^2$		Studless chain Weight calculated for each design		
Length L over 5 links	$22d \le L \le 22.55d$				

where: $k = d^2$ (44-0.08d);
d—nominal chain diameter, in mm.

(2) A break test specimen consisting of at least 3 links is to be either taken from the chain or produced at the same time and in the same manner as the chain. The test frequency is to be based on tests at sampling intervals according to Table 10.3.8.5(2) provided that every cast is represented. Each specimen is to be capable of withstanding the break load specified in Table 10.3.8.5(1) without fracture and is not to crack in the flash weld. It will be considered acceptable if the specimen is loaded to the specified value and maintained at that load for 30 s.

Sampling Frequency of Break and Mechanical Tests Table 10.3.8.5(2)

Nominal chain diameter (mm)	≤ 48	49~60	61~73	74~85	86~98	99~111	112~124	125~137
Maximum sampling interval (m)	91	110	131	152	175	198	222	250
Nominal chain diameter (mm)	138~149	150~162	163~175	176~186	187~199	200~210	211-222	
Maximum sampling interval (m)	274	297	322	346	370	395	420	

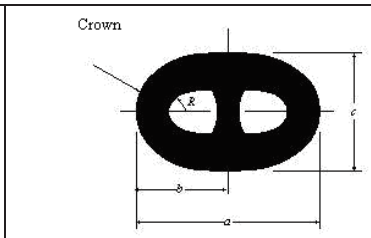
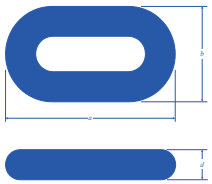
(3) For chain diameters over 100 mm, alternative break-test proposals to the above break test will be considered whereby a one link specimen is used. Alternatives are to be approved by CCS, every heat is to be represented, the test frequency is to be in accordance with Table 10.3.8.5(2), and it is to be demonstrated and proven that the alternative test represents an equivalent load application to the three link test.
(4) If the loading capacity of the testing machine is insufficient, an alternative load testing machine is to be used that does have sufficient capacity (e.g. two loading machines in parallel) provided the testing and calibration procedure are agreed with CCS.
10.3.8.6 After proof load testing, measurements are to be taken on at least 5 per cent of the links in accordance with the following requirements. The shape and proportions of links are to comply with recognized standards or specially approved design requirements as well as the following tolerance requirements:
(1) The maximum and minimum dimensions measured at the crown are to comply with the tolerance requirements in Table 10.3.8.6(1). However, the cross-sectional area at the crown must have no negative tolerance. The cross sectional area at the crown is to be calculated using the average of the diameters with negative tolerance and plus tolerance, measurements are to be taken from at least 2 locations approximately 90 degrees apart.

Allowable Tolerance of Diameter at Crown Table 10.3.8.6(1)

Nominal chain diameter d (mm)	≤ 40	40<d ≤84	84<d≤122	122<d ≤ 152	152<d≤184	184<d≤222
Negative tolerance (mm)	1	2	3	4	6	7.5
Plus tolerance (mm)	For diameters of 20 mm or greater: 0.05d For diameters less than 20 mm: to be agreed with CCS at the time of approval					

(2) Diameter measured at locations other than the crown is to have no negative tolerance. The plus tolerance may be up to 5% of the nominal diameter. The plus tolerance of the diameter at the flash-butt weld is to comply with the manufacturer's specifications approved by CCS. For diameters less than 20 mm, the plus tolerance is to be agreed with CCS at the time of approval.
(3) The allowable manufacturing tolerance on a length of 5 links is to be 0% to +2.5% (measured with the chain loaded up to 10% of the minimum proof load).
(4) Except as required by Table 10.3.8.6(5), all other dimensions are to be subject to a manufacturing tolerance of 2.5%, provided that all of the final link parts of the chain fit together properly.
(5) The tolerance of stud link and studless common links is to comply with the relevant requirements of Table 10.3.8.6(5). The internal and external radii of the link are to be uniform.
(6) For stud links, studs are to be located in the links centrally and at right angles to the sides of the link. The following tolerances in Table 10.3.8.6(5) are acceptable provided that the stud fits snugly and its ends lie practically flush against the inside of the link. In general the stud is to penetrate the link for 2-6% of the diameter of link.

Dimensions and Tolerances of Common Links **Table 10.3.8.6(5)**

							
Designation	Description	Nominal dimension of stud link	Minus tolerance	Plus tolerance	Nominal dimension of studless link	Minus tolerance	Plus tolerance
A	Link length	6*d*	0.15*d*	0.15*d*	6*d*	0.15*d*	0.15*d*
B	Link half length	a*/2	0.1*d*	0.1*d*	Not applicable	–	–
C	Link width	3.6*d*	0.09*d*	0.09*d*	3.35*d*	0.09*d*	0.09*d*
E	Stud angular misalignment	0°	4°	4°	Not applicable	–	–
R	Inner radius	0.65*d*	0	–	0.60*d*	0	–

Notes: ① *d* = Nominal diameter of chain, a* = Actual link length.
② Other dimension ratios of studless links are subject to special approval by CCS.

10.3.8.7 After proof testing, the entire g chain is to be checked for the length, five links at a time. By the check the first five links are to be measured. From the next set of five links, at least two links from the previous five links set are to be included. This procedure is to be followed for the entire chain length. The measurements are to be taken preferably while the chain is loaded to 10% of the minimum proof load. The tolerances for the 5 link measurements are indicated in Table 10.3.8.5(1), and any deviation from the 5 link tolerances are to be agreed by the client and CCS. The links held in the end blocks may be excluded from this measurement.

10.3.8.8 According to the test frequency and sampling requirements in Table 10.3.8.5(2), links of samples detached from finished, heat treated chain are to be sectioned for metallurgical examination and determination of mechanical properties as follows:

(1) A metallographic sample (one from each ladle in case the heat number of material can be confirmed) is to be taken to examine the austenitic grain size according to a recognized standard (e.g. ISO 643) at 1/3 radius and centre from surface for the base material, HAZ and weld. The austenitic grain size is to be 6 or finer.

(2) A test unit is to consist of one tensile specimen and three sets of three Charpy V-notch impact test specimens. The sampling locations are as shown in Figure 10.3.8.8(2) or Figure 3.12.5.2, Section 12, Chapter 3 of this PART and comply with the following requirements:

the tensile specimen is to be taken in the side opposite the flash weld;

the first set of three impact specimens is to be taken across the flash weld with the notch centered in the middle;

the second set of three impact specimens is to be taken across the unwelded side;

the third set of three impact specimens is to be taken from the bend region.

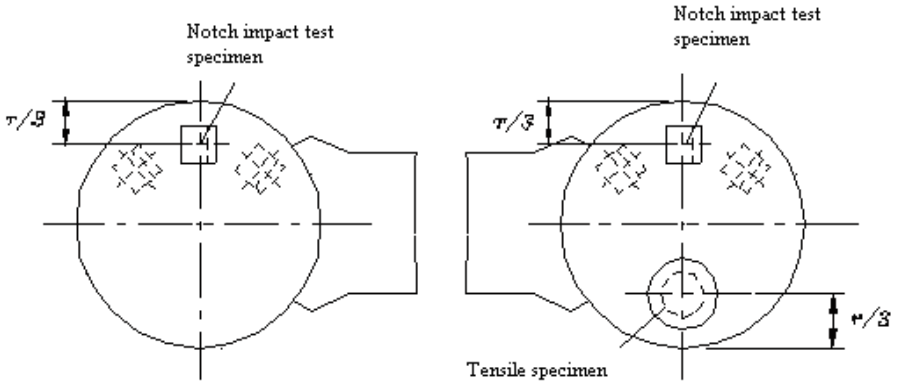


Figure 10.3.8.8(2)

(3) The frequency of impact testing in the bend may be reduced at the discretion of CCS provided it is

verified by statistical means that the required toughness is consistently achieved.
(4) The test results are to comply with the requirements of Table 10.3.8.8(4).

Mechanical Properties of Mooring Chains and Accessories Table 10.3.8.8(4)

Grade	Yield point $R_{P0.2}$ (N/mm^2)	Tensile strength R_m (N/mm^2)	Elongation A_5 (%)	Reduction of area Z (%)	Charpy V-notch impact test		
					Test temperature (℃)	Impact energy (J)	
						Base metal	Weld metal
R3	≥ 410	≥ 690②	≥ 17	50	0(-20) ①	≥ 60(40)	≥ 50(30)
R3S	≥ 490	≥ 770②	≥ 15	50	0(-20) ①	≥ 65(45)	≥ 53(33)
R4	≥ 580	≥ 860②	≥ 12	50	-20	≥ 50	≥ 36
R4S③	≥ 700	≥ 960②	≥ 12	50	-20	≥ 56	≥ 40
R5③	≥ 760	≥ 1000②	≥ 12	50	-20	≥ 58	≥ 42

Notes: ① In general, the temperature of impact test for Grades R3 and R3S chains is 0℃. Where it is required by the purchaser, -20℃ may be regarded as a supply condition.
②The yield to tensile ratio is generally not to be greater than 0.92.
③ Maximum hardness for R4S is to be 330 HBW and R5 340 HBW.

10.3.8.9 Hardness tests are to be carried out on finished chain. The frequency and locations are to be agreed with CCS. The recorded values are for information only and used as an additional check to verify that the heat treatment process has been stable during the chain production.
10.3.8.10 After proof testing, chain is to be positioned in order to have good access to all surfaces and all surfaces of every link are to be visually examined. In order to allow optimal access to the surface area it is recommended that chain be hung in the vertical position, however access to inspect the interlink area may only be possible with the chain in the horizontal position. Burrs, irregularities and rough edges are to be contour ground. Links are to be free from mill defects, surface cracks, dents and cuts, especially in the vicinity where gripped by clamping dies during flash welding. Studs are to be securely fastened and free from loosening.
10.3.8.11 Magnetic particles are to be employed to examine the following positions in accordance with the following requirements and using the same equipment, procedures and acceptance criteria submitted to CCS at the time of approval:
(1) flash welded area including the area gripped by the clamping dies; additionally,
(2) all accessible surfaces of 10% of links;
(3) testing is to be performed in accordance with a recognized standard (e.g. ISO 9934) using wet continuous fluorescent magnetization technique. Non fluorescent techniques can be accepted in special cases where the standard inspection procedures are impractical;
(4) Link surfaces and the surface at the flash weld are to be free from cracks, lack of fusion and gross porosity. Links are to be free from relevant linear indications exceeding 1.6 mm in transverse direction, relevant linear indications exceeding 3.2 mm in longitudinal direction or relevant non-linear indications exceeding 4.8 mm.
10.3.8.12 Ultrasonics are to be employed to examine the mooring chain in accordance with the following requirements and using the same equipment, procedures and acceptance criteria submitted to CCS at the time of approval:
(1) On-site calibration standards for chain configurations are to be approved by CCS.
(2) Ultrasonics are to be employed to examine the flash weld fusion of every link.
(3) The flash butt welds are to be ultrasonic tested (UT) in accordance with a recognized standard (e.g. ASTM E587) using single probe, angle-beam shear waves in the range from 45 to 70°. Single probe technique has limitations as far as testing of the central region is concerned and the flash weld imperfections such as flat spots may have poor reflectivity. Where it is deemed necessary, detectability of imperfections may need to be carried out by using a tandem technique, TOFD or phased array.
(4) The flash weld is to be free from defects causing ultrasonic back reflections equal to or greater than the calibration standard.
10.3.8.13 Stud welds, if used, are to be visually inspected. The toes of the fillets are to have a smooth transition to the link with no undercuts exceeding 1.0 mm. Additionally, at least 10% of the stud welds distributed through the length are to be dye penetrant or magnetic particle tested according to a recognized standard (e.g. ASTM E1417 or ASTM E1444). Cracks, lack of fusion or gross porosity are not acceptable. If defects are found, testing is to be extended to all stud welds in that length.

10.3.9 Retest, rejection and repair criteria

10.3.9.1 If the length over 5 links is short, the chain may be stretched by loading above the proof test load specified provided that the applied load is not greater than that approved and that only random lengths of the chain need stretching. If the length exceeds the specified tolerance, the over length chain links are to be cut out and 10.3.9.2 is to apply. The stretched links are to be recorded in the report.

10.3.9.2 If single links are found to be defective or to not meet other applicable requirements, defective links may be cut out and a connecting common link inserted in their place. The individual heat treatment and inspection procedure of connecting common links is subject to approval by CCS. Other methods for repair are subject to the written approval of CCS and the end purchaser. Weld repair of chain is not permitted.

10.3.9.3 If a crack, cut or defect in the flash weld is found by visual or magnetic particle examination, it is to be ground down no more than 5% of the link diameter in depth and streamlined to provide no sharp contours. The final dimensions must still conform to the agreed standard.

10.3.9.4 If indications of interior flash weld defects in reference to the accepted calibration standards are detected during ultrasonic examination, such links are to be cut out and replaced in accordance with the requirements of 10.3.9.2.

10.3.9.5 If link diameter, length, width and stud alignment do not conform to the required dimensions, these are to be compared to the dimensions of 40 more links; 20 on each side of the affected link. If a single particular dimension fails to meet the required dimensional tolerance in more than 2 of the sample links, all links are to be examined. Defective links are to be cut out and replaced in accordance with the requirements of 10.3.9.2.

10.3.9.6 If a break load test fails, a thorough examination with the Surveyor informed in a timely manner is to be carried out to identify the cause of failure. Two additional break test specimens representing the same sampling length of chain are to be subjected to the break load test. Based upon satisfactory results of the additional tests and the results of the failure investigation, it will be decided what lengths of chain can be accepted. Failure of either or both additional tests will result in rejection of the sampling length of chain represented and satisfactorily tested chains with the same length are to be used.

10.3.9.7 If a link fails during proof load testing, a thorough examination with the Surveyor informed in a timely manner is to be carried out to identify the probable cause of failure of the proof test. In the event that two or more links in the proof loaded length fail, that length is to be rejected. The above failure investigation is to be carried out especially with regard to the presence in other lengths of factors or conditions thought to be causal to failure.

10.3.9.8 In addition to the above failure investigation, a break test specimen is to be taken from each side of the one failed link, and subjected to the break test.

Where multiple chains are produced simultaneously it is recognised that the preceding flash butt welded link and subsequent flash butt welded link will be on an alternative chain length or the other end of the chain length. In such cases CCS may require that two additional break tests are to be taken from the lengths of chain that include the preceding and subsequent welded links. Based upon satisfactory results of both break tests and the results of the failure investigation, it will be decided what length of chain can be considered for acceptance. Failure of either or both breaking tests will result in rejection of the same proof loaded length. Replacement of defective links is to be in accordance with 10.3.7.

If the investigation identifies defects in the flash butt weld or a lower strength flash weld “a glue-weld” is found, additional NDT such as phased array UT is to be carried out to identify if other links are affected. A full assessment of the flash butt welding machine is to be carried out, together with assessment of the condition of the bar ends prior to welding.

10.3.9.9 Re-test requirements for tensile and impact tests are to be in accordance with the relevant requirements of Section 2, Chapter 1 of this PART. Failure to meet the specified requirements of either or both additional tests will result in rejection of the sampling length of chain represented.

10.3.10 Marking, certification and documentation

10.3.10.1 The chain which has been satisfactorily inspected by CCS is to be marked at the following places:

(1) at each end;

(2) at intervals not exceeding 100 m;

(3) on connecting common links;

(4) on links next to shackles or connecting common links.

10.3.10.2 All marked links are to be stated on the certificate, and the marking is to make it possible to

recognize the leading and tail end of the chain. In addition to the above required marking, the first and last common link of each individual charge used in the continuous length is to be adequately and traceably marked. The marking is to be permanent and legible throughout the expected lifetime of the chain.

10.3.10.3 The chain is to be marked on the studs as follows:

(1) chain grade;

(2) certificate number;

(3) CCS stamp.

10.3.10.4 The certificate number may be exchanged against an abbreviation or equivalent. If so, this is to be stated in the certificate.

10.3.10.5 The chain certificate is to contain information on number and location of connecting common links. The certificate number and replacement link number may be exchanged against an abbreviation or equivalent. If so, this is to be stated in the certificate.

10.3.10.6 A complete Chain Inspection and Testing Report in booklet form is to be provided by the chain manufacturer for each continuous chain length. This booklet is to include all dimensional checks, test and inspection reports, NDT reports, process records, photographs as well as any non-conformity, corrective action and repair work. In addition, certificates for materials, the location and number of replacement links are to be included.

Individual certificates are to be issued for each continuous single length of chain. All accompanying documents, appendices and reports are to carry reference to the original certificate number.

The manufacturer will be responsible for storing, in a safe and retrievable manner, all documentation produced for a period of at least 10 years.

10.3.11 Testing and inspection of accessories

10.3.11.1 This section applies to but is not limited to testing and inspection of finished accessories such as detachable connecting links (shackles), detachable connecting plates (triplates), end shackles, swivels and swivel shackles.

10.3.11.2 All accessories are to be subjected to proof load tests, sample break load tests and sample mechanical tests after final heat treatment in the presence of a Surveyor. Where the manufacturer has a procedure to record proof loads and the Surveyor is satisfied with the adequacy of the recording system, he need not witness all proof load tests. The Surveyor is to satisfy himself that the testing machines are calibrated and maintained in a satisfactory condition. Prior to testing and inspection the chain accessories are to be free from scale, paint or other coating.

10.3.11.3 For accessory production a Manufacturing Procedure Specification (MPS) is to be submitted to CCS that details all critical aspects of accessory production, casting, forging, heat treating (including arrangement and spacing of components in the heat treatment furnaces, quenching), mechanical testing, proof and break loading and NDE.

10.3.11.4 All accessories are to be subjected to the proof load specified for the corresponding stud link chain.

10.3.11.5 At least one accessory out of every batch or every 25 accessories, whichever is less, is to be tested to the break load prescribed for the grade and size of chain for which they are intended. A batch is defined as accessories that originate from the same heat treatment charge and the same heat of steel.

For individually produced or individually heat treated accessories or accessories produced in small batches (less than 5), alternative equivalent testing is to be approved by CCS and the following additional conditions may apply.

(a) Alternative testing is described in a written procedure and manufacturing procedure specification (MPS).

(b) A finite element analysis is provided at the break load and demonstrates that the accessory has a safety margin over and above the break load of the chain.

(c) Strain age testing (as per approved procedure by CCS) is carried out on the material grade produced to the same parameters at the time of qualification.

(d) If an accessory is of a large size that will make heat treating in batches unfeasible or has a unique design, strain gauges are to be applied during the proof and break load tests during initial qualification and during production. The strain gauge results from production are to be comparable with the results from qualification.

The accessories which have been subjected to the break load test are to be destroyed and not used as part of an outfit.

10.3.11.6 At least one accessory (of the same type, size and nominal strength) out of 25 is to be checked

for dimensions after proof load testing. The manufacturer is to provide a statement indicating compliance with the purchaser's requirements.

10.3.11.7 The following tolerances are applicable to accessories:

nominal diameter: 0% to +5%;

other dimensions: ±2.5%.

These tolerances do not apply to machined surfaces.

10.3.11.8 Mechanical tests are to be taken from proof loaded full size accessories that have been heat treated with the production accessories they represent. At least one accessory out of every batch or every 25 accessories, whichever is less, is to be tested. Hardness tests are to be carried out on finished accessories. The frequency and locations are to be agreed with CCS. The recorded values are for information only and used as an additional check to verify that the heat treatment process has been stable during the accessory production.

The use of separate representative coupons is not permitted except for accessories with complex geometries.

10.3.11.9 Mechanical tests of accessories are to satisfy the following requirements:

(1) Forged shackle bodies and forged Kenter shackles are to have a set of three impact test specimens and a tensile test specimen taken from the crown of the shackle as shown in Figure 10.3.8.8(2), with the impact specimens on the outside radius. Tensile test specimens on smaller diameter shackles can be taken from the straight part of the shackle, where the geometry does not permit a tensile specimen from the crown. The tensile properties and impact values are to meet the requirements of Table 10.3.8.8(4).

(2) The locations of mechanical tests of cast shackles and cast Kenter shackles can be taken from the straight part of the accessory. The tensile properties and impact values are to meet the requirements of Table 10.3.8.8(4) in the locations specified in Figure 10.3.8.8(2).

(3) The locations of mechanical tests of other accessories with complex geometries are to be agreed with CCS. For non-circular sections, 1/4t (thickness) from the surface is considered appropriate. Rolled plates are to be tested to the Standard to which they are produced.

10.3.11.10 For individually produced (heat treated) accessories or accessories produced in small batches (less than 5), alternative testing can be proposed. Each proposal for alternative testing is to be detailed by the manufacturer in a written procedure and submitted to CCS for approval, and the following additional conditions may apply:

(1) If separately forged or cast coupons are used, they are to have a cross-section and, for forged coupon, a reduction ratio similar to that of the accessories represented, and are to be heat treated in the same furnace and quenched in the same tank at the same time, as the actual forgings or castings. Thermocouples are to be attached to the coupon and to the accessories.

(2) If separately forged or cast coupons are agreed, it is to be verified by procedure test that coupon properties are representative of accessory properties.

10.3.11.11 Mechanical tests of pins are to be taken as per right part of Figure 10.3.8.8(2) from the mid length of a sacrificial pin of the same diameter as the final pin. For oval pins, the diameter taken is to represent the smaller dimension. Mechanical tests may be taken from an extended pin of the same diameter as the final pin that incorporates a test prolongation and a heat treatment buffer prolongation, where equivalence with mid length test values have been established. The length of the buffer is to be at least equal to 1 pin diameter dimension which is removed after the heat treatment cycle is finished. The test coupon can then be removed from the pin. The buffer and test are to come from the same end of the pin as per Figure 10.3.11.10.

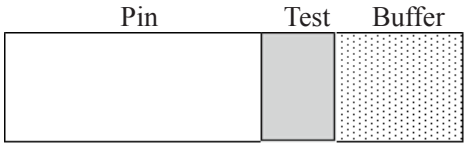


Figure 10.3.11.10 Buffer and test piece location

10.3.11.12 After proof load testing, non-destructive testing is to be carried out according to the following requirements:

(1) All chain accessories are to be subjected to a close visual examination. Special attention is to be paid to machined surfaces and high stress regions. Prior to inspection, chain accessories are to have a suitably prepared surface as per the applied NDE testing standard. All non-machined surfaces are to be sand or shot blasted to permit a thorough examination. Where applicable, accessories are to be dismantled for inspection of internal surfaces. All accessories are to be checked by magnetic particles or dye penetrant. UT of

accessories may be required by CCS.
(2) Non-destructive testing is to be carried out according to approved standards (such as those indicated in Table 10.3.11.11). Testing procedures and relevant acceptance criteria are to be submitted to CCS for review.

Applicable NDE Standards of Mooring Chain Accessories Table 10.3.11.11

Accessory materials	Testing method	Applicable standards
Forgings	Magnetic particle testing	ISO 4986, IACS Rec.69, EN 10228-1, ASTM A275
	Ultrasonic testing	ISO 13588, EN 10228-3, ASTM A388
Castings	Magnetic particle testing	ASTM E709, wet continuous magnetization technique
	Ultrasonic testing	ISO 13588, ASTM A609

(3) All surfaces are to be magnetic particle tested (MT). Testing is to be performed in accordance with standards referenced using the fluorescent technique. As a minimum surfaces are to be free from:
relevant linear indications exceeding 1.6 mm in transverse direction;
relevant linear indications exceeding 3.2 mm in longitudinal direction;
relevant non-linear indications exceeding 4.8 mm.
(4) When required by CCS, ultrasonic testing is to be carried out on 100% of cast or forged accessories. The acceptance/rejection criteria established for the design is to be met.
(5) The manufacturer is to provide a statement that non-destructive testing has been carried out with satisfactory results. This statement is to include a brief reference to the techniques and to the operator's qualification.
10.3.11.13 Weld repairs of finished accessories are not permitted.
10.3.11.14 In the event of a failure of any test, the entire batch represented is to be rejected unless the cause of failure has been determined and it can be demonstrated to the Surveyor's satisfaction that the condition causing the failure is not present in any of the remaining accessories.

10.3.12 Marking, certification and documentation of accessories

10.3.12.1 Each accessory satisfactorily inspected by CCS is to be marked with chain grade.
10.3.12.2 The Certificate number may be exchanged against an abbreviation or equivalent. If so, this is to be stated in the certificate.
10.3.12.3 A complete Inspection and Testing Report in booklet form is to be provided by the manufacturer for each order. This booklet is to include all dimensional checks, test and inspection reports, NDT reports, process records and example photographs of components positioned in furnaces, as well as any nonconformity, corrective action and repair work.
10.3.12.4 Each type of accessory is to be covered by separate certificates. All accompanying documents, appendices and reports are to carry reference to the original certificate number.
10.3.12.5 The manufacturer will be responsible for storing, in a safe and retrievable manner, all documentation produced for a period of at least 10 years.

Section 4 STEEL WIRE ROPES

10.4.1 Application

10.4.1.1 The requirements of this Section apply to steel wire ropes intended to be used for anchoring, mooring and towing.
10.4.1.2 The manufacture of steel wire ropes used for lifting appliances and cargo securing may be referred to this Section.

10.4.2 General requirements

10.4.2.1 Steel wire ropes are to be manufactured at works approved by CCS.
10.4.2.2 The construction of wire ropes used as mooring lines, towlines and stream wires is generally to comply with the requirements given in Table 10.4.2.2, or other relevant recognized standards, or alternative types of wire ropes will be specially considered on the basis of an equivalent breaking load and the suitability of the construction for the purpose intended.
10.4.2.3 Boat falls are to be of rotation-resistant and corrosion-resistant steel wire rope.

Construction of Steel Wire Ropes **Table 10.4.2.2**

Purpose	Construction of rope			Construction of strands					
	Strands	Wires	Core	Core	Core wire	Inner layer	Middle layer	Outer layer	Designation
Stream wires Towlines Mooring lines	6	24	Fibre	Fibre	0	–	9	15	(0 + 9 + 15)
	6	37	Fibre	Wire	1	6	12	18	(1 + 6 + 12 + 18)
	6	26	Fibre	Wire	1	5	(5+5)	10	$(1 + 5 + \frac{5}{5} + 10)$
	6	31	Fibre	Wire	1	6	(6+6)	12	$(1 + 6 + \frac{6}{6} + 10)$
	6	36	Fibre	Wire	1	7	(7+7)	14	$(1 + 7 + \frac{7}{7} + 10)$
	6	41	Fibre	Wire	1	8	(8+8)	16	$(1 + 8 + \frac{8}{8} + 10)$
	6	30	Fibre	Fibre	0	–	12	18	(0 + 12 + 18)
Towlines and mooring lines used in association with mooring winches	6	31	Wire	Wire	1	6	(6+6)	12	$(1 + 6 + \frac{6}{6} + 12)$
	6	36	Wire core	Wire	1	7	(7+7)	14	$(1 + 7 + \frac{7}{7} + 14)$
	6	41	Wire core	Wire	1	8	(8+8)	16	$(1 + 8 + \frac{8}{8} + 16)$

10.4.3 Steel wire

10.4.3.1 The wire used in the manufacture of the rope is to be made from high quality structural carbon steel, the content of sulphur and phosphorus of which is not to exceed 0.035% respectively and that of other elements is to comply with the relevant standards acceptable to CCS. The wire drawn from steel is to have a round cross section, and is to be of homogeneous quality, uniform strength and free from surface defects likely to impair the performance of the rope, such as cracks, corrugations, burrs, rust and scratches.

10.4.3.2 According to the specified minimum tensile strength, steel wires are divided into six grades as 1,420 N/mm^2, 1,570 N/mm^2, 1,670 N/mm^2, 1,770 N/mm^2, 1,870 N/mm^2 and 1,960 N/ mm^2. Unless otherwise specified in the contract, the actual tensile strength of steel wires is not to exceed 1.2 times the specified minimum tensile strength.

10.4.3.3 Unless otherwise specified in the contract, steel wire ropes are in general to be manufactured from fully galvanized wires. The wire is to be galvanized by a hot dip or an electrolytic process to give a smooth, continuous and secure coating which may be any of the following grades:

grade 1: heavy coating, drawn after galvanizing;
grade 2: heavy coating, finally galvanized;
grade 3: light coating, drawn after galvanizing.

10.4.3.4 Individual steel wires are to have no joint throughout their length , so far as practicable. If joints are unavoidable for the manufacturing procedure, they are to be far apart from each other as is practicable. In any strand, only one steel wire joint is allowed in each 10 m length.

10.4.4 Test samples and tests

10.4.4.1 Wire samples are to be taken from a suitable length of the completed rope. After unstranding and straightening, visual inspection is to be carried out. Steel wires are to be smooth and even, and free from defects which would impair their use, such as cracks, burrs, scratches and rust. The coating of galvanized steel wires is to be continuous and uniform.

10.4.4.2 Six wire samples of each size/diameter (except for the centre wire of a strand and the steel core) are to be taken at random from the above-mentioned unstranded rope for torsion tests and wrap tests so as to examine the adhesion of coating. Alternatively, visual inspection and torsion test may be required for steel wires before the rope is stranded, as appropriate. Additionally, test to determine the mass of the zinc coating is to be carried out.

10.4.4.3 Torsion test is to comply with the following requirements:

(1) The length of the sample is to be such as to allow a length between the grips of 100 times the wire diameter or 300 mm, whichever is less.

(2) The wire is to be twisted by causing one or both of the vices to be revolved. A tensile load not exceeding 2% of the nominal breaking load of the wire may be applied to keep the wire stretched.

(3) The speed of the twisting is to comply with the recognized standards and the number of complete twists is to meet the requirements of Table 10.4.4.3(3).

Minimum Number of Twists of Torsion Test **Table 10.4.4.3(3)**

Diameter *d* of galvanized wire (mm)	Minimum number of twists					
	Grade 2 zinc coating		Grade 1 or 3 zinc coating			
	1570	1670/1770	1420	1570	1670/1770	1870/1960
< 1.3	19	17	31	29	27	23
1.3 ≤ *d* < 2.3	17	16	28	26	24	21
2.3 ≤ *d* < 3.0	14	12	26	24	22	19
3.0 ≤ *d* < 3.5	11	10	24	22	20	16
3.5 ≤ *d* < 4.0	9	8	22	20	18	13

10.4.4.4 Zinc coating test: The thickness of zinc coating is to be determined by the mass per unit area, and the minimum mass of unit area of zinc coating is not to be less than that given in Table 10.4.4.4. Determination of the mass of zinc coating is to be in accordance with a recognized standard. Generally, wires of various diameters are to be removed from the steel rope and tested individually. The zinc coating is to be removed by dipping the wire in a chemical solution. The loss of mass of the uncoated wire is measured and thus the mass of the zinc coating is determined. The manufacturer is to demonstrate that the zinc coating is continuous, uniform and suitable to the intended purpose.

Mass of Zinc Coating of Steel Wire Ropes **Table 10.4.4.4**

Diameter *d* of galvanized wire (mm)	Minimum mass of zinc coating per unit area (g/m^2)		
	Grade 1	Grade 2	Grade 3
0.20 ≤ *d* < 0.25	–	30	20
0.25 ≤ *d* < 0.33	–	45	30
0.33 ≤ *d* < 0.40	–	60	30
0.40 ≤ *d* < 0.50	60	75	40
0.50 ≤ *d* < 0.60	70	90	50
0.60 ≤ *d* < 0.80	85	110	60
0.80 ≤ *d* < 1.00	95	130	70
1.00 ≤ *d* < 1.20	110	150	80
1.20 ≤ *d* < 1.50	120	165	90
1.50 ≤ *d* < 1.90	130	180	100
1.90 ≤ *d* < 2.50	150	205	110
2.50 ≤ *d* < 3.20	165	230	125
3.20 ≤ *d* < 4.00	190	250	135

10.4.4.5 Wrapping test: The adhesion of the coating is to be tested by wrapping the wire round a cylindrical mandrel for 10 complete turns. After wrapping on the appropriate mandrel, the zinc coating is to have neither flaked nor cracked. At least 5 wires of each size are to be tested. The ratio between the diameter of the mandrel and that of the wire is to comply with the requirements given in Table 10.4.4.5.

Specifications for Wrapping Test **Table 10.4.4.5**

Coating	Diameter of coated wire (mm)	Ratio of mandrel to wire diameter
Grade 1 or 2	< 1.5	1 : 4
	≥ 1.5	1 : 6
Grade 3	< 1.5	1 : 2
	≥ 1.5	1 : 3

10.4.4.6 Breaking test of completed ropes is to be carried out in accordance with the following requirements:

(1) For ropes having a manufactured length less than 10,000 m, a section of test sample is to be cut from the end of each rope for breaking tests. The sample is to be of a sufficient length to provide a clear test length of at least 30 times the rope diameter between the grips. Where the manufactured length is more than 10,000 m, a second test sample is to be taken from the rope and tested.

(2) During testing, the application of breaking load on the testing machine is to be well controlled. Not more than four-fifths of the nominal breaking load is to be applied quickly, and thereafter the load is to be applied slowly and steadily without any impact load on the rope. Tests in which a breakage occurs adjacent to the grips are to be rejected, and further samples may be taken for retests. If the applied breaking load is less than the minimum value given in the standards acceptable to CCS, the result will be considered to be unacceptable.

(3) If facilities are not available for making a breaking test on completed ropes, the summation of actual test results of individual wires may be accepted. In such cases, the breaking strength of a single wire is to be multiplied by the total number of wires and the product so obtained is to be divided by a relevant conversion factor to determine the breaking load of the rope. The relevant conversion factor is to be determined according to a recognized standard.

10.4.5 Marking

10.4.5.1 All completed ropes which have been accepted are to be identified with attached labels detailing the rope structure, strength, length and manufacturer's name, and each rope is to be additionally identified with CCS stamp.

PART TWO NON-METALLIC MATERIALS

CHAPTER 1 GENERAL

Section 1 GENERAL PROVISIONS

1.1.1 Application

1.1.1.1 The requirements of this PART apply to the manufacture, testing and inspection of non-metallic materials or products used for ships and offshore installations.

1.1.1.2 Where it is proposed to use non-metallic materials or products (including newly developed materials and products) other than those specified in this PART, details of the chemical composition, mechanical properties and other special properties may be tested or inspected in accordance with the relevant standards acceptable to CCS.

1.1.1.3 All non-metallic materials or products which have been approved or satisfactorily inspected by CCS are to be marked with CCS stamp. Builders of ships or offshore installations are to preferably order those non-metallic materials or products approved and inspected by CCS. Non-metallic materials or products without the CCS stamp are not to be put into use on board ships unless prior approval of CCS is obtained.

1.1.2 Approval and inspection

1.1.2.1 Manufacturers making marine non-metallic materials or products are to apply for type approval or works approval in accordance with the procedures specified by CCS.

1.1.2.2 For materials and marine products such as components and equipment intended to be used for ships or offshore installations classed with CCS, manufacturers are in general to submit plans and documents required to be approved, as specified in the Rules, in triplicate to the plan approval unit designated by CCS, prior to manufacturing. When the submitted plans and documents are approved, one set of them is to be kept in the plan approval unit, one delivered to the survey unit carrying out the inspection, and one returned to the manufacturer. Where the plan approval location and the inspection location are the same one, plans and documents are to be submitted in duplicate only.

In special cases and subject to agreement of CCS, the manufacturer may submit plans and documents directly to the survey unit carrying out the inspection for review. Where plans of components and fittings are included in the plans of ships and have been approved, re-submission of such plans is not necessary.

1.1.2.3 Inspections after approval may be carried out in different ways according to specific nonmetallic materials or products and their production process control.

Section 2 TEST AND INSPECTION

1.2.1 General requirements

1.2.1.1 Manufacturers of marine non-metallic materials or products are to be provided with necessary manufacturing and testing facilities, good working conditions, qualified personnel and a strict inspection system so as to ensure the quality of products.

1.2.1.2 Manufacturers are to provide complete certificates of conformity for received and delivered materials or products and necessary documents reflecting the production process control to enable the Surveyor to confirm that the materials or products are made and their quality is controlled in accordance with the manufacturing procedure specification approved by CCS.

1.2.2 Test and re-test

1.2.2.1 Unless otherwise specified in this PART, the dimensions, orientation, preparation and individually required chemical composition, thermal properties, physical and chemical properties, mechanical properties and other special properties of test specimens may be determined in accordance with the standards given by CCS or other equivalent standards, but the results of each test is to be in compliance with the relevant requirements of this PART.

1.2.2.2 Where an individual test result in a group is unsatisfactory, two additional specimens are to be taken from the same piece (or sample) or a new piece (or sample) prepared from the same batch of material with the same procedure for each unsatisfactory test item. The results of both re-tests are to be satisfactory.

1.2.2.3 If any result of re-tests is still unsatisfactory, tests for all items may be carried out again on a new test sample, provided prior agreement of the Surveyor is obtained. All the results of these tests are to be satisfactory.

1.2.2.4 All test results are to be recorded in the test report.

1.2.3 Marking

1.2.3.1 Accepted marine non-metallic materials or products are, in addition to CCS stamp, to be furnished with the Certificate of Marine Products issued by CCS, or alternatively, with the manufacturer's quality certificate endorsed by the Surveyor (or his deputy).

CHAPTER 2 PLASTICS MATERIALS

Section 1 GENERAL PROVISIONS

2.1.1 Application

2.1.1.1 The requirements of this Chapter apply to those plastics materials or products thereof which are to be used in ships and offshore installations intended for classification, or explicitly required to be certified by CCS for their design and manufacture.

2.1.1.2 The plastics materials to be used in ships and offshore installations, including thermoplastic polymers, thermosetting resins, reinforcements and associated materials are to be manufactured, tested and inspected in accordance with this Chapter.

2.1.1.3 The plastics materials to be used in plastics products such as hull structures, composite cases or ducts are also to comply with the requirements of Chapter 3 or 4 respectively.

2.1.2 Definitions and terms

2.1.2.1 *Plastics materials* are regarded as organic macromolecular substances which may be thermoplastic or thermosetting and which, in their finished state, may contain reinforcements or additives.

2.1.2.2 *Additives* are substances that are added to improve or adjust certain properties of polymers (or resins), including fillers, thixotropes, thickeners, pigments, etc.

2.1.2.3 *Molding compounds* are pre-mixed or pre-impregnated materials including thermoplastic and thermosetting molding compounds, which are formed by molding. Thermoplastic polymers, used as the matrix of thermoplastic molding compounds, are softened by heating till they are melted, and then cooled down to hardening. Thermosetting resins, used as the matrix of thermosetting molding compounds, are cured by heating or other means (e.g. radiation or catalyst) to a condition in which they are neither soluble nor fusible.

2.1.2.4 A *pre-mixed material* is a mixture of resin, reinforcement, filler (if any) etc., prepared prior to molding of plastics products.

2.1.2.5 A *pre-impregnated material* is an intermediate material dried out or pre-polymerized from fibers or their products (rovings, mats, fabrics) impregnated with resin and used in the manufacture of reinforced plastics products. Such materials are capable of being molded or laminated in a heat pressing condition.

2.1.2.6 *Granulated fibers* are fixed-length granular molding compounds prepared prior to molding of fiber-reinforced thermoplastic products. There are short and long granulated fibers. Short granulated fibers are made by an extruder whereby polymers together with fibers of a certain length are plasticized, extruded and granulated. Long granulated fibers are made by passing continuous fiber bundles through the horned head of an extruder and thereby coating them evenly with molten polymers and when cooled down, they are cut by a pelletizer into granules with a certain length, capable of being molded, extruded or injected.

2.1.2.7 *Sheet molding compounds* are intermediate lamellar products of generally 1 to 25 mm in thickness, made by thoroughly mixing resins, chopped or unchopped reinforced fibers and fine granular fillers (occasionally without filler), capable of being molded or laminated in a heat pressing condition.

2.1.2.8 *Blocky molding compounds* are semi-finished blocky products made by thoroughly mixing resins, chopped reinforced fibers and specific fillers (or without filler), capable of being molded or injected in a heat pressing condition.

2.1.3 General requirements

2.1.3.1 The plastics materials to be delivered as products (e.g. machinery chock castings) are to be manufactured at works approved by CCS.

2.1.3.2 Plastics products are to be manufactured at CCS-approved works with approved or inspected raw materials and procedures.

2.1.3.3 The quality and specifications of the raw materials (e.g. fillers, additives) not required to be manufactured at approved works are to be acceptable according to the relevant requirements in this Chapter.

2.1.3.4 For the plastics products intended for classification, it is the responsibility of the manufacturer to define necessary specifications (including various inspection requirements) to the manufacturer of materials for ensuring that the raw materials to be used comply with classification requirements and product specifications.

2.1.3.5 The manufacturer of plastics products is to have evidence showing that the equipment and capability necessary for production and testing are available and managed by qualified personnel. Required test items are to be completed in the presence of the Surveyor, and test results are to comply with CCS rules or technical standards acceptable to CCS.
2.1.3.6 In the event of any material proving unsatisfactory during subsequent working, machining or fabricating, such material is to be rejected, notwithstanding any previous certification by CCS.

2.1.4 Identification
2.1.4.1 All materials which have been inspected with satisfactory results are to be clearly marked with CCS stamp in at least one place of their external packaging or the material itself.
2.1.4.2 The manufacturer of approved materials is to identify each batch (or external packaging) with a unique number (e.g. batch no.).
2.1.4.3 The manufacturer of plastics products is to adopt a system of identification which will enable all finished products to be traced to the original batches of base materials.
2.1.4.4 Manufacturers of materials and products are to provide a certificate of quality endorsed by the Surveyor (or his deputy), with appropriate particulars stated thereon.

Section 2 RAW MATERIALS

2.2.1 Thermoplastic polymers
2.2.1.1 The manufacturer is to provide data to the following items, as applicable, for each thermoplastic polymer used:
(1) appearance;
(2) melting point;
(3) melt flow index;
(4) density;
(5) bulk density or specific volume;
(6) water content and volatile content;
(7) in-process shrinkage;
(8) filler/reinforcement content (if any).
2.2.1.2 The manufacturer is to adopt suitable molding or extruding means to prepare test samples in accordance with the procedures and specifications recommended by the polymer manufacturer.
2.2.1.3 The following tests, as applicable, are to be carried out on these samples:
(1) tensile stress at yield or break;
(2) modulus of elasticity in tension at yield or break;
(3) elongation at break;
(4) compressive strength;
(5) flexural strength;
(6) temperature of deflection under load (Martin heat endurance, Vicat softening point or temperature of deflection);
(7) density;
(8) water absorption (if necessary).

2.2.2 Thermosetting resins
2.2.2.1 The usual thermosetting resins are mainly unsaturated polymer resins (orthophthalic, isophthalic), vinyl ester resins and epoxy resins.
2.2.2.2 The thixotropes, fillers, pigments and other inorganic substances, which are to be added to resins in advance depending on the nature of products or their processing, are to be properly described.
2.2.2.3 The manufacturer is to provide appropriate data for each thermosetting resin used.
(1) Unsaturated polymer resins (orthophthalic, isophthalic) and vinyl esters:
① appearance;
② density or relative density;
③ viscosity;
④ gelation time;
⑤ solid or volatile content;
⑥ acid value;

⑦ thermal stability;
⑧ content of inorganic substances (if any, including thixotropes, fillers, pigments etc.).

(2) Epoxy resin:
① appearance;
② density or relative density;
③ viscosity;
④ gelation time;
⑤ volatile content;
⑥ epoxide content;
⑦ organochlorine number, inorganic chlorine number;
⑧ content of inorganic substances (if any).

2.2.2.4 For each thermosetting resin to be used, cast samples are to be prepared by the manufacturer in accordance with the resin manufacturer's recommendations. The type of curing agent (or catalyst/promoter) used, the ratio of curing agent to resin and the curing system (temperature and time of cure/postcure) are to be consistent with the intended use and recorded.

2.2.2.5 The following are to be determined using these samples, the results of which are to comply with the requirements of Table 2.2.2.5. For items not mentioned in the table, the results are to comply with limit values specified in the standards or by the manufacturer:

(1) density or relative density;
(2) volume shrinkage after cure;
(3) Barcol hardness;
(4) tensile strength;
(5) elongation at break;
(6) water absorption (if required);
(7) temperature of deflection.

Properties for Resin Castings Used for Lay-up **Table 2.2.2.5**

Items	Standard	Unsaturated polyester/vinyl ester resin	Gel coat/topcoat resin/ epoxy resins
Tensile strength (N/mm^2)	ISO527-2	≥45	≥55
Elongation at break (%)	ISO527-2	≥1.5	≥2.5
Flexural modulus of elasticity (N/mm^2)	ISO178	≥2700	≥2700
Flexural strength (N/mm^2)	ISO178	≥80	≥100
Heat deflection temperature (℃)	ISO75-2	≥75	≥75
Barcol hardness	ASTM D2583	≥35	≥35
Water absorption (mg)	ISO62	≤ 80（hull） ≤100（non hull）	≤ 70
Note 1: Test samples are to be solidified for 24 h under 50℃. Note 2: The size of test sample for water absorption is 50 mm × 50 mm × 4 mm, exposure time 672 h at 23℃±2℃.			

2.2.2.6 Resins are to be reinforced by glass-fibre chopped strand mat (the content of glass fibre not exceeding 30%), and be fabricated into laminates according to the curing process recommended by the manufacturer. The thickness of laminates is not to be less than 4 mm, the minimum mechanical properties of which are as follows:

Property index of laminate **Table 2.2.2.6**

Items	Standard	Criteria
Tensile strength (N/mm^2)	ISO 527-4	≥80
Tensile modulus (N/mm^2)	ISO 527-4	≥6350
Flexural strength (N/mm^2)	ISO 14125	≥135
Flexural modulus (N/mm^2)	ISO 14125	≥5200
Glass fibre content (%, mass)	ISO 1172	≤30

2.2.3 Reinforcements

2.2.3.1 Reinforcements are in general fibrous substances or fabrics, and are to be free from imperfections or defects such as impurities, contamination and rot. They are to be well compatible with the polymers and resins which are to be reinforced and be stored strictly according to the manufacturer's recommendations in dry, ventilated and dust-free places with a relatively stable temperature.

2.2.3.2 The manufacturer is to provide data to the following items, as applicable, for each type of

reinforcements used:
(1) reinforcement type;
(2) fibre type for each direction;
(3) linear density of fibres or yarns (tex value);
(4) fibre finish and/or treatment;
(5) density of the fibre material;
(6) tensile strength at break and elongation at break of fibers, rovings or fabrics;
(7) content of combustible matters;
(8) moisture content;
(9) type and content of wetting agent and/or treating agent;
(10) weave type;
(11) weight per unit area of fabric or felt;
(12) width, thickness of fabric or felt;
(13) compatibility (suitable for which polymer or resin);
(14) other necessary items.

2.2.3.3 In the case of a multi-ply reinforcement comprising felt, cloth and fabric, detailed data of its structural composition are to be listed: e.g. density, type, repeat frequency and orientation of yarns/threads.

2.2.3.4 Tests of the mechanical properties are to be made, as necessary, on laminate samples containing the reinforcement (rovings may be rod-shaped in accordance with a relevant standard). The samples are to be prepared as follows, using the curing system recommended by the manufacturer:
(1) An approved resin (polymer) of suitable type is to be used.
(2) A minimum of three layers of the reinforcement is to be laid with parallel ply to give a laminate not less than 4 mm thick.
(3) The weights of resin and reinforcement used are to be recorded together with the measured thickness of the laminate, including the measured weight per unit area of the reinforcement used.
(4) For glass reinforcements, the nominal glass fiber content is as follows:

Nominal Fiber Content by Mass **Table 2.2.3.4(4)**

	Open mould (%)	Vacuum bag (%)
Chopped strand mat (CSM)	30	36
Roving and woven roving (WR)	48	58
Roving mat combination (Mat + Cloth)	46-18*R*	56-22*R*
Multidirectional fabric (3-directional and 4 directional)	50	60
Unidirectional fabric	55	66
Note: *R* = total weight of mat in roving mat combination/(total weight of mat and cloth in roving mat combination)		

The total nominal glass fiber content G of a laminate can be calculated using the following formula:

$$G = \frac{W}{\frac{W_1}{G_1} + \frac{W_2}{G_2} + \cdots + \frac{W_n}{G_n}}$$

where: W_1, W_2,…W_n are respectively the total weight of various reinforcements per unit area of a laminate, in g;
$W = W_1 + W_2 + \ldots + W_n$ are total weight of reinforcements per unit area of a laminate, in g;
G_1, G_2,…G_n are respectively the nominal glass fiber content of various reinforcements per unit area of a laminate, to be obtained from Table 2.2.3.4(4).

(5) For reinforcement types other than glass, a fibre volume fraction recommended by the manufacturer may be used.

2.2.3.5 Glass fiber rovings intended for filament winding may be regarded as unidirectional reinforcements and in this case, tests with glass fibre content of 70±5% by weight are recommended.

2.2.3.6 The properties of laminate samples prepared according to 2.2.3.4 are to be tested for the following items, as applicable:
(1) resin or fiber content;
(2) density;
(3) water absorption;
(4) hardness (Shore hardness, Rockwell hardness, Brinell hardness for thermoplactics, or Barcol hardness for thermosetting plastics);
(5) temperature of deflection under load (Martin heat endurance, Vicat softening point or temperature of

deflection);
(6) tensile strength, modulus, elongation;
(7) compressive strength, modulus;
(8) flexural strength, modulus;
(9) interlaminar shear strength (for laminates);
(10) impact strength.
2.2.3.7 For approval of glass fiber woven roving, felt and cloth, the flexural strength is to be tested in wet condition, with test samples being boiled in distilled water for 2 h prior to the test.
2.2.3.8 Test specimens are to be taken to the orientation of the fiber reinforcement in the laminate. In general, gun roving and chopped strand mat may be taken in any direction, unidirectional material at 0° direction, woven roving and woven cloth at 0° and 90°, multi-ply combined reinforcement at 0°, 45°, 90° or -45° as necessary.

2.2.4 Reinforced thermoplastic polymers
2.2.4.1 Thermoplastic polymers intended for use with reinforcements are to be tested in accordance with paragraph 2.2.1.3 of this Section.
2.2.4.2 Where granulated fibers delivered by a supplier are to be used, they need to be tested in accordance with (3), (6), (7) and (8) of 2.2.1.1 of this Section.
2.2.4.3 Where thermoplastic polymers and reinforcements are used, or where reinforced granules are used to make reinforced thermoplastic polymers, laminate samples are to be prepared in accordance with a manufacturing specification.
2.2.4.4 Laminate specimens are to be taken from the laminate sample and tested in accordance with 2.2.3.6 of this Section, and testing is to be confined to one direction only.

2.2.5 Reinforced thermosetting resins
2.2.5.1 Thermosetting resins intended for use with reinforcements are to be tested in accordance with paragraph 2.2.2.5 of this Section.
2.2.5.2 Where thermosetting molding compounds delivered by a supplier are to be used, including blocky, sheet molding compounds and pre-impregnated materials, these pre-mixed materials are to be at least tested technologically for their flow, in-process shrinkage, compression ratio, water and volatile content, resin content etc., and laminates are to be prepared in accordance with a manufacturing specification.
2.2.5.3 The laminate is to be tested in accordance with the relevant requirements of 2.2.3.6 of this Section in one fibre direction only.

2.2.6 Core materials
2.2.6.1 The core of laminates are generally used in the construction of fibre-reinforced plastic crafts, such as rigid foams, balsa, plywood or pine. The manufacturer is generally to provide data to the following items:
(1) type of material;
(2) density;
(3) description (block, scrim mounted, grooved);
(4) thickness;
(5) sheet/block dimensions;
(6) surface treatment (if any);
(7) tensile strength and modulus;
(8) shear strength and modulus;
(9) compressive strength and modulus;
(10) moisture content (wood);
(11) water absorption (rigid foams);
(12) other necessary descriptions (e.g. service temperature).
2.2.6.2 Rigid foam core materials are to be approved and are to comply with the following requirements:
(1) being of closed-cell types and impervious to water, fuel and oils;
(2) being compatible with the resin system;
(3) having good ageing stability;
(4) having good strength retention at 60℃;
(5) if core materials are manufactured as small sheets to be adhered to open weave backing material, then the backing and adhesive are to be compatible with the laminating resin and soluble for easy moulding;

(6) where necessary, foam core materials are to be conditioned in accordance with the manufacturer's recommendations. Conditioning at an elevated temperature in excess of that which may be experienced in service may be necessary to ensure the release of entrapped residual gaseous blowing agents from the cells of the foam core.

2.2.6.3 The test data to the following items, as applicable, are to be submitted for each type of foam core materials:

(1) density;
(2) water absorption;
(3) compressive strength;
(4) compressive modulus of elasticity;
(5) tensile strength;
(6) tensile modulus of elasticity;
(7) shear strength;
(8) shear modulus of elasticity;
(9) maximum recommended service temperature;
(10) linear shrinkage (dimensional stability).

2.2.6.4 If PVC and SAN (Styrene acrylonitrile copolymer) foams are used as the core materials of sandwich panel, their density is not to be less than 60 kg/m^3, and their basic mechanical properties at ambient temperature are not to be less than those as required in Table 2.2.6.4. For other foams, this table may be used as a reference. For items not mentioned in the table, the results are to comply with limit values specified in the standards or by the manufacturer.

Basic Mechanical Properties of Rigid Foam Core Materials **Table 2.2.6.4**

Tensile strength N/mm^2	Compressive strength N/mm^2	Compressive modulus N/mm^2	Shear strength N/mm^2	Shear modulus N/mm^2	Water absorption %	Water resistance %	Heat resistance %
ISO 1926	ISO 844	ISO 844	ISO 1922	ISO 1922	ISO 2896	ISO 2896	ISO 844
≥0.6	≥0.6	≥40	≥0.4	≥9	≤1.5	≥70	≥50

Notes:
1. The test speed (mm/min) of tensile and compressive tests is 10% of the initial thickness of test samples, in mm.
2. The dimensions of samples for tensile and compressive tests are 50 mm × 50 mm × thickness of product, in mm. The test direction is in the direction of thickness.
3. Both of the compressive sides of the compressive specimen are to be sealed by fibre reinforced materials with a fibre content in the range of (50±5)% (chopped strand mat + BIAXIAL is recommended form of reinforcement). The seal layer of each compressive side is not to be greater than 10% of the thickness of the foam.
4. Water absorption test measures the volume change rate after the samples are soaked at 40℃ for 1 week.
5. Water resistance test requires that after the samples are soaked in water at 23℃ for 4 weeks, the tensile and compressive strength is not to be less than 70% of the test results before soaking at ambient temperature.
6. Heat resistance test requires that the test results of compressive strength and modulus at 45℃ are not to be less than 50% of the test results at ambient temperature.

2.2.6.5 Manufacturers are required to provide a full application procedure, instructions on construction and precautions and other necessary technical documents for ensuring proper use of the product.

2.2.6.6 The compressive strength and the compressive modulus of elasticity are to be determined at a minimum of five points over the temperature range ambient to maximum recommended service or 70℃, whichever is the greater.

2.2.6.7 Balsa wood core materials are to be approved and are to comply with the following requirements:

(1) being end-grained;
(2) having been chemically treated against fungal and insect attack and kiln dried shortly after felling;
(3) having been sterilized;
(4) having been homogenized;
(5) having a moisture content of not greater than 12%;
(6) if core materials are manufactured as small sheets to be adhered to open weave backing material, then the backing and adhesive are to be compatible with the laminating resin and soluble for easy moulding.

2.2.6.8 Balsa is to be tested for the following items, the results of which are to comply with the requirements of Table 2.2.6.8. For items not mentioned in the table, the results are to comply with limit values specified in the standards or by the manufacturer:

(1) density;
(2) water content;

(3) tensile strength (both parallel to and perpendicular to the grain);
(4) compressive strength (both parallel to and perpendicular to the grain);
(5) compressive modulus of elasticity (both parallel to and perpendicular to the grain);
(6) shear strength (parallel to the grain).

Basic Mechanical Properties of Balsa Wood Core Materials **Table 2.2.6.8**

Density (kg/m^3)	Strength (N/mm^2)					Compressive modulus of elasticity (N/mm^2)		Shear modulus of elasticity (N/mm^2)
	Compressive		Tensile		Shear	ISO 844		ISO 1922
	ISO 844		ASTM C297		ISO 1922			
ISO 845	Direction of stress					Direction of stress		
	Parallel to grain	Perpendicular to grain	Parallel to grain	Perpendicular to grain		Parallel to grain	Perpendicular to grain	
96	5.00	0.35	9.00	0.44	1.10	2300	35.20	105
144	10.60	0.57	14.60	0.70	1.64	3900	67.80	129
176	12.80	0.68	20.50	0.80	2.00	5300	98.60	145

2.2.6.9 Where the balsa is mounted on a carrier material (e.g. scrim), any adhesive used is to be of a type compatible with the proposed resin system.
2.2.6.10 Where foams and balsa are to be used as structural core materials of a sandwich structure, sandwich panels are to be prepared and subjected to four-point bending tests (ASTM C393) to determine the apparent shear properties at two representative thicknesses (i.e. 15 mm and 30 mm). Sandwich panels are to be prepared as follows:
(1) Approved reinforcements and suitable types of approved resins are to be used.
(2) Each skin is to be identical and have a thickness not greater than one tenth of the nominal core thickness, and is to comprise chopped strand mat plus checked woven roving which are laid up alternately in the same sequence.
(3) Glass fiber content: (50±5) %.
(4) Fibers of checked woven roving are warpwise consistent with longitudinal direction of test specimens.
(5) The preparation of the panels is to reflect the core material manufacturer's recommendations for use, e.g. application of bonding paste, surface primer.
(6) Curing system is to be in accordance with the requirements for resins used.
(7) Where vacuum bagging techniques are used, these will be subject to individual consideration.
2.2.6.11 If wooden materials, such as pine and plywood, are used as core materials, these wooden materials are to be dried and primed, with the moisture content being not more than 18%.

2.2.7 Machinery chocking compounds (epoxy resin chocks)

2.2.7.1 The bicomponent thermosetting epoxy resin chocks for filling the space between the base of machinery and its foundation where the maintenance of accurate alignment is necessary are to be approved by CCS before use.
2.2.7.2 The casting manufacturer is to provide full details of construction, including design principles, operational methods and requirements, and installation procedure for information.
2.2.7.3 Cast samples of the resin chocks, for which approval is sought, are to achieve the minimum exotherm value as specified for use under practical conditions and be subject to the following approval tests.
2.2.7.4 The casting manufacturer is to determine the maximum temperature achieved by the reacting casting under conditions equivalent to those of intended use.
2.2.7.5 The following properties are to be determined on cured chock material:
(1) Barcol hardness;
(2) compressive strength and modulus of elasticity;
(3) notched Izod impact strength;
(4) curing linear shrinkage;
(5) heat deflection temperature;
(6) water absorption (immersed in artificial sea water and distilled water for 7 days);
(7) oil absorption (immersed in diesel oil and lubricating oil for 7 days);
(8) flammability.
2.2.7.6 The casting manufacturer is to have suitable test methods and data to demonstrate that the creep of epoxy resin chocks occurred at different temperatures will not affect their use under pressure for a

sufficiently long period.

2.2.7.7 The working conditions of epoxy resin chocks intended for approval are a static load usually not greater than 0.7 N/mm^2 caused by equipment weight, maximum static load (equipment weight plus bolt fastening force) not greater than 4.5 N/mm^2 on chocks and temperature not greater than 80℃. The requirements for properties of the castings are given in Table 2.2.7.7. For items not mentioned in the table, the results are to comply with limit values specified in the standards or by the manufacturer.

Requirements for Properties of Resin Chock Castings **Table 2.2.7.7**

Compressive strength N/mm^2	Compressive modulus N/mm^2	Barcol hardness	Heat deflection temperature ℃	Flammability	Water absorption① %	Oil absorption① %
ASTM D695	ASTM D695	ASTM D2583	ISO 75-2	ASTM D635	ISO 62	ISO 62
≥120	≥5000	≥35	≥80	Self-extinguishing	≤0.9	≤0.9

Note: ① The size of test sample for water and oil absorption is 50 mm × 50 mm × 4 mm.

2.2.7.8 Where the castings are to be used for installation of stern tubes and stern bushes, the measured tensile strength and modulus of elasticity in tension are to be provided, in addition to the requirements of 2.2.7.7. The tensile strength is not to be less than 34 MPa (ASTM D638).

2.2.8 Synthetic bearing materials for rudder stocks, rudder pintles, rudder axles and stern shafts

2.2.8.1 The requirements of this paragraph apply to nylon (polyamide) and modified nylon materials used in manufacturing bearings of rudder stocks, rudder pintles, rudder axles and stern shafts. For other types of bearing materials, details of the technical specification are to be submitted to CCS for examination.

2.2.8.2 Synthetic bearing materials for rudder stocks, rudder pintles, rudder axles and stern shafts are to be approved by CCS before use.

2.2.8.3 Synthetic bearing materials for rudder stocks, rudder pintles, rudder axles and stern shafts may generally be shaped into cylinders, strips or half.

2.2.8.4 The following physical properties of bearing materials are to be inspected:

(1) compressive stress and elastic modulus;

(2) tensile strength;

(3) temperature resistance (compressive stress and modulus at 50℃);

(4) volumetric swelling in ocean water (at 20℃ and 80℃ for 4 weeks/672 h);

(5) volumetric swelling in oil (at 20℃ for 4 weeks/672 h);

(6) water resistance (compressive stress and modulus after 4 weeks/672 h in ocean water);

(7) linear heat expansion coefficient (vertical to the compression side);

(8) wear rate (volume);

(9) hardness;

(10) impact strength;

(11) friction coefficient (dynamic and static friction coefficients at both 20℃ and 80℃ in dry and wet conditions of the material);

(12) limit PV value (a product of the bearing pressure intensity and the linear velocity of relative slide on bearing surfaces);

(13) density.

2.2.8.5 The physical properties of synthetic bearing materials for rudder stocks, rudder pintles, rudder axles and stern shafts are to comply with the requirements of Table 2.2.8.5. For items not mentioned in the table, the results are to comply with limit values specified in the standards or by the manufacturer.

Requirements for Physical Properties of Synthetic Bearing Materials **Table 2.2.8.5**

Compressive stress N/mm^2	Compressive modulus N/mm^2	Friction coefficient	Temperature and water resistance	Volumetric swelling in lubricating medium③ %	Tensile strength N/mm^2
ISO 604	ISO 604	–	–	ISO 175	ISO 527-2
≥120① ≥85②	≥1500①	≤0.25	Not less than 80% of test value in 2.2.8.4(1)	≤3	≥70

Notes:

① Vertical to the compression side.

② Parallel to the compression side, only for bearings of strip shape.

③ For test of volumetric swelling in lubricating medium, the size of test sample is 50 mm × 50 mm × t, t is generally 4 mm, and minimum product thickness may also be adopted.

2.2.8.6 The maximum permissible surface pressure of synthetic bearing materials for rudder stocks, rudder pintles, rudder axles and stern shafts is generally not greater than 5.5 N/mm^2. If a permissible surface pressure greater than 5.5 N/mm^2 need to be approved, in addition to complying with the requirements of 2.2.8.4 and 2.2.8.5, immersion tests of the material in alternate dry and wet conditions are to be carried out, with volumetric swelling not exceeding 3%.
2.2.8.7 The following are to be inspected for delivery of each batch of products:
(1) compressive stress and module;
(2) hardness;
(3) tensile strength;
(4) density.

2.2.9 Cast epoxy putty for low-temperature tanks

2.2.9.1 Bi-component thermosetting epoxy putty used to bind saddle of low-temperature liquefied gas (such as LEG, LPG, LNG) tanks and supporting frame is subject to CCS approval before use.
2.2.9.2 Product manufacturers are to provide complete construction technical files, including recommended design principle, construction methods and requirements for reference.
2.2.9.3 Samples are to be cast in accordance with the construction procedures and the following performances are to be tested after the samples are set:
(1) Barcol hardness;
(2) density;
(3) compressive strength and compressive modulus of elasticity (tests are carried out at 20℃, -50℃, -110℃, -195℃);
(4) shearing strength (tests are carried out at 20℃, -50℃, -110℃, -195℃);
(5) linear expansion coefficient (-30℃~+30℃);
(6) creep (at 70℃, for 2000 h, creep under 2.5 MPa and 7 MPa are tested respectively);
(7) compressive deformation (20℃, -195℃);
(8) compressive yield strength (20℃, -195℃).

Section 3 SPECIMENS AND TESTING

2.3.1 Application

2.3.1.1 This Section applies to the preparation of specimens required for the inspection and testing of the plastics materials described in this Chapter.
2.3.1.2 These requirements may be referenced for plastic products.

2.3.2 General requirements

2.3.2.1 In general, testing is to be carried out by a competent independent test house which may or may not require witnessing by the Surveyor.
2.3.2.2 Alternatively, testing may be carried out by a manufacturer having perfect test conditions and capabilities, subject to these tests being witnessed by the Surveyor.
2.3.2.3 All testing is to be carried out by competent personnel using qualified test equipment according to a specified procedure.
2.3.2.4 Unless specified otherwise, testing is to be carried out in accordance with recognized international or national standards, and all written test programmes provided by the manufacturer are to be reviewed and agreed by the Surveyor.
2.3.2.5 All base material samples for testing are to be prepared under conditions that are as close as possible to those under which the product is to be manufactured.
2.3.2.6 Test materials (either base materials or product sample materials) are to be selected by the Surveyor or a person nominated by him, and these are to be identified by markings which are to be maintained during the preparation of the test specimens. Any transfer of such materials is subject to agreement of the Surveyor.

2.3.3 Preparation of test samples

2.3.3.1 The material or product manufacturer is to provide sufficient test materials, ensuring that adequate samples be taken by the Surveyor for preparation of specimens.
2.3.3.2 Thermoplastic polymer samples are to be prepared in accordance with the manufacturer's

recommendations for moulding. Technological conditions for the preparation are to be implemented according to the recommended pressure, temperature, time etc. For finished products, samples are to be taken from the product during production in accordance with the manufacturer's quality management procedure, but where this is impractical, separate test samples may be prepared in a manner identical with that of the product.

2.3.3.3 Samples of thermosetting resins are to be prepared using the curing system (including curing agent (or catalyst/promoter) and proportional amount), curing time, temperature recommended by the manufacturer and identical with that used for the finished product.

2.3.3.4 Where post-curing is required for samples of thermosetting resins, the post-curing conditions are to be as recommended by the manufacturer.

2.3.3.5 It is recommended that post-cure heating be carried out in properly constructed ovens which are capable of uniformly heating and efficiently maintaining the temperature, and have adequate means for control and recording of temperature. In the case of very large components which require post-cure heating, alternative methods agreed by the Surveyor may be used.

2.3.3.6 Test samples of the cured chock casting are to be prepared under ambient conditions and then post-cured at the exotherm temperature as determined in 2.2.7.4 of Section 2.

2.3.3.7 Where a reinforcement is to be used, the ratio of reinforcement to resin is to be nominally the same as that of the finished product or in accordance with that as recommended in 2.2.3.4(4) of Section 2.

2.3.3.8 Cured samples of thermosetting moulding compounds or pre-impregnated material are to be prepared according to the manufacturer's recommendations or the same specifications as those for the finished product.

2.3.3.9 Where laminates are prepared specifically for approval test purposes, the reinforcement is generally to be laid parallel plied.

2.3.3.10 Reinforced thermosetting resin laminates and sandwich panels may be prepared according to the manufacturer's recommendations or the respective requirements in 2.2.3.4 and 2.2.6.10 of Section 2.

2.3.4 Preparation of test specimens

2.3.4.1 The dimensions, number and orientation of test specimens are to be in accordance with recognized international or national standards.

2.3.4.2 The test sample from which specimens are to be taken may be directly prepared by molding or alternatively, cut from a prepared laminate (or sandwich panel).

2.3.4.3 Specimens are to be taken from the laminate sample at an area 20 ~ 30 mm from the edge and free of porosity, delamination, resin accumulation, warping etc.

2.3.4.4 Where orientation is required for the specimens, they are to be taken parallel to the main orientation of fibers, strictly ensuring that fiber direction and laminating direction be in consistency with test requirements.

2.3.4.5 Precautions are to be taken during machining to ensure that the temperature rise in the specimen will not affect its properties. Oil cooling is prohibited for machining while delamination, scratches or local squeezing is to be prevented.

2.3.4.6 Processing of the surface of finished specimens is to be avoided so far as possible. Where this is necessary, one finished surface is to be retained.

2.3.5 Test operations

2.3.5.1 The ambient test conditions and the pre-test conditioning of specimens are to be in accordance with recognized international or national standards.

2.3.5.2 The testing machine used for mechanical tests is to be calibrated in accordance with a recognized standard, at least once each year, by an institution or organization recognized by CCS. The test equipment used for the determination of physical properties is to be in accordance with the relevant requirements for such tests.

2.3.5.3 Strain measurement is to be made by the use of a suitable extensometer or strain gauge.

2.3.5.4 The number of test specimens from each sample to be tested is to be in accordance with a recognized standard. This is to be more than 5 in respect to the same batch of effective specimens for each mechanical testing.

2.3.5.5 If a test specimen fails because of faulty preparation or incorrect operation of the testing machine, it is to be discarded and replaced by a new specimen.

2.3.5.6 If the deviation of one result in a group of five exceeds or is below the mean by more than two standard deviations, that result is to be discarded and one further specimen tested. Such discarding is

permitted once only for any test group.

2.3.6 Testing

2.3.6.1 Specimens of unreinforced thermoplastic polymers are to be tested for the relevant items specified in 2.2.1.3.

2.3.6.2 Specimens of unreinforced thermosetting resins and their castings are to be tested for the relevant items specified in 2.2.2.5.

2.3.6.3 Specimens of reinforced materials are to be tested for the relevant items specified in 2.2.3.2.

2.3.6.4 Laminate specimens of any type are to be tested for the relevant items specified in 2.2.3.6.

2.3.6.5 Foam cores and balsa are to be tested for the relevant items specified in 2.2.6.3 and 2.2.6.8 respectively.

2.3.6.6 Test sandwich panels are to be subjected to four-point flexural tests to determine the apparent shear properties at ambient temperature and at 70℃, using a span of not less than 400 mm.

2.3.6.7 Machinery chock specimens are to be tested according to 2.2.7.5 and in compliance with 2.2.7.7.

2.3.6.8 For synthetic bearing materials of rudder stocks, rudder pintles, rudder axles and stern shafts, the specimens are to be tested according to the requirements of 2.2.8.4, and the results are to comply with the requirements of 2.2.8.5 and 2.2.8.6.

2.3.6.9 Test results are to be in compliance with the relevant recognized product standards or the manufacturer's product specifications.

2.3.7 Test report

2.3.7.1 The measured values, arithmetical mean values and calculated standard deviation of each specimen are to be tabulated and if necessary, damage to specimens is to be described.

2.3.7.2 Details of the sample and specimen preparation are to be provided, including (where applicable):

(1) catalyst/accelerator or curing agent types and mix ratio;

(2) weights of resins, and/or reinforcements used;

(3) number of layers of reinforcement used;

(4) dimensions, shape and external quality of casting/laminate sample;

(5) curing/post-curing conditions;

(6) other items deemed necessary, e.g. ambient temperature, humidity, specimen conditioning.

CHAPTER 3 FIBER-REINFORCED PLASTIC HULL MATERIALS

Section 1 GENERAL PROVISIONS

3.1.1 Application

3.1.1.1 The requirements of this Chapter apply to the manufacture, testing and inspection of fiber-reinforced plastics intended for use in the construction of craft.

3.1.1.2 The requirements may also be referred to for marine products of fiber-reinforced plastics.

3.1.2 General requirements

3.1.2.1 The manufacturer is to submit structural design drawings and necessary technical documents, including full information on fiber-reinforced plastics, as required by the relevant rules.

3.1.2.2 Approved or inspected materials are to be preferably adopted in the design. Novel resins, reinforcements and associated materials are not excluded provided that sufficient data to the satisfaction of the Surveyor are available to demonstrate equivalence to the properties specified in the rules.

3.1.2.3 The raw materials (e.g. fiber-reinforced materials, resins, core materials) used in manufacturing fiber-reinforced plastics are to comply with the relevant requirements of Chapter 2 of this PART.

3.1.2.4 Builders of fiber-reinforced plastic craft or products are to have a perfect quality assurance system. Where the builder has a quality assurance system, this is to include the requirements of this Chapter.

3.1.3 Procedure approval

3.1.3.1 The builders of fiber-reinforced plastic craft are to be approved by CCS. The necessary molding procedure specification is to be developed and submitted to CCS for review prior to the commencement of construction.

3.1.3.2 The submitted molding procedure specification for fiber-reinforced plastic craft are to contain at least the following items:

(1) description of construction facilities, including environmental control and material storage and handling;

(2) specifications for resins, reinforcements and core materials, including the manufacturer’s recommendatio and description;

(3) proportions of various raw materials (percentages in the mass of pure resin);

(4) lay-up method, including type of reinforcement, orientation and sequence, number of layers, mixing and pot life of resins;

(5) method of ejection and technical parameters of ejection;

(6) connection of parts and components (including join of sections, secondary gluing, connection of metal and non-metal, gluing technique of core material);

(7) type, model and characteristic parameters of lay-up equipment;

(8) conditions and instruction of curing;

(9) requirements and basis for inspection.

3.1.3.3 Approval test of molding procedures for fiber-reinforced plastic craft:

(1) Prior to the commencement of construction of fiber reinforced plastic craft where a new construction technology or a new laminating method or new resins and reinforced materials will be used, the manufacturer is to provide a test specimen laid up by operators in accordance with the procedure specification submitted for approval under the same condition as that of the molding workshop, for verification of fiber reinforced plastic hull design. The thickness of the specimen is to be the smallest thickness of the hull.

(2) The surface of the specimen is to be smooth, even and free from defects such as porosity, lamination, naked fiber, etc.

(3) Laminated plate specimens are to be prepared in accordance with the relevant accepted standards for mechanical tests such as tensile test, compression test, bending test, etc. The density (complying with limit values specified by the manufacturer), Barcol hardness, fiber content of the specimen are also to be measured.

(4) Shearing test is to be carried out for sandwich panel specimen in accordance with the relevant accepted standards, and the shear strength is not to be less than 1.33 times that of core material. In addition, a laminate specimen of sandwich panel plate is to be prepared for other tests. The test requirements, methods and results are to be the same as those for the laminated plate specimen.

(5) For hull using glass fiber as reinforcing material, the results of the above-mentioned tests are not to be

lower than the requirements given in Table 3.1.3.3(5); for hull using Aramid fiber or carbon fiber as reinforcing material, the performance tests mentioned above are to be carried out and the test results are not to be lower than the requirements of the strength calculation, with interlaminar shear strength not to be less than 17MPa, and are to be submitted to the Surveyor for confirmation.
(6) The laminated plate moulded by laying up chopped strand mat (CSM) and BIAXIAL woven rovings alternately is recommended.

Mechanical Properties of Test Specimen **Table 3.1.3.3(5)**

Items	Standard	CSM & BLAXIAL / BLAXIAL type complex mat / CSM & BLAXIAL type complex mat
Tensile strength (N/mm^2)	ISO 527-4	$800\ G^2 - 80\ G + 37$
Tensile modulus (N/mm^2)	ISO 527-4	$38000\ G - 5000$
Bending strength (N/mm^2)	ISO 14125	$502\ G^2 + 107$
Flexural modulus (N/mm^2)	ISO 14125	38000G - 6500
Compressive strength (N/mm^2)	ISO 604	$150\ G + 72$
Compressive modulus (N/mm^2)	ISO 604	7000
Interlaminar shear strength (N/mm^2)	ISO 14130	glass fiber ≥ 20 carbon fiber and aramid fiber ≥ 17
Fiber content (%, by mass)	ISO 1172 (glass fiber) ASTM D3171(carbon fiber / aramid fiber)	G
Barcol hardness	ASTM D2583	40

Notes: ① Tensile and compressive properties in the Table mean in-plane properties, and out-plane compression are not to be used instead of in-plane property test.
② In the Table, G is total nominal glass fiber content and is to be rounded to one digit after the decimal point. The calculation formula can be the calculation formula for G in 2.2.3.4(4). The formula for complex mat in 2.2.3.4(4) may be used as simplified formula, i.e. the laminate is simplified as a big complex mat, and mat and cloth are calculated respectively. If the laminating structure includes complex mat, the complex mat may be simplified as separate mat and cloth for calculation.

Section 2 RAW MATERIALS

3.2.1 Application

3.2.1.1 Provision is made in this Section for fibre reinforced plastic hull materials manufactured by hand lay-up, spray lay-up or vacuum bagging techniques.
3.2.1.2 With respect to lay-up molding of hull and structures, such materials are suitable for either single-skin or sandwich construction, or a combination of both.
3.2.1.3 Other materials (i.e. non-GF materials) are to be of good quality, suitable for the purpose intended.

3.2.2 General requirements

3.2.2.1 The builder is to hold certificates of conformity provided by the material manufacturer for each batch of material supplied, indicating the relevant values specified in 2.2.2.3, 2.2.3.2 and 2.2.6.1 of this PART, for tracing or if necessary, random check by the Surveyor.
3.2.2.2 Where the resin manufacturer mixes resins from different batches for certain reasons, the mixed resins are to be tested for their properties in accordance with 2.2.2.3 of this PART. The mixed resins, if satisfactorily tested, are then to be given a unique batch number.
3.2.2.3 The following tests are to be carried out on receipt of any material:
(1) The consignment is to be divided into its respective batches and each batch is to be labeled accordingly.
(2) Each batch is to be visually examined for conformity with the batch number, visual quality and date of expiry.
(3) Each unit within the batch is to be labeled with the batch number and the date of delivery.
(4) Any non-conforming piece, if found, is to be promptly separated.
(5) Records are to be maintained of the above and these are to be cross-referenced with the certificate of conformity for the material and/or the builder's own test results and retained.

3.2.3 Resins

3.2.3.1 The resins employed are to be unsaturated polyester resins, vinyl ester resins or epoxy resins approved for marine use. Where carbon fiber is used for hull, unsaturated polyester resins are not to be used.

3.2.3.2 The properties of a resin are to be for the final form of the resin actually used in production with all additives (fillers included, if any). The amount of silicon dioxide or other material added to provide thixotrophy is to be the minimum necessary to resist flowing or draining.
3.2.3.3 The gel coat resin, laminating resin and topcoat resin (if any) are to comply with the requirement of 2.2.2 of this PART.
3.2.3.4 For lifeboats and rescue boats for which fire resistance is required, fire-retardant resins are to be used for construction.
3.2.3.5 Gel coat resins are to be of waterproof polyester resin for marine use. There is to be a good adhesiveness between gel coat resins and fiber-reinforced plastics. The elongation at break for gel coat resins is to be greater than that of the laminating resin, and the difference is in general not to be greater than 1%.

3.2.4 Additives
3.2.4.1 Additives added into the resins such as various curing agents or catalysts/accelerators, pigments, fillers, fire retardant additives and thixotropes are to be of proper amount and of types recommended by the manufacturer. They are not to alter significantly the properties of the resin (e.g. viscosity), nor are they to affect the overall strength properties of the laminate. Details of various additives are to be submitted for assessment.
3.2.4.2 Additives are in general to be added by the resin manufacturer in accordance with the agreed procedure and tested accordingly. Where a resin contains an ingredient that can settle within the resin system, it is the builder's responsibility to ensure that the resin manufacturer's recommendations regarding mixing and conditioning are complied with prior to use.
3.2.4.3 All fillers and pigments added by operators are to be of the dispersed type, i.e. a mash dispersed in resins which are same or similar to the base resin. The types and amount of fillers used are to be as recommended by the resin manufacturer. No filler is to be added in the resin of shell plates.
3.2.4.4 Amounts of fillers in excess of 13% by weight of the base resin are to be subject to individual testing and approval. Pigments, thixotropes and fire-retardant additives are to be considered as fillers in the calculation of total filler content.
3.2.4.5 Fillers are to be carefully and thoroughly mixed into the base resin that is then to be allowed to stand to ensure that entrapped air is released. The resin manufacturer's recommendations regarding the method of mixing are to be followed. The duration and rate of mixing are to be proper.
3.2.4.6 The type and amount of curing agent (or catalyst/accelerator) used are to comply with the specification of the resin manufacturer, and variations may be are allowed according to operating and environmental conditions. Full curing of the resin is to be ensured, while the gelation time is to be appropriate for laminates laid up in the mould.

3.2.5 Reinforcing materials
3.2.5.1 The reinforcing materials used for marine fiber-reinforced plastics are, in addition to complying with the requirement of 2.2.3 of this PART, to be approved E glass fiber, high strength/high elasticity glass fiber or other special fibers, and fabrics or products of such fibers. They may be rovings, woven rovings, chopped strand mat or combination thereof. The medium alkali glass fibers and fabrics of such fibers are not to be used as the reinforcing materials for the construction of fiber reinforced plastic craft.

3.2.6 Core materials
3.2.6.1 Core materials are generally to be made of rigid foams, balsa, plywood or pine wood, etc. and the requirements of 2.2.6 are to be complied with.
3.2.6.2 The core bonding paste to be used with the core material are to be of a type recommended by the manufacturer and used in accordance with the manufacturer's instructions. The paste is to be indicated on material data sheets and construction plans.
3.2.6.3 For pinewood, attention is to be paid to the fact that the mechanical properties are influenced by the direction of wood fiber. Before core materials are used, the measured values of their basic mechanical properties, including tensile, compressing, bending, horizontal shearing and vertical shearing strengths, are to be submitted.

3.2.7 Built-in materials
3.2.7.1 Built-in materials or units which are encapsulated within or bonded to laminates as required in structural applications, are to be corrosion resistant and not to adversely affect the cure of the resin system.

3.2.7.2 The surface of the built-in materials is to be suitably prepared prior to use so that they will be well bonded to resin.
3.2.7.3 If wooden materials are used as build-in materials, they are to be thoroughly dried, and free from defects such as obvious knots, flashes, cross fibers, cracks and rot, etc.
3.2.7.4 The surface of wood is to be suitably prepared and coated with diluted resin paint.

3.2.8 Adhesives for structural applications
3.2.8.1 Adhesives for structural applications in construction of fiber reinforced plastic craft are to be approved by CCS.
3.2.8.2 The type and quantity of adhesives for structural applications are to be in accordance with the manufacturer's recommendations and compatible with the lamination resins.
3.2.8.3 Adhesives for structural applications may not be used for joining of shell plates.
3.2.8.4 Prior to the application of structural adhesives, the surfaces to be bonded is to be cleaned and free of dust, grease, resin or reinforced fiber residues.
3.2.8.5 The process for the application of the adhesive is to be submitted to CCS for information and is to include the maximum bondline thickness, maximum creep and water resistance.
3.2.8.6 Adhesives for structural applications are to be such that minimum shear strength is not less than 7 N/mm^2 in temperatures ranging from ambient to 60℃(ISO 4587).

Section 3 LAMINATING PROCEDURE

3.3.1 Application
3.3.1.1 The requirements of this Section apply to general procedures for fabricating laminates by hand lay-up in a wet process or assisted by spray lay-up, vacuum bagging, with glass fibers and unsaturated polyesters as main raw materials.
3.3.1.2 Other unusual techniques will be subject to individual consideration.

3.3.2 General requirements
3.3.2.1 Laminating is to proceed as a continuous process, as far as practicable, with the minimum of delay between successive plies so as to ensure that the resin remains active in reaction, thereby reducing unnecessary secondary bonds. Where a standing time is necessary, means (e.g. a peel ply on the cured laminate, which is to be removed upon completion) are to be provided to keep the surface clean and obviate contamination by dust, etc. so as to achieve a good bonding of the subsequent layer to the previous one.
3.3.2.2 Test panels are to be laid up while laminating is proceeding. Test panels may be taken from hull openings or hull extensions. Where this is impracticable, test panels are to be simulated by ordinary operators using a plate mould placed at an angle of about 45°, with the same environmental conditions, raw materials, mixing ratio and process techniques (except for gel coat) as in actual production. Specimens are to be taken in the as-cured condition and their properties tested in accordance with the requirements in 3.4.3.5 with the results in compliance with the requirements in 3.4.3.6. For small craft produced in batches according to the same type as shown in drawings, the same procedure specification and the same production conditions, one specimen is permitted for 10 craft.
3.3.2.3 Where resins other than epoxy resins are being used, the first of any subsequent layers to be laid is to be of chopped strand mat, so far as practicable, to enhance the interlaminar strength properties of the laminate or component, regardless of laminating interrupted, secondary bonding or repair.

3.3.3 Conditions for production
3.3.3.1 The manufacturer is to have storage premises arranged according to the material manufacturer's recommendations. In general, the following conditions for storage and management are to be met:
(1) the premises are to be enclosed, protected from the sun, clean, dry, ventilated as necessary and sufficiently free from dust so that materials are not contaminated or degraded. Remaining materials are to remain sealed in storage as recommended by the manufacturer;
(2) resins, catalysts, hardeners and accelerators are to be stored in a well-ventilated space at temperatures recommended by the manufacturer. The storage period is not to exceed the shelf life. Fillers and additives are to be stored in closed containers impervious to humidity and dust;
(3) before use, fiber reinforcements are to be stored for at least 48 h at a temperature and humidity similar to that of the laminating premises;
(4) core materials are to be stored in a dry space and protected against damage; they are to be contained in

their protective packaging until immediately prior to use;
(5) materials that may be considered hazardous to each other are to be stored separately. Catalysts are to be stored in a cool, dry location away from manufacturing facility in accordance with fire and insurance codes.
3.3.3.2 Laminating premises are to comply with the following basic conditions:
(1) The premises are to be fully enclosed, dry, clean, free of dust, adequately ventilated and well lighted. Precautions are to be taken to avoid any effects on the resin cure due to direct sunlight or artificial lighting.
(2) Temperature is to be maintained between 15℃ and 32℃ and the relative humidity kept at less than 80%, and these values are to remain stable to prevent dewfall or condensation. In the area used for spray molding, the humidity is in general not to be less than 40%.
(3) Temperature and humidity monitoring equipment is to be provided, adjusted as necessary at any time and detailed records are to be kept.
3.3.3.3 Laminating molds are to comply with the following requirements:
(1) The molds are to have sufficient stiffness and strength, and are not liable to deformation. The dimensions and roughness of the molds are to meet the requirements for the products, and their overall shape and fairness of form are to be maintained.
(2) The molds are to be constructed of a suitable material that is not to be eroded by the resin and any auxiliary materials and not to affect the resin cure.
(3) The release agent is not to affect the cure of the resin and is to be evenly applied on the surface of the mold without any unfilled part. Prior to use, all moulds are to be conditioned to the workshop temperature.
3.3.3.4 Persons engaged in management and operation of laminating work are to be qualified at least as follows:
(1) Operators are to be specially trained, familiar with the properties of fibers and resins, have a good command of laminating processes and are capable of determination and elimination of defects.
(2) The quality management personnel are to have the capability for judgement of process techniques and construction quality and are responsible for strict monitoring of the whole molding process.
3.3.3.5 Production, measurement and test equipment are to be checked, calibrated regularly, and operated and managed by qualified personnel.

3.3.4 Preparation of liquid resin

3.3.4.1 Liquid gel coat resins and laminating resins are to be prepared depending on ambient workshop conditions, thickness of products, laminating areas, molding methods, and amounts of gel used. The liquid resins are to have proper viscosity, suitable gelation time and intended cure.
3.3.4.2 The viscosity of liquid resins is to be proper to facilitate laminating operations and wet-out of the reinforcement so as to prevent any unfilling or resin accumulation due to drainage.
3.3.4.3 The gelation time is to be varied to suit changing ambient workshop temperatures. The duration of gelation is to be so determined that full wet-out of the reinforcement can be obtained without excessive loss of the monomer or unnecessary drainage on vertical surfaces.
3.3.4.4 Prior to the formation, gel test is to be carried out to determine the best proportion of resins. For a great amount of resin used for large or thick products which are to be cured at room temperature, small portions may generally be prepared in sequence to extend time of their availability. For unsaturated polyester and vinyl ester resins this is, in general, to be adjusted by variation of the accelerator and not by variation of the catalyst. The gelation time is to be the typical gelation time for a laminate as laid in the mould, i.e. the working life of the resin.
3.3.4.5 Liquid resins are to be prepared in accordance with specified proportions. In general, the catalysts (including various additives) are to be first mixed with the resin thoroughly, and the mixture is to be mixed with the accelerator thoroughly immediately prior to use. The duration and rate of mixing is to be suitable to avoid entrapping air. The liquid resin mixed with catalysts is not to be stored for an excessively long time.

3.3.5 Preparations prior to commencement of construction

3.3.5.1 Before decanting, all materials are to be conditioned to shop temperature.
3.3.5.2 Resins and gel resins, additives, catalysts and accelerators are to be thoroughly mixed according to specified proportions and application sequence, and to stand to be deaerated.
3.3.5.3 The mold is to be inspected to ensure that there is adequate mold release agent, that the surface is dry and clean and that the mold temperature is the same as the shop temperature.

3.3.6 Application of gel coat

3.3.6.1 The gel coat resin containing catalyst/accelerator is to be applied by brush, roller or spraying equipment.
3.3.6.2 The applied gel coat is to have a uniform thickness of 0.3 mm to 0.6 mm and to be smooth. Multiple uniform passes may be used to apply the gel coat, with proper time interval between passes (15 s to 30 s).
3.3.6.3 The exposed surface of gel coat is to be kept clean, free of dust and contaminants.

3.3.7 Lamination of skin coat
3.3.7.1 Lamination of skin coat is to be commenced as soon as adequate cure of the gel coat resin has occurred, but not ended. The period of exposure of the gel coat is to be as short as practicable.
3.3.7.2 The resin containing catalyst/accelerator is to be applied by brush, roller or spraying equipment to the entire gel coat surface.
3.3.7.3 300 g/m^2 chopped strand mat or other skin coat, as indicated on the approved plans, is to be applied to wet resin and sufficient additional resin applied to completely wet out the reinforcement, i.e. resin encirclement of each individual fiber of the reinforcement.
3.3.7.4 The skin coat is to be gently rolled out to ensure saturation of fibers and elimination of air and voids in the skin coat. This is to be done with care not to damage the gel coat.

3.3.8 Laminate lay-up
3.3.8.1 The following principles are to be followed in laying up laminates:
(1) Reinforcements are to be arranged in a continuous manner, without any abrupt change in thickness, so as to maintain continuity of strength throughout the laminate.
(2) Laminating by using chopped strand mat (CSM) and BIAXIAL woven rovings (BIAXIAL) alternately is recommended.
(3) Adjacent pieces comprising a layer or ply of reinforcing material are in general to be overlapped along their edges and ends. The width of each overlap is to be not less than 50 mm. Where they are butted, butts in the same vertical plane are to be separated by not less than five passing plies, and tests are required to demonstrate continuity of strength.
(4) The position of the joints in the laminate (of either successive or lengthwise layers) is to be staggered at least by 150 mm.
(5) Changes in laminate thickness are to be made using a gradual taper, and the width of such transition area is to be at least 30 times the difference in thickness. A gradual transition in fiber reinforcement is to be provided between bidirectional and unidirectional laminates.
3.3.8.2 The resin containing catalyst/accelerator is to be applied by pouring, brushing or spraying to the entire skin coat (or gel coat). Next reinforcing ply is to be applied as required and sufficient additional resin applied to completely wet out the reinforcement, and the laminate is to be rolled out to remove air pockets and voids.
3.3.8.3 The amount of resin used for each layer is to be strictly controlled, and the resin contents of different reinforcing materials are to be kept within the limits given in Table 3.1.3.3(5).
3.3.8.4 The reinforcing material is to be laid according to required laminate type, weight, fibre orientation, alternating sequence, edge and end overlap, time interval for laminating, and gelation time. Complete saturation is to be ensured, and there is to be no drainage on vertical surfaces and no excessive loss of the monomer.
3.3.8.5 Excessive exothermic heat generation caused by thick laminate construction is to be avoided. Where thick laminates are to be laid, the single laminating thickness is normally not to be more than 10 mm and laminates exceeding this thickness are to be given secondary bonding.
3.3.8.6 Laminating is to proceed as a continuous process, as far as practicable. Where multi-shell curing is used, the delay between successive plies is to be minimized and non-wax resin is to be used for the surface of the second shell. If wax resin is used, the surface is to be roughed before lay-up.
3.3.8.7 When laminating is interrupted, measures are to be taken to keep the surface clean. The first of any subsequent layers of reinforcement to be laid in that area is to be of chopped strand mat.
3.3.8.8 Spray lay-up is to be limited to the parts of the structure to which sufficient access can be obtained to ensure satisfactory laminating.
3.3.8.9 The spray equipment is to be calibrated before using to ensure that the percentage of sprayed resin and fiber meets the prescribed requirements. The thickness of the sprayed layer is to be even. The chopped fibre length for a structural laminate is to be not less than 35 mm.
3.3.8.10 Where the amount of fiber sprayed reaches 600 g/m^2 or a thickness of 2 to 3 mm, rolling or other methods are to be used to eliminate bubbles.

3.3.9 Sandwich panel lay-up

3.3.9.1 Sandwich panels may be laminated with cores that are either effective in resisting bending, tension, compression, shear and deflection (e.g., plywood) or essentially ineffective in resisting bending, tension, compression, shear and deflection, but capable of transmitting shear loads (e.g. balsa wood and plastic foam).

3.3.9.2 For sandwich laminates, where applicable, single skin requirements are to be adhered to so far as possible.

3.3.9.3 The ply before the core is to be chopped strand mat, and the mat is to be thoroughly wet-out with a generous application of resin. Alternatively, suitable putty or compound may be used. Core is to be laid up as required and then, a generous coat of resin or putty is to be applied to the core and subsequent ply (generally chopped strand mat), thoroughly wetted out and rolled out. The core is to be vacuum bagged to the skins.

3.3.9.4 Where the core material is to be laid onto a pre-moulded skin, it is to be laid as soon as practicable after the laminate cure has passed the exothermic stage.

3.3.9.5 Where the core is applied to the uneven surface of a laminated surface, additional building-up of the surface or contouring of the core is to be done to ensure that a uniform bond is obtained.

3.3.9.6 Where resins other than epoxy resins are being used, the reinforcement against either side of the core is to be of the chopped strand mat type. Additional flow coating is not to be applied to the foam core prior to laminating.

3.3.9.7 Prior to bonding, the core is to be cleaned and primed (sealed), as required. The primer is to be allowed to cure and is not to inhibit the subsequent cure of the materials contained within the bonding process.

3.3.9.8 Thermoforming of core materials is to be carried out with care. Maximum temperature limits are to be strictly observed.

3.3.9.9 Where panels of rigid core materials are to be used, the vacuum bagging techniques are to be adopted. The core is to be prepared by providing “breather” holes to ensure efficient removal of air under the core. Bonding paste is to be visible at such breather holes after vacuum bagging. The number, size and distribution of such “breather” holes are to be in accordance with construction specifications and the manufacturer’s requirements.

3.3.9.10 The level of vacuum applied for initial consolidation and during the cure period is to be suitable to avoid the possibility of evaporative boiling and excessive loss of monomer.

3.3.9.11 Joints in core materials are to be scarped and bonded or connected by similar effective means, and where the thickness of adjacent core materials is different, the width of such transition area is to be at least 3 times the difference in thickness.

3.3.9.12 Inserts in sandwich laminates, where required, are to be of a material capable of resisting crushing. Inserts are to be well bonded to the core material and to the laminate skins.

3.3.9.13 Scored core material is to be avoided. However, when necessary, only single cut core material is to be used in all external panels with the scored side placed upwards, to facilitate subsequent processing.

3.3.9.14 In all application procedures cured, excess bonding material is to be removed and the panel cleaned and primed (sealed) prior to the lamination of the final sandwich skin.

3.3.10 Vacuum molding techniques

3.3.10.1 The vacuum molding procedures are divided into the following two types:

(1) Dry molding: lay all fiber reinforced materials on the mould according to the requirements of laminating design and lay all dressings needed for vacuumization, then vacuumize.

(2) Wet molding: similar as open molding, apply base resin in conjunction with laying fiber reinforced material and carry out vacuumization on completion of lamination.

3.3.10.2 For dry molding, reinforcements laid on elevation or side are to be fixed appropriately, and adhesives used are to be compatible with resins used for molding.

3.3.10.3 The deployment of the peelply is to facilitate mold release and the peelply is to be extended over the laminated fiber layer at the flange of the mold. Then a piece of diversion cloth is to be laid on the peelply.

3.3.10.4 Nozzles are to be deployed along the longitudinal direction of craft and fixed with the diversion cloth by appropriate means. The quantity and deployment of nozzles are to be determined according to area and shape of laminated layers to ensure infiltration of resins during molding so as to prevent any dry area from occurring.

3.3.10.5 Sealing between vacuum bag film and mould are to be ensured before vacuum molding. If the vacuum bag film is not of sufficient width and splicing is needed, appropriate measures are to be taken to ensure splicing is well sealed.
3.3.10.6 The determination of the level of vacuum is relevant with the viscosity of resins used. The resins are to be selected according to the technological specification of the shipyard or the recommendation of the resin manufacturer. The whole vacuum bag is to be examined for leakage after vacuumization and before resin injection. If leakage is found, appropriate measures are to be taken in time for sealing before resin is injected.
3.3.10.7 The vacuum bag may be removed after heat release and solidifying cooling of infused resin.

3.3.11 Removal from mould and cure
3.3.11.1 After completion of the lay-up, the moulding is to be left in the mould for a period to allow the resin to cure. This period is to be not less than 24 h.
3.3.11.2 Removal from the mould is not to be attempted until Barcol hardness is not less than 40. For large products, removal from the mould is to be done after the internal members have been installed.
3.3.11.3 Care is to be exercised during removal from the mould to ensure that the moulding is adequately braced and supported to maintain its form. Mouldings are, in general, to be stabilised in the moulding environment for at least 24 h.

3.3.12 Secondary bonds
3.3.12.1 Secondary bonding is the application of a wet resin ply to an already fully cured surface. In general, secondary bonds are only to be used when an integral moulding cannot be achieved or internal members are to be bonded to the hull or, repairs are to be carried out.
3.3.12.2 Laminating is to proceed as a continuous process, as far as practicable, with the minimum of delay between successive plies. Where a secondary bond is to be made, it is to be carried out in accordance with the resin manufacturer's recommendations, details of which are to be incorporated in the quality control documentation.
3.3.12.3 When preparing for a secondary bond, the following principles are to be followed so far as possible:
(1) The area is to be clean and free from all foreign particles such as wax, grease, dirt and dust.
(2) When grinding is required (especially in highly stressed areas), this is not to damage glass fibers of any structure or reduce the thickness of the laminate.
(3) The first ply during the secondary lay-up is to be chopped strand mat.
(4) The area, which has been lightly abraded or a peel ply of which has been removed, is to be wiped with a suitable solvent and allowed to dry prior to laminating.

3.3.13 Repairs of defects
3.3.13.1 Products are to be visually examined and are to be free from surface defects and blemishes. Repairs of minor surface blemishes are permitted. A repair procedure for these minor blemishes is to be included in the moulding procedure specification.
3.3.13.2 For repairs of those defects which may affect structural strength, full written details (including areas to be repaired, materials to be used, repair process and procedures etc.) are to be provided by the manufacturer, showing that the required strength can be attained. Such repair documents are to be approved prior to introduction.

Section 4 INSPECTION AND TEST

3.4.1 Inspection
3.4.1.1 A constant visual inspection of the laminating process is to be maintained by the manufacturer. If improper curing, blistering, void, delamination or fold of the laminate, or resin drainage or accumulation thereon is observed, appropriate remedial action is to be taken. The following inspections are to be carried out:
(1) checking the mold to ensure that it is clean and that releasing agent is thoroughly and evenly applied to the entire working area;
(2) checking gel coat for thickness, uniformity and application and cure before applying laminating resin to the first layer of reinforcement;
(3) checking resin formulation and mixing. Checking and recording amounts of base resin, catalysts /

accelerators / hardeners, additives and fillers;
(4) checking that reinforcements are uniformly impregnated, well wet-out and rolled out, and that lay-up and overlaps are in accordance with the required sequence and orientation;
(5) checking and recording resin/fiber ratio;
(6) checking that curing is occurring as specified. Appropriate remedial action is to be taken when improper curing or blistering, void is noted;
(7) the ambient temperature, humidity and gelation time is to be monitored and recorded.
3.4.1.2 Overall visual inspection of completed lay-up is to be carried out. Minor defects may be corrected before release from the mold. The laminated parts are to be free of open voids, pits, grooves, cracks or protruding fibers.
3.4.1.3 Thickness and other necessary dimensions of cured products are to be checked and recorded prior to release from mold.

3.4.2 Specimens
3.4.2.1 Test panels for verification are to be prepared while laminating is proceeding, in accordance with the requirements of 3.3.2.2 of Section 3 of this Chapter.
3.4.2.2 Specimens are to be cut and prepared in accordance with the relevant requirements of 2.3.4 of Chapter 2 of this PART.

3.4.3 Test
3.4.3.1 The gelation time is to be measured at least twice for each shift, at specified time intervals. If the resin, catalyst / accelerator, or their amounts are changed, two additional measurements of the gelation time are to be carried out for each change. The measurements of gelation time may be carried out to the relevant accepted standards, and the measured gelation time is to be that as desired in production or within the upper and lower limits recommended by the resin manufacturer.
3.4.3.2 Prior to removal from the mold, the laminate is to be checked with a Barcol hardness tester at a suitable number of locations to determine the degree of cure. The Barcol hardness of the cured laminate measured on the surface without the gel coat is to be not less than 40.
3.4.3.3 The resin/fiber content (weight) of laminates are to be readily measured according to the relevant accepted standards during lay-up, generally by means of burnout or in the case of special reinforcements (carbon fibre, etc.), by means of etching. Where fibre content is correlated with laminate thickness, specimens are to be taken from the same position of the product, or the positions from which they are cut are to be at least in close proximity to each other.
3.4.3.4 The thickness of the laminates are, in general, to be measured at not less than ten points, evenly distributed across the surface. In the case of large sections, at least ten evenly distributed measurements are to be taken in bands across the width at maximum spacing of 2 m along the length. Where electronic thickness measurement methods are employed, the equipment is to be calibrated against a laminate of identical construction. The measured thickness is to be not less than that indicated on the approved plans.
3.4.3.5 Tests associated with the laminate properties are to be carried out for the following items :
(1) fibre content (Glass fibre: ISO1172; carbon fiber/aramid fiber: ASTM D3171);
(2) tensile strength and modulus(ISO 527-4);
(3) flexural strength and modulus(ISO 14125);
(4) compressive strength and modulus (ISO 604);
(5) shear strength and modulus (ISO14129);
(6) interlaminar shear strength (ISO14130);
(7) shear strength and modulus of core material(ISO1922);
(8) flatwise tensile test of core to skin bondline(ASTM C297).
3.4.3.6 The report on test results is to be prepared according to the relevant requirements of 2.3.7 of Chapter 2 of this PART. The test results of various properties are to be not inferior to those as designed for the laminates.

Section 5 MATERIAL PROPERTIES USED FOR DIRECT CALCULATIONS OF FIBER-REINFORCED PLASTIC CRAFT

3.5.1 General requirements
3.5.1.1 Where direct calculations are required for fiber-reinforced plastic craft, the submitted data of material properties are to satisfy the requirements of this Section.

3.5.1.2 All submitted data of material properties are to be furnished with corresponding testing report. For finished products such as core materials, the technical data sheet may be accepted. For Poisson ratio, the data in the literature may be accepted.
3.5.1.3 For direct calculations of fiber-reinforced plastic craft, the overall mechanical properties of structural members may be calculated or laminated calculation of material properties given by laminated methods of structural members.

3.5.2 Definitions and terms
3.5.2.1 One ply material means the material combined by 1 layer of reinforced material (mat or cloth) and resin.
3.5.2.2 Fiber-reinforced plastic laminated plate means a fiber-reinforced plastic plate consisting of multiple one ply material.
3.5.2.3 Direction 1 means the in-plane direction of fiber main bearing strength.
3.5.2.4 Direction 2 means the in-plane direction vertical to fiber main bearing strength direction.
3.5.2.5 Direction 3 means the direction vertical to directions 1 and 2.

3.5.3 Material properties required for the overall calculation of structural members
3.5.3.1 For fiber-reinforced plastic laminated plates, the tensile modulus (E_t), compressive modulus (E_c) and shear modulus (G) along directions 1 and 2 and Poisson ratio are to be submitted.
3.5.3.2 For sandwich structural materials, the overall mechanical performance properties may be submitted; or the material properties of fiber-reinforced plastic laminated plates and core materials may be submitted in accordance with the provisions of 3.5.3.1. For non-isotropic core materials, the data along direction 3 is also to be submitted.

3.5.4 Material properties required for laminated calculation
3.5.4.1 The tensile modulus (E_t), compressive modulus (E_c) and shear modulus (G) of one ply materials along directions 1 and 2 and Poisson ratio are to be submitted.
3.5.4.2 For core materials of sandwich structures, the data specified in 3.5.4.1 is to be submitted. For non-isotropic core materials, the data along direction 3 is also to be submitted.
3.5.4.3 The performance of one ply materials above is recommended to be obtained by testing methods as follows:

Properties of One ply Materials **Table 3.5.4.3**

Item	Testing method
Tensile strength and modulus	ISO 527-4, ISO 527-5
Compressive strength	ISO 14126
In-plane shear strength and modulus	ISO14129

3.5.4.4 Where the stress criteria are used for direct calculation, in addition to the material properties required by 3.5.3.1 or 3.5.4.1, the tensile strength, compressive strength and shear strength of overall structural members or one ply materials are also to be submitted.”

CHAPTER 4 PLASTIC PIPES AND FITTINGS

Section 1 GENERAL PROVISIONS

4.1.1 Application

4.1.1.1 The requirements of this Chapter apply to plastic pipes and fittings intended for use on ships and offshore installations.

4.1.1.2 This Chapter does not apply to plastic flexible pipes, hoses and their joints.

4.1.2 Definitions and terms

4.1.2.1 *Plastic(s)* means both thermoplastic polymers and thermosetting resins with or without reinforcement.

4.1.2.2 *Pipes*/*piping systems* mean those made of plastics and include the pipes, fittings, system joints, method of joining and any internal or external liners, coverings and coatings required to comply with the performance criteria.

4.1.2.3 *Fittings* mean bends, elbows, telescoping pipelines, fabricated branch pieces etc., of plastic materials.

4.1.2.4 *Joint* means joining pipes by adhesive bonding, laminating, welding, etc.

4.1.2.5 *Fire endurance* means the capability of piping to maintain its strength and integrity (i.e. capable of performing its intended function) for some predetermined period of time while exposed to fire.

4.1.3 General requirements

4.1.3.1 The main material of which plastic pipes and fittings are made, construction and design strength of the pipe, manufacturing process, method of joining are to be approved by CCS.

4.1.3.2 Plastic pipes are to be selected according to their chemical composition, temperature limits, mechanical and physical properties, chemical properties and pressure rating of fluid being conveyed.

4.1.3.3 Except as validated by reliable data, plastic pipes and fittings are generally not used in a piping system with carried fluid temperature over 60℃ or below 0℃.

4.1.3.4 The performance of fittings, joints and method of joining are to be equal to that of the plastic pipes to which they are attached.

4.1.3.5 Plastic pipes and fittings conveying fluids capable of generating electrostatic charge in the pipes or pass through a hazardous area are to be electrically conductive.

4.1.3.6 Fire endurance and low flame spread characteristics are required according to application and location of plastic pipes, and in addition to the requirements for design and construction in this Chapter, the fire resistance classes and low flame-spread characteristics as specified in the fire test procedures, adopted by IMO resolution A.753(18) and revised resolution A.653(16), are to be respectively required.

4.1.3.7 The material properties, sets and groups of pipe products, sampling, preparation of test specimens, test procedure, measuring method and evaluation of results covered by this Chapter are to be in accordance with recognized international or national standards.

Section 2 MATERIAL, DESIGN, MANUFACTURE AND STRENGTH TEST

4.2.1 Material

4.2.1.1 The main material of which plastic pipes and fittings are made are to be approved by CCS.

4.2.1.2 Where the main material is not approved, the manufacturer is, prior to using such material in fabricating pipes and fittings, to provide sufficient evidence for compliance of the properties and characteristics of the material with the specifications for piping. If necessary, the Surveyor may require a partial or complete test.

4.2.1.3 Thermoplastic pipes are generally of polymers without reinforcement, e.g. polyvinyl chloride (PVC), polyethylene (PE), Polypropylene(PP) and acrylonitrile-butadiene-styrene (ABS). Fittings may be also of the above polymers reinforced with fiber glass. Thermoplastics used are to comply with the requirement of 2.2.1 of this PART.

4.2.1.4 Thermosetting plastic pipes and fittings may be of unsaturated polyester resin and epoxy resin. Thermosetting plastics used are to comply with the requirement of 2.2.2 of this PART.

4.2.1.5 Fiber glass reinforcing materials may be E glass fibers, high strength fibers and their fabrics or products, e.g. continuous rovings, surfacing mats, chopped strand mats and nets. Medium-alkali glass fibers are forbidden in pipes. The materials above are to comply with the requirement of 2.2.3 of this PART.
4.2.1.6 Extruded, cast or laminated test specimens are to be prepared as far as practicable under conditions similar to those for the manufacture of products.
4.2.1.7 The values measured for properties of the above polymers, resins and reinforcing materials are to comply with the specifications for plastic pipes and fittings and the requirements for design approval.

4.2.2 Design
4.2.2.1 The design strength of plastic pipes is to be in accordance with the design criteria and specifications in recognized international or national standards, and in accordance with the requirements of this Section for strength evaluation.
4.2.2.2 The design strength of plastic pipes and fittings are to be examined by CCS. The submitted information is to contain a list of the materials used with confirmation that the properties and characteristics of the listed materials comply with the values used in the submitted design. This list is to include at least the following:
(1) resin;
(2) accelerator (type, concentration);
(3) catalyst/curing agent (type, concentration);
(4) cure/post-cure conditions;
(5) ratio of resin to reinforcement;
(6) reinforcement (specifications, varieties);
(7) wind pattern (or lay-up sequence), wind angle and orientation;
(8) dimensions and tolerances.
4.2.2.3 If materials other than those covered by the application for approval are expected to be used, a list of such materials is to be submitted together with evidence showing that such materials will not adversely affect the properties of products.
4.2.2.4 Where any alteration to the materials used and manufacturing process is intended after approval, CCS is to be notified of this alteration and if necessary, a new approval is to be applied for.
4.2.2.5 The strength of the pipes is to be determined by a hydrostatic test failure pressure of a pipe specimen under the standard conditions: atmospheric pressure equal to 0.1 MPa, relative humidity 30%, environmental and carried fluid temperature 298°K (25℃).
4.2.2.6 The hydrostatic test failure pressure and collapse pressure are to be verified by experiments and the testing methods are to be acceptable.
4.2.2.7 Where the circumferential strength of the pipes, as determined by the short-term hydrostatic test failure pressure, is the failure circumferential stress in respect to inner pressure, the safety factor is not to be less than 6.0.
4.2.2.8 Axial strength is to comply with the following:
(1) The sum of the longitudinal stresses due to pressure, weight and other loads is not to exceed the allowable stress in the longitudinal direction.
(2) In the case of fibre reinforced plastic pipes, the sum of the longitudinal stresses is not to exceed half of the nominal circumferential stress derived from the nominal internal pressure condition.
4.2.2.9 The information submitted for design approval is to include details and explanations for fittings and the method of connecting fittings to pipes, in addition to pipe structure (for thermosetting pipes) and strength calculations.

4.2.3 Manufacture
4.2.3.1 Plastic pipes and fittings are to be manufactured at works approved by CCS.
4.2.3.2 The manufacturer is to have the production, testing equipment and manufacturing capability necessary for production of plastic pipes as well as a perfect quality system to ensure that pipes and fittings are produced with consistent and uniform mechanical and physical properties.
4.2.3.3 Plastic pipes may be drawn by an extruder (for thermoplastic pipes) or wound by a filament winding machine (for thermosetting pipes). Fittings may be manufactured by mold pressing, filament winding, cutting/mitering and contact molding (for thermosetting fittings) or by injection, extrusion, etc. (for thermoplastic fittings).
4.2.3.4 The manufacturer is to submit the necessary technological process specifications, including the following:

(1) Details of all components;
(2) Manufacturing process and main parameters:
① at least cylinder heating temperature, each section temperature of head, extrusion speed and drawing speed for extrusion;
② liner lay-up sequence, structural layer winding procedure or winding angle, the filament tension, the ratio of curing agent to resin and of reinforcement to resin, the laminate thickness, mandrel dwell time (initial cure), cure/post-cure conditions for forming by filament winding (if applicable);
③ repair procedure for slight surface defects.

4.2.3.5 Sufficient quality control points are to be available during manufacturing to ensure at any time that the sequence of use of all raw materials, their amounts and proportions and other technological elements such as wind angle, gel time, laminate thickness and degree of cure remain within the limits set in the manufacturing specifications and design requirements.

4.2.4 Strength tests

4.2.4.1 When applying for approval, the actual strength of pipes is to be proved by the manufacturer through tests.

4.2.4.2 A strength test is to include the following items:

(1) short-term hydraulic bursting test: Failure circumferential stress due to burst pressure is to be greater than such minimum stress specified in recognized standards;

(2) axial tensile strength: Test specimens may be full-size, scaled-down or manually laminated ones and the axial tensile strength achieved during tests is to be greater than such minimum strength specified in recognized standards;

(3) impact resistance: After going through an impact test procedure as specified in the accepted standard, the pipe specimen is to be subjected to hydrostatic pressure equal to 2.5 times the design pressure for not less than 1 h and no delamination or leakage is allowed;

(4) external load test of parallel plates: The minimum rigidity of parallel plates under 5% radial deflection is to be greater than such minimum rigidity specified in recognized standards;

(5) external load test: A concentrated load of 100 kg is to be applied at midspan of the pipe having a diameter of 100 mm and no cracks are allowed. The test span is generally to be 6 m for at least 5 min.

4.2.4.3 The sampling, measuring and the evaluation of results for the above tests are to be in accordance with the procedures as specified in recognized international or national standards.

Section 3 QUALITY OF FINISHED PIPES AND REPAIRING OF DEFECTS

4.3.1 Surface

4.3.1.1 All pipes and fittings are to be visually examined and are to be free from surface defects and blemishes.

4.3.1.2 The inner surface of the pipe is to be smooth and free from cracks, delamination, pinholes, impurities, bubbles and unfilled parts affecting its performance.

4.3.1.3 The pipes are to be reasonably straight with neat bells and spigots and smooth grooves. The cut ends are to be square to the axis of the pipe.

4.3.2 Dimensions and tolerances

4.3.2.1 The dimensions and tolerances of pipes and fittings are to comply with the manufacturing specifications.

4.3.2.2 Each pipe is to be measured for diameter, length, wall thickness and liner thickness (if any).

4.3.2.3 The wall thickness of the pipes may be measured around the circumference of the pipe end square to the axis of the pipe. At least 7 measuring points are to be uniformly distributed and the mean value is to be taken. Where an electronic thickness gauge is used, measurements are to be made at intervals around the circumference square to the axis of the pipe and along the length, and the number and distribution of measuring points may be determined according to the accepted standard. The minimum thickness is to be more than 90% of the nominal thickness, and the mean thickness is to be not less than the nominal thickness. For fiber-reinforced pipes, the nominal thickness is the sum of inner lining thickness and the structural layer thickness.

4.3.3 Properties of pipes

4.3.3.1 Where electrical conductivity is to be ensured, the resistance of the pipes and fittings is not to exceed 0.1 MΩ/m.
4.3.3.2 The minimum temperature of deflection is to be more than 80℃.
4.3.3.3 The degree of cure of fiber-reinforced thermosetting plastic pipes is to be over 40 Barcol hardness. The recommended resin content and fiber glass content of the structural layer is to be controlled respectively at 30 ±5% and 70 ±5%.

4.3.4 Hydraulic tests
4.3.4.1 Each pipe is to be tested at a hydrostatic pressure 1.5 times the design pressure of the pipe. The test pressure is to be maintained for 5 min to permit proof and inspection.
4.3.4.2 The tested pipes are not to exhibit dripping, leakage, bulging or cracking.

4.3.5 Rectification of defects
4.3.5.1 Significant defects, such as fragmentation and deep scuffing are generally not allowed to be repaired. The procedure for intended repairs is to be submitted in advance. The quality of repairs is to be proved through appropriate tests.
4.3.5.2 Minor surface blemishes not affecting mechanical properties of the pipes are allowed to be repaired, provided that a repair procedure for such blemishes is included in the manufacturing specifications.
4.3.5.3 Minor surface blemishes may be removed by a grinding machine and/or repaired with same resin and thin glass fiber felt or fabric, provided that after repairs, the dimensions are acceptable and no structural defects are demonstrated so far.

Section 4 IDENTIFICATION

4.4.1 Identification
4.4.1.1 All pipes and fittings are to be identified in such a way that traceability to all the component materials used in their manufacture is ensured.
4.4.1.2 All plastic pipes and fittings satisfactorily inspected by CCS are to be permanently marked by the manufacturer by molding, spray painting or by any other suitable method such as printing, at least at one clearly visible position with the identification of CCS and the following:
(1) type or specifications of the pipe;
(2) manufacturer’s name or trade mark;
(3) pressure rating;
(4) base material(s) of which the pipe is made;
(5) the standard applied;
(6) recommended service temperature;
(7) batch number or production number;
(8) fire endurance and/or low flame spread characteristics (if any).

4.4.2 Certification
4.4.2.1 For each batch of pipes and fittings, the manufacturer is to provide quality certificates containing the following particulars:
(1) purchaser’s name and contract number (if known);
(2) specifications or grades of materials used;
(3) name or type of product;
(4) dimensions and specifications;
(5) batch number or production number;
(6) necessary properties and report of hydraulic test results.

CHAPTER 5 SKIRT MATERIALS AND CONNECTORS

Section 1 GENERAL PROVISIONS

5.1.1 Application

5.1.1.1 This Chapter applies to the manufacture and tests of skirt pieces and connectors intended for use in side-wall cushion craft and air-cushion vehicles.

5.1.2 General requirements

5.1.2.1 Skirt pieces are to be manufactured at works approved by CCS.

5.1.2.2 The manufacturers are to be provided with necessary facilities for manufacturing and testing of skirt pieces. In all cases, details of the processes of preparation of rubber unvulcanizate, pressing of coated fabrics, splicing and forming of skirt and sulphurating are to be submitted to CCS for approval.

Section 2 SKIRT PIECE MATERIALS AND CONNECTORS

5.2.1 Skirt piece materials

5.2.1.1 Skirt pieces are to be the compound of reinforced fabrics and elastic materials. The physical properties and visual quality of the fabrics (such as nylon, etc.) and elastic coating materials (such as natural rubber, neoprene and the mixture of them, etc.) as well as the thickness of the skirt pieces and weight per unit area are to comply with the relevant recognized technical specifications.

5.2.1.2 The surface of the skirt material is to be free from defects due to any original stress or other defects affecting the normal application.

5.2.2 Connectors of skirt

5.2.2.1 The connectors of skirt are to be corrosion resistant against seawater, and corrosion and ageing resistant against oil and acid.

5.2.2.2 The connecting strength of skirt connectors is to be at least equal to the breaking strength of the skirt material.

5.2.2.3 Where necessary, skirt connectors are to be subjected to tensile, shear and fatigue tests.

Section 3 TEST AND MECHANICAL PROPERTIES OF SKIRT MATERIALS

5.3.1 Tests and test specimens

5.3.1.1 Skirt material is to be subjected to breaking test, tearing test, ripping test, tensile test for lap joint and flapping test in accordance with recognized standards.

5.3.1.2 Skirt test specimens are to be taken from the same batch used for manufacturing the skirt. The specimens are to be cut at a position at least 0.1 m warpwise from the edge and 1 m from the end of the skirt material. A batch is to consist of skirt pieces of the same textile structure, made by the same process of sticking and sulphurating. The preparation, dimension and number of the specimens are to be in accordance with the following specifications:

(1) Breaking test: the specimens are to be of 200 mm × 50 mm in dimension, at least 5 specimens warpwise and 5 specimens across warp are to be taken from each batch. The longitudinal direction of the specimen is to be precisely parallel to the fabric both warpwise and across warp.

(2) Tearing test: wing-shaped specimens as shown in Figure 5.3.1.2(2) are to be prepared. At least 3 specimens warpwise and 3 specimens across warp are to be taken from each batch.

(3) Ripping test: the specimen is to be a double lapped 200 mm × 50 mm strip with a lap length of 150 mm. At least 3 specimens warpwise or across warp are to be taken from each batch.

(4) Lap joint tensile test: the lap joint is to be formed by two pieces of skirt material with a lap width of 50 mm. After being sulphurated, strips of 50 mm in width are to be cut perpendicular to the lap line. At least 5 lap joint specimens are to be prepared for each batch.

(5) Flapping test: where necessary, flapping test may be required by CCS. The specimen is to be 200 mm × 400 mm in dimension. At least 3 specimens warpwise and 3 specimens across warp are to be taken from each batch and tested in accordance with the relevant recognized standards. The average damaged area is to be submitted as the test result to CCS for approval.

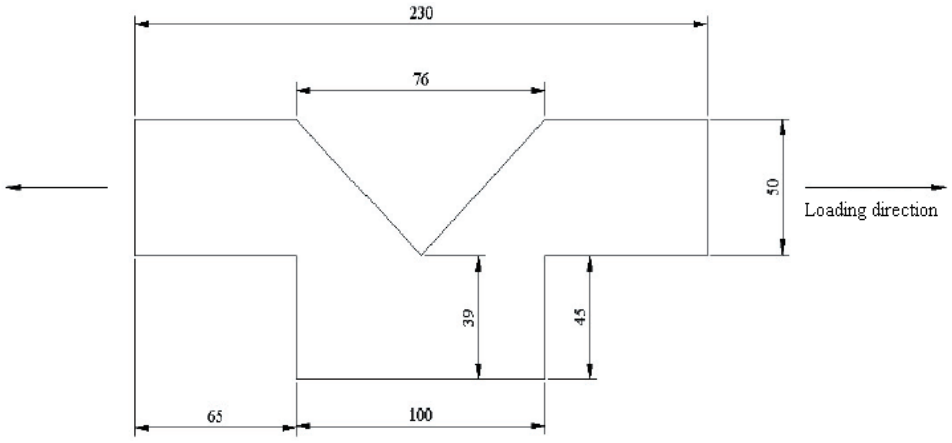


Figure 5.3.1.2(2)

5.3.2 Mechanical properties of skirt materials

5.3.2.1 The mechanical properties of the skirt material are to comply with the specification given in Table 5.3.2.1.

Mechanical Properties of Skirt Material **Table 5.3.2.1**

Grade of skirt piece	Breaking strength min. (N/5 cm)		Tearing force min. (N)		Ripping strength min. (N/5 cm)	Lap joint tensile strength min. (N/5 cm)
	ISO 1421		–		ISO 2411	ISO 1421
	Warpwise	Across warp	Warpwise	Across warp		
A	2940	2940	340	340	590	2940
B	4410	4410	585	585	680	4410
C	4900	4900	780	780	680	4900

CHAPTER 6 CONCRETE

Section 1 GENERAL PROVISIONS

6.1.1 Application

6.1.1.1 The requirements of this Chapter apply to the concrete platforms of gravity type, concrete structures and the materials and construction intended for weighting layers of submarine pipelines.

6.1.2 General requirements

6.1.2.1 Before materials are used, a test certificate or a certificate of appraisal issued by a laboratory recognized by CCS is to be submitted.

6.1.2.2 The test method, items and results for the related material are to comply with the relevant standards acceptable to CCS.

6.1.2.3 Newly developed materials and products are subject to assessment with sufficient test data prior to being used.

Section 2 RAW MATERIALS

6.2.1 Cement

6.2.1.1 The quality of cement is to comply with the relevant recognized standards.

6.2.1.2 For the selection of cement, the corrosion effects of its chemical composition on steel reinforcement, its durability against marine corrosion or the effects of sulphate, freezing and thawing, and wind and water conditions are to be considered.

6.2.1.3 The tricalcium aluminate ($3CaO \cdot Al_2O_3$) content of the cement (measured in weight) is generally to be in the range of 4% to 10%.

6.2.2 Aggregates

6.2.2.1 The aggregates, including rough aggregates and fine aggregates, may be in the form of natural sand, gravel, crushed stone and light aggregates or other materials which are widely used on the basis of tests and experience, and are to have sufficient strength and durability.

6.2.2.2 The aggregates are to be approximately in cubic or globular shape and properly graded and of the same quality and proportion.

6.2.2.3 Aggregates containing substantial reactive or deleterious constituents (e.g. certain reactive siliceous or carbonaceous mineral constituents, salt, sulphuret, clay, silt, excessively flat or long particles, organic substances or other impurities) are not to be used. Sea pebbles are to be washed thoroughly with fresh water when they are to be used.

6.2.2.4 Special consideration will be given to the utilization of heavy aggregates.

6.2.3 Steel reinforcements and ducts

6.2.3.1 Steel reinforcements may be in the form of plain steel bars, shaped steel bars and welded steel meshes. Their mechanical properties and sizes are to comply with the relevant standards acceptable to CCS. Manufacturers are to provide detailed data and guarantee, with respect to yield stress or tensile strength and elongation. Where necessary, a description on the holding power of steel reinforcing bars is to be provided.

6.2.3.2 Prestressed tendons may be in the form of high strength steel bars, wires, strands or cables to the same requirements as those in 6.2.3.1, and the breaking strength and fracture toughness are to be specially considered.

6.2.3.3 Ducts are to be rigid or semi-rigid watertight metal ducts. They are to be made by splicing tightly fitting sleeves, and all joints between sleeves are to be bonded with waterproof adhesive tape. Curved post-tensioning prestressed ducts are to be smooth in the inside wall to reduce prestress loss due to friction between the reinforcement and the inside wall.

6.2.4 Mixing water and admixtures

6.2.4.1 The water for mixing concrete is to be the drinking water which does not affect normal coagulation and hardening of cement and will not lead to rust corrosion of the reinforcements. Seawater, marsh water, industrial waste water and the water containing organic and pernicious substances (such as salt, acid, oil) are not to be used.

6.2.4.2 Admixtures used in mixing concrete are to be capable of maintaining basic concrete performance specified in design and are subject to approval by CCS. When sufficiently demonstrated or shown by experience as non-pernicious, more than one kind of admixtures may be used in the same concrete mix.
6.2.4.3 The use of calcium chloride is prohibited.

Section 3 REINFORCED CONCRETE

6.3.1 General requirements

6.3.1.1 The design of reinforced concrete is to meet basic requirements for strength, and the anti-freezing, corrosion prevention and anti-permeability requirements are to be satisfied respectively according to the working conditions of the platform.
6.3.1.2 Materials used in design and construction of the concrete platforms are to be certified for their previous fine performance in similar environmental conditions or sufficient test data and experience are to be available for such performance, and the relevant recognized standards are to be met.
6.3.1.3 For reinforced concrete structures, reinforcement arrangement and necessary calculations are to be submitted.

6.3.2 Strength grade of concrete

6.3.2.1 The strength grade of concrete is the compressive strength with 95% assurance rate obtained by standard test method from a cubic test specimen with side length of 15 cm, 28 days after it was made and maintained in a standard way. If a different specimen is used, the obtained strength is to be multiplied by conversion ratio of dimension, the value of which is 1.05 for 20 cm cubic test specimens, or 0.95 for 10 cm cubic test specimens.
6.3.2.2 Normal concrete is not to be less than Grade C35 for structures exposed in atmosphere and splash zone, and not less than Grade C30 for other structures.
6.3.2.3 The strength grade of prestressed concrete is not to be less than C40.

6.3.3 Design strength of concrete

6.3.3.1 Design strength of concrete is given in Table 6.3.3.1.

Design Strength of Concrete **Table 6.3.3.1**

Type of strength (N/mm^2)	Strength grade of concrete				
	C30	C35	C40	C50	C60
Axial compression	17.5	20.0	23.0	28.5	32.5
Bending compression	22.0	25.0	29.0	35.5	40.5
Tensile	1.75	1.90	2.15	2.45	2.65
Crack	2.10	2.35	2.55	2.85	3.05

6.3.4 Characteristics of concrete

6.3.4.1 Elastic modulus of concrete in tension or compression may generally be selected from Table 6.3.4.1.

Elastic Modulus of Concrete **Table 6.3.4.1**

Grade of concrete	C30	C35	C40	C50	G60
Elastic modulus, $\times 10^4$ (N/mm^2)	3.00	3.15	3.30	3.50	3.65

6.3.4.2 Unit weight of concrete and reinforced concrete is to be obtained from test, if necessary. In general, the following values may be taken:

Concrete 2.3 ~ 2.4 t/m^3
Reinforced concrete 2.4 ~ 2.5 t/m^3

6.3.4.3 Other physical characteristic values of concrete are generally to be determined by tests. In the absence of test data, the following values may be taken:

Poisson ratio $\gamma = 1/6$
Linear expansion factor $a = 1.0 \times 10^{-5}/℃$

6.3.5 Steel reinforcements

6.3.5.1 The characteristics of steel reinforcements and prestressed reinforcements are obtained from the data supplied by manufacturers or from GB, such as yield stress, tensile strength, elastic modulus, Poisson

ratio, etc.

6.3.5.2 For structural members subjected to impact load or alternate load and structures in low-temperature zones, cold-drawn reinforcements are preferably not to be used.

6.3.5.3 Generally, lapped joint is to be avoided when arranging reinforcements in the areas subjected to fatigue load, towing load and in mooring bollard area. Where lapped joints need to be used in these areas, the length of lapped joints is to be twice that required in the relevant recognized standards.

6.3.6 Concrete cover

6.3.6.1 For normal reinforcing bars, the following minimum thickness of concrete cover is required:

atmospheric zone not subjected to severe splash: 40 mm;
other zones: 50 mm.

Moreover, the thickness of cover is not to be less than 1.5 times the normal aggregate diameter.

6.3.6.2 For prestressed reinforcements, the thickness of concrete cover of ducts is not to be less than twice the above values. Special attention is to be paid to the cover which may be subjected to high temperature.

6.3.6.3 The exposed steel components and anchorages are to be isolated with concrete at least 50 mm thick from electrical equipment. The cathodic protection system for exposed steel components, such as steel skirt and elevatable attached platform, is to be of sacrificed anode type. Impressed current protection may be used if reliable control methods are employed to prevent reinforcements and prestressed reinforcements from brittle fracture.

6.3.7 Construction

6.3.7.1 The construction method and technology, the preparation of test samples, the test methods and standards of concrete are to comply with the relevant national regulations and the approved procedures. The procedures and methods that may reduce the structural safety and cause difficulties to subsequent construction or installation are not permitted.

6.3.7.2 The mooring components, the walls subjected to squeezing by barges and the structures temporarily bearing heavy dynamic loads in subsequent construction are to be analyzed for the forces acting on them to ensure that they have sufficient strength.

6.3.7.3 Materials used in construction are to have distinct marks. Materials with unclear marks are generally not to be used.

6.3.7.4 The measuring instrument such as tensiometer used in making prestressed concrete is to be calibrated by the competent national authority or organization and to be within the period of effective service.

6.3.7.5 In order to ensure that the concrete quality meets the design requirements, the material quality, mixing ratio and main points of construction are to be inspected, including:

(1) type, quality and weight of raw materials;
(2) moisture content of sand and gravel;
(3) water-cement ratio and quantity of the cement;
(4) admixtures;
(5) quality of mixing water;
(6) mixing ratio of concrete.

The inspected items mentioned above are to be recorded in detail and kept on file for reference.

6.3.7.6 Design of composition of concrete is to comply with the following requirements:

(1) Water-cement ratio (W/C) of mixed concrete is not to be greater than 0.45;

(2) Under the condition that water-reducing agent is not added, the amount of cement is not to be less than the following values:

in splash zone 400 kg/m^3;
in other zones 360 kg/m^3.

6.3.7.7 Steel reinforcements are to comply with the following requirements:

(1) Normal reinforcements are to be clear and free from rust, grease, salt deposit and any other sediment which may be injurious to the durability and adhesive strength of the reinforcements. Concrete covers for reinforcements are to strictly comply with the specified requirements. Attention is to be paid to the cutting, bending and binding of reinforced bars to ensure their correct positioning and fastening and avoid any displacement during casting of concrete.

(2) Prestressed reinforcements are to be clean, and grease, insoluble oil, salt deposit and any other sediment which may be injurious to durability and adhesive strength of the reinforcements are to be cleared away. Where protective coating is applied, the coating is to be chemically neutral to avoid chemical or

electrochemical corrosion to the reinforcements.
6.3.7.8 Metal ducts with post-tensioning prestressed reinforcement are to be stored in good condition. The ducts are to be kept apart from water, and blocked up or sealed up to prevent seawater, cement grout or concrete from flowing in during construction.
6.3.7.9 In grouting, inspections arc to be carried out to the tendons, admixtures of grout, mixing and grouting procedures so as to ensure grouting density.

6.3.8 Construction during floating and temporary resting on the sea bottom
6.3.8.1 Where structures are constructed in floating condition, the velocity of pouring concrete is to suit the velocity of sinking of structures to prevent over-stress in concrete.
6.3.8.2 Where structures are resting on the sea bottom temporarily, the concrete strength at that time is to be considered and the condition of seabed is also to be taken into account.

6.3.9 Concrete cure
6.3.9.1 Concrete cure is to be done to ensure the durability and to minimize cracks.
6.3.9.2 Seawater is not to be used in curing reinforced concrete and prestressed concrete. Where concrete structures are sunk in water according to a specified construction procedure, they are to have sufficient strength to withstand breaking due to environmental and constructional conditions.

Section 4 CONCRETE WEIGHT COATING OF SUBMARINE PIPELINES

6.4.1 General requirements
6.4.1.1 This Section applies to concrete weight coating of submarine pipelines. Other pipeline anchoring systems will be subject to special consideration. The main purposes of concrete weight coating are to provide negative buoyancy to submarine pipeline throughout its designed service life, and to protect corrosion resistant coating against mechanical damage during pipeline laying, installation and service.
6.4.1.2 In cases where the towing method is used for installation, the concrete weight coating is to withstand the friction and mechanical wear caused by the contact between the sea bottom and the pipeline during the towing operation. The wear resistance and the friction coefficient are to be verified through tests. Such tests are to be carried out using relevant pipe diameters, submerged weight, concrete quality, jointing and covering methods and along a route similar to the actual towing one (including seabed properties).
6.4.1.3 For preventing weight coating from cracking due to bending stresses of the pipeline, the weight coating may be divided into several sections by partitions in the pipeline axial direction, where necessary.
6.4.1.4 Bared pipe edges with a sufficient length are to be provided for welding on both ends outside the concrete weight coating and anti-corrosion coating for each pipe length or section. In general, the length is 225 mm to 375 mm, depending on the repaired mouthpiece structure on site and the workmanship requirements.
6.4.1.5 In general, the technical requirements for concrete weight coating arc to include the following:
(1) type and properties of materials to be used;
(2) thickness, strength, density and weight per unit volume;
(3) method of application;
(4) curing method;
(5) inspection and tests;
(6) requirements for storage, handling and transportation of coated pipes;
(7) acceptance criteria for weight coating.

6.4.2 Properties of concrete
6.4.2.1 The concrete for weight coating is to have sufficient strength, density and durability.
6.4.2.2 The strength grade of weight coating is to be determined by design. In general, the concrete grade is C30.
6.4.2.3 The permeability is a major property for determining the density and durability of concrete submerged in seawater. The concrete with high density and low permeability may be obtained by use of:
(1) high cement content and concrete grade;
(2) low water-cement ratio preferably 0.40 or less, but not greater than 0.45;
(3) sound and dense aggregates;
(4) proper grading and proportions of fine and coarse aggregates;
(5) good concreting practice and good workmanship ensuring adequate workability, thorough compaction,

proper curing and handling.

6.4.3 Steel reinforcements

6.4.3.1 The steel reinforcements used for concrete weight coating are to be of plain bars or the other proper bars, as specified by recognized standards. Where the steel reinforcements needed to be cold-drawn, this is to be clearly stated.

6.4.3.2 The steel reinforcements for concrete weight coating may be in the form of steel wire mesh or welded cage fabricated of plain or deformed bars. The type and amount of the reinforcements are to be determined by design and to be selected with due account of the anticipated pipeline loading and service conditions so as to control the crack pattern of the concrete coating.

6.4.3.3 Reinforcement type and application method are to ensure the continuity of the hoop reinforcement.

6.4.3.4 The steel reinforcements are to be accurately placed and adequately supported and to ensure the designed thickness of concrete coating of the reinforcements. Reinforcements are not to be electrically connected with the pipe or anodes.

6.4.4 Application

6.4.4.1 Concrete is to be applied to pipe joint using suitable equipment and procedures such as spray, casting or extrusion, which will result in adequately consolidated concrete coating of uniform thickness, density and strength.

6.4.5 Curing

6.4.5.1 The selected method of curing, the conditions for curing and its duration are to be such as to ensure design properties of the concrete weight coating, and to prevent undue cracking.

6.4.5.2 Documentation of the adequacy of the proposed curing method for adverse climatic and environmental conditions is to be submitted to CCS.

6.4.6 Testing and inspection

6.4.6.1 The testing methods for concrete materials are to be in compliance with the relevant requirements for general building materials. Description together with information and data for the testing and inspection methods to be used in the concrete casting are to be provided prior to their use.

6.4.6.2 On-site measurement and testing of the individual materials during concrete production are to be carried out in accordance with the relevant regulations. The frequency of inspection is to be determined taking the batch, quality and homogeneity of delivered materials into account.

6.4.6.3 Prior to casting the concrete, the mix ratio, strength and weight per unit volume are to be determined by tests in accordance with the relevant recognized standards and documented as appropriate. During casting, the concrete is to be inspected regularly for thickness, strength and density. The frequency is to be minimum one set of specimens (three pieces) per 10 to 15 pipe sections coated and minimum one set per shift. One set of specimens is to be taken respectively for concrete castings with individual specifications and requirements. Except for molded test specimens, the strength tests may be supplemented by resilience method to evaluate the compressing strength of concrete.

6.4.7 Repair

6.4.7.1 Where cracks and surface peeling are found on prefabricated pipe sections with concrete weight coating by the visual inspection, repairing is to be carried out in accordance with the approved technological specification.

6.4.7.2 In general, the rejection of the weight coating due to serious cracks or peeling may be in accordance with the design requirements.

CHAPTER 7 FIBER ROPES

Section 1 MARINE FIBER ROPES

7.1.1 General requirements

7.1.1.1 The requirements of this Section apply to fiber ropes used as towlines and mooring lines made from natural or synthetic fibers.

7.1.1.2 The materials, constructions, linear density and rated breaking strength of marine fiber ropes are to comply with the relevant recognized standards.

7.1.1.3 Definitions and terms

(1) Linear density means the mass per length of a fiber rope under preload.

(2) Preload means the load applied to determine nominal diameter and linear density of a fiber rope in accordance with recognized standards.

(3) Rated breaking load means the nominal value which is to be reached or exceeded in breaking test, and is also used to check the nominal diameter of a fiber rope.

(4) Actual breaking load means the measured value of breaking load of a fiber rope in breaking test.

7.1.2 Materials

7.1.2.1 Fiber ropes may be made of natural fibers (coir, hemp, manila or sisal) or may be composed of synthetic fibers (polyamide, polyester, polypropylene, ultra-high molecular weight polythene or the mixture of above materials). If it is intended to use other materials, sufficient data are to be available to show compliance of their properties with service requirements.

7.1.2.2 The material used for the manufacture of fiber ropes is to be of good and consistent quality and resistant to corrosion and aging.

7.1.2.3 The fiber used for the manufacture of fiber ropes is to be subjected at least to the testing of:

(1) breaking load;

(2) elongation to break;

(3) linear density .

7.1.3 Manufacture

7.1.3.1 Fiber ropes are to be manufactured at works approved by CCS.

7.1.3.2 Any lubricant in the natural fiber ropes is to be kept to a minimum, and any rot-proofing or water repellency treatment is not to be deleterious to the fiber.

7.1.3.3 Fiber ropes may be of a three-strand, four-strand, six-strand, eight-strand or twelve-strand construction appropriate to their respective materials and types, other construction forms will be specially considered.

7.1.4 Tests

7.1.4.1 Completed fiber ropes are usually to be subjected to breaking tests and line density measurements.

7.1.4.2 Samples are to be selected from fiber ropes manufactured from the same batch of raw material, with the same structure, the same size and the same technology. Unless otherwise agreed, samples are to be selected randomly from such fiber ropes for test. The number S of samples is to be obtained from the following formula:

$$S = 0.4 \times \sqrt{N}$$

where: S – number of samples;

N – number of fiber rope coils in one batch.

If the calculated S value is not an integer, it is to be rounded to the closest integer. When S is less than 1, one sample only is to be taken.

7.1.4.3 The breaking test is to be carried out according to the following requirements:

(1) The sampling length and preload of breaking test specimens are to comply with the requirements of Table 7.1.4.3(1).

Specifications for Breaking Test **Table 7.1.4.3(1)**

Material	Test length min. (mm)	Load ratio* (%)	Test speed (mm/min)
Natural fiber	1800	2	150 ±50
Synthetic fiber	900	1	75 ±25

Note: Load ratio is the ratio of preload to rated breaking load.

(2) After application of preload, the diameter and even lay-up of the sample are to be checked. The sample is then to be uniformly strained at the test speed given in Table 7.1.4.3(1) until it breaks.
(3) Test results are to comply with the following requirements:
① The actual breaking load of the test sample is not to be less than the rated breaking load given in relevant recognized standards;
② During testing, if the sample is held by grips and the break occurs within 150 mm of the grips, the test may be repeated;
③ If the break occurs at the gripped or twisted portion while the breaking load has attained to more than 90% of the rated breaking load, the test may be accepted.

7.1.4.4 Linear density measurements are to comply with the following requirements:
(1) The linear density is to be calculated by dividing the gross mass of the sample by its length under pretension after adjusting its temperature and moisture according to recognized standards, using the following formula:

$$\rho_x = m_0/L \quad \text{ktex}$$

where: ρ_x – linear density, in ktex;
m_0 – mass of sample, in g;
L – length of sample under preload, in m, $L = D_p \times L_0/D_0$
where: L_0 – initial length of straightened sample prior to being installed on testing machine, in m;
D_0 – initial distance between two gauge lengths when the sample is flattened, in m (at least 0.5 m);
D_p – distance between two gauge lengths measured under preload, in m.

(2) The measured value of linear density is to be recorded.

7.1.5 Marking and certificate

7.1.5.1 Each coil of rope which has been accepted is to be marked at a clearly visible position with an attached label detailing the rope name, no., material, construction, diameter and length, and the maker's name, and additionally identified with CCS stamp.
7.1.5.2 The maker is to provide qualified fiber ropes with a qualification certificate detailing at least:
(1) product name, type and no.;
(2) material of fiber ropes;
(3) linear density of fiber ropes;
(4) length and diameter of a whole fiber rope coil;
(5) construction of fiber ropes;
(6) rated breaking load of fiber ropes (actual breaking load to be added when necessary).

Section 2 FIBER ROPES FOR OFFSHORE MOORING

7.2.1 Application

7.2.1.1 The requirements of this Section apply to synthetic fiber ropes used in the mooring of offshore installations.

7.2.2 Raw materials

7.2.2.1 Fiber ropes used in the mooring of offshore installations are usually made of polyethylene terephthalate (polyester, PET), polyaramide (Aramid), high modulus polyethylene (UHMWPE) and polyamide (nylon). If it is intended to use other materials, sufficient data are to be available to show compliance of their properties with service requirements.
7.2.2.2 The material for the manufacture of fiber ropes used in the mooring of offshore installations is to be of good and consistent quality and resistant to corrosion and aging.
7.2.2.3 The manufacturer of fiber material used for the manufacture of ropes is to provide each batch of the material with a certificate of quality detailing the following performance parameters:
(1) fiber type and grade;
(2) linear density;
(3) dry breaking strength and elongation;
(4) wet breaking strength and elongation (for nylon only);
(5) wet yarn-on-yarn abrasion property;

(6) dry creep property;
(7) type of marine finish added and relevant specifications (Technical Data Sheet) (if any);
(8) content of marine finish and description of water-solubility.

7.2.2.4 On receipt of each batch of fibers to be used for the manufacture of fiber ropes, the fiber rope manufacturer is to inspect the following items, and the test methods and sampling requirements are given in Table 7.2.2.4. The inspection results are to comply with the relevant technical requirements indicated by the fiber manufacturer.

Inspection Items **Table 7.2.2.4**

Inspection item	Standard	Sampling method and amount
Dry breaking strength and elongation	ASTM D885	At least 1 sample per 5000 kg fiber material
Wet yarn-on-yarn abrasion	ISO18692	1 sample per 20000 kg fiber material, at least 1 sampling test for each fiber rope order
Linear density	ISO18692	At least 1 sample per 5000 kg fiber material
Content of marine finish	ASTM D2257	1 sample per 20000 kg fiber material, at least 1 sampling test for each fiber rope order

7.2.2.5 Marine finishes to make ropes are to comply with the following requirements:
(1) Marine finishes are not to be deleterious to the properties of fiber or fiber rope, and the treated fiber may increase the rope's service life by reducing yarn-to-yarn abrasion.
(2) Marine finishes are to remain effective during the rope's service life. The fiber supplier is to demonstrate the long-term durability of marine finishes.

7.2.2.6 Material for rope jacket is to comply with the following requirements:
(1) The jacket is to be sufficiently flexible to permit the fiber rope assembly to be safely deployed over rollers or sheaves of diameter specified under the design deployment loads.
(2) Limiting bend radius based on jacket or rope bending rigidity is to be established for short periods during installation and for prolonged periods when wound onto the specified transportation drums.
(3) The selected jacket material is to be able to withstand low temperature to ensure adequate protection of fiber ropes at low temperature.

7.2.2.7 The raw material for ropes is to be stored and used according to following principles:
(1) All raw materials for ropes are to be stored against light and water.
(2) The packing of each fiber material is to be clearly marked.

7.2.3 Constructional design

7.2.3.1 The typical construction of fiber ropes used for offshore mooring are parallel fiber (parallel yarn), parallel twisted-strand (multi-rope), parallel braided-strand (multi-rope), six-strand (with non-load-bearing core), seven-strand (six strand with load-bearing core), eighteen-strand (6+12), thirty-six-strand (6+12+18), plaited (eight-strand rope), single-braid (twelve-strand rope) and double-braid.

7.2.3.2 The design of protective jackets is to comply with the following requirements:
(1) The jacket is to be able to provide adequate protection for the rope during transportation, handling at installation or in service.
(2) The jacket is to be designed to provide adequate resistance to the ingress of sand or other hard foreign particles floating in seawater.
(3) In regions exposed to fish bite, consideration may be given to hardening the jacket.
(4) Jackets may be braided, extruded, wound or otherwise applied.
(5) Rope jackets are to be tightly fixed to the termination area to prevent slippage of the jacket away from the termination.

7.2.3.3 The design of end terminations is to comply with following requirements:
(1) For synthetic fiber rope assemblies for deepwater mooring, the typical type of end terminations is spliced eye.
(2) The minimum breaking strength indicated by the manufacturer is to be representative of the rope assembly break strength, which includes the strength efficiencies of all terminations within the rope assembly. Break strength of the rope is to be determined through testing on prototype or production ropes of the same rope construction, material and termination design as those which will be used in the actual mooring installation.

7.2.4 Manufacture

7.2.4.1 Fiber ropes for offshore mooring are to be manufactured at works approved by CCS.

7.2.4.2 The manufacturer is to have the production, testing equipment and manufacturing capability necessary for production of fiber ropes as well as a perfect quality assurance system to ensure that fiber ropes are produced with consistent and uniform physical and mechanical properties.
7.2.4.3 Prior to production, the manufacture is to submit relevant manufacturing specifications to CCS for approval, which are to include at least:
(1) fiber assembly process;
(2) yarn assembly process;
(3) strand assembly process;
(4) rope jacketing process (if applicable);
(5) termination handling process.
7.2.4.4 The production process is to be strictly according to the approved manufacturing specifications. Where there is any change to the process, the manufacturing specification is to be submitted to CCS for re-approval.

7.2.5 Inspection of fiber rope
7.2.5.1 For completed fiber rope product for offshore mooring, external visual inspection is to be carried out to verify compliance of rope structure with design and check the evenness of lay-up.
7.2.5.2 One sample is to be taken from each coil of fiber rope product to examine linear density, wet breaking load and nominal diameter.
7.2.5.3 Five specimens are to be taken for wet breaking test and examination of nominal diameter as follows:
(1) The specimens are to be terminated in the same manner as intended for service. The specimen length is to be at least 40 times nominal rope diameter between terminations.
(2) The specimen is not to have been previously tensioned to more than 5% of its estimated maximum breaking strength.
(3) The entire specimen including terminations is to be soaked in fresh water between 22 h and 26 h before testing. The specimen is to be tested as soon as practical after being removed from the water. If there is a delay of more than 12 h after soaking, the specimen is to be soaked again for an additional 2 h for each 24-hour period of delay up to a maximum of an additional 24 h of soaking before the rope is tested. The temperature of the water is to be maintained between 15℃ and 25℃.
(4) Preload of 1% estimated maximum breaking strength is applied to the fiber rope to measure its nominal diameter.
(5) Cycle the rope ten times from 1% of its estimated maximum breaking strength (initial tension) to 50% of its estimated maximum breaking strength. On the eleventh cycle, apply force to the rope until it breaks.
(6) The rate of travel of the pulling head during the break test is to be such that the rope is loaded to 20% of its estimated maximum breaking strength in not less than 2 s nor more than 30 s.
(7) The breaking force (maximum force applied to the rope) and the point at which the rope broke are to be recorded for each specimen.
(8) The average wet break strength and the standard deviation of wet break strength are to be calculated.
7.2.5.4 Linear density test for fiber ropes is to be carried out according to 7.1.4.4 of this Chapter.

7.2.6 Storage and transportation of fiber ropes
7.2.6.1 During storage and transportation, necessary measures are to be taken to protect synthetic fiber ropes for offshore mooring from the effects of ultra-violet radiation and moisture, and the ambient temperature is not to exceed permissible limits as appropriate.
7.2.6.2 In general, synthetic fiber ropes for offshore mooring are stored/wrapped onto a reel. Adequate protection is to be provided to prevent chafing of the ropes in the storage reel.
7.2.6.3 It is to be noted that the bending radius at termination is not to be less than the manufacturer's recommended allowable minimum bending radius.
7.2.6.4 Metallic end fittings are to be wrapped or kept separately to prevent adverse effects on the rope.

7.2.7 Marking and certificate
7.2.7.1 Each coil of completed rope is to be marked at a clearly visible position (such as protective jacket) with the rope name, diameter and length and the maker's name (or brand name).
7.2.7.2 The fiber ropes which have been accepted are to be identified with securely attached labels (lead sealing recommended) detailing at least the rope no., material, construction and additionally identified with CCS stamp at the end of each rope.

7.2.7.3 The manufacturer is to provide qualified fiber ropes with a qualification certificate detailing at least:
(1) product name, type and no.;
(2) material of fiber ropes;
(3) linear density of fiber ropes;
(4) length and diameter of a whole fiber rope coil;
(5) construction of fiber ropes;
(6) nominal breaking load of fiber ropes and actual wet breaking load;
(7) date of manufacture and inspection;
(8) highest service temperature;
(9) shelf-life of product.

PART THREE　WELDING

CHAPTER 1 GENERAL

Section 1 GENERAL PROVISIONS

1.1.1 Application

1.1.1.1 This PART applies to the welding of ship structures, offshore structures, boilers, pressure vessels, submersibles, piping systems and important machinery components, as well as to the approval of welding consumables and qualification tests of welders.

1.1.1.2 The requirements of this PART apply to manual arc welding, submerged arc welding, gas shielded arc welding and electro-slag welding processes. Other welding processes are to be approved by CCS and relevant documents proving applicability are to be provided.

1.1.1.3 Where welding consumables including novel welding consumables, other than those specified in the Rules are proposed for use in the construction of ships or offshore structures, relevant technical data such as chemical compositions, mechanical properties and methods of testing are to be submitted to CCS for approval.

1.1.1.4 The welding of higher strength hull structural steels for large container ships with thicknesses of 50 mm to 100 mm and the specified minimum yield strength not less than 460 N/mm^2 is to comply with the requirements of CCS Guidelines for Inspection of Thick Higher Strength Steel Plates for Ships, in addition to the relevant requirements of this PART.

1.1.2 Welding consumables, facilities and operating environment

1.1.2.1 Welding consumables (including electrodes, wires, fluxes and shielding gases) are to comply with the relevant requirements of Chapter 2 of this PART, and are to be approved by CCS.

1.1.2.2 The storage, transportation, preliminary treatment (including baking of electrodes and fluxes, rust–removing of wires, dehumidification of shielding gases) and usage of welding consumables are to be in accordance with the instructions of manufacturers.

1.1.2.3 Welding plant and appliances are to be suitable for the intended purpose and are to be maintained in an efficient condition. And they are to be properly arranged so as to provide good conditions for welding operations.

1.1.3 Welders and welding procedures

1.1.3.1 In order to ensure welding quality, welders engaged in building ships, offshore structures or manufacturing marine products are to take part in qualification tests in accordance with the requirements in Chapter 4 of this PART. Only the welders holding a Qualification Certificate of Welder issued or accepted by CCS are permitted to engage in welding operations appropriate to their qualified range of work.

1.1.3.2 The welding procedure specification is to be submitted to CCS for approval in accordance with Chapter 3 of this PART.

1.1.4 Control and non-destructive testing personnel

1.1.4.1 The works are to be provided with a perfect quality assurance department capable of operating efficiently. All important welds are to be made under the supervision of skilled supervisors so as to ensure the quality of welding.

1.1.4.2 Non-destructive testing personnel are to hold a Qualification Certificate of NDT Personnel issued or accepted by CCS, and can only engage in the non-destructive testing appropriate to their qualified category and level of work.

Section 2 TESTING

1.2.1 General requirements

1.2.1.1 Unless otherwise specified in this Section, the methods for mechanical tests of welds are to comply with the requirements of Chapter 2 of PART ONE of the Rules.

1.2.2 Preparation of test specimens

1.2.2.1 The dimensions of samples and the positions of specimens are to comply with the relevant requirements of this PART.

1.2.2.2 When test material is cut from products, a reasonable margin is required to allow sufficient material, which would affect test results, to be removed from the cut edges by machining of test specimens.
1.2.2.3 If any test specimen shows defects irrelevant to the welding, it may be discarded and another specimen substituted.

1.2.3 Shapes and dimensions of specimens

1.2.3.1 Deposited metal tensile test specimens (longitudinal) are to be machined to the dimensions shown in Figure 1.2.3.1. The specimens may be heated to a temperature not exceeding 250℃ for a period not exceeding 16 h for hydrogen removal, prior to testing.

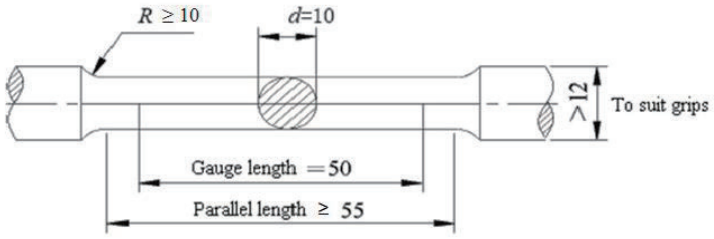
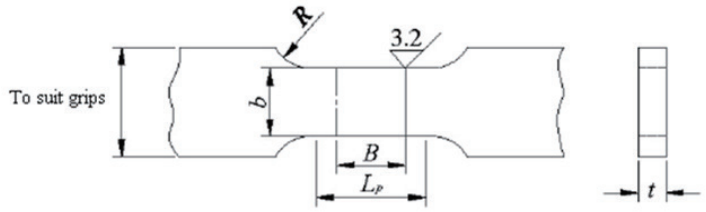
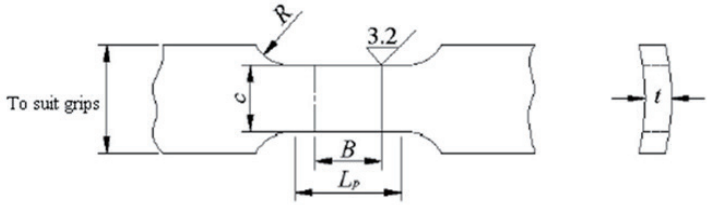


Figure 1.2.3.1

1.2.3.2 Butt weld tensile test specimens (transverse) are to be machined to the dimensions shown in Figure 1.2.3.2(1). The upper and lower surfaces of the weld are to be filed, ground or machined flush with the surface of the plate.
When the breaking strength of a test specimen exceeds the capacity of the test machine, the test specimen may be divided into several portions in accordance with Figure 1.2.3.2(2), and the thickness of each portion is not to be less than 25 mm. The average value of the test results obtained from the portions is to be taken as the test result of the full thickness butt weld joint.



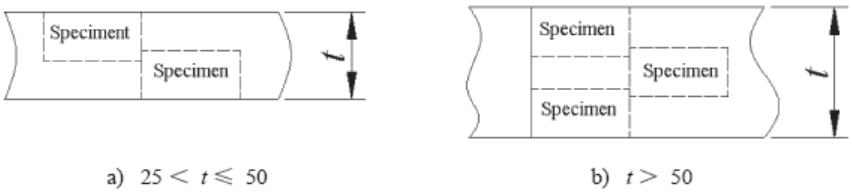
a) Flat specimen



b) Tubular specimen

B – Width of weld, in mm; *t* – Thickness of specimen, in mm; *b* – Parallel breadth of flat specimen, to be taken as 25 mm (for $t > 2$ mm) or 12mm (for $t \leq 2$ mm); *c* – Parallel breadth of tubular specimen, to be taken as 20 mm for tube diameter equal to or greater than 76 mm, and 12 mm or full tube for tube diameter less than 76 mm; L_P – Parallel length of specimen, to be taken as *B*+60 mm; *R* – Radius of curvature, taken as greater than 25 mm.

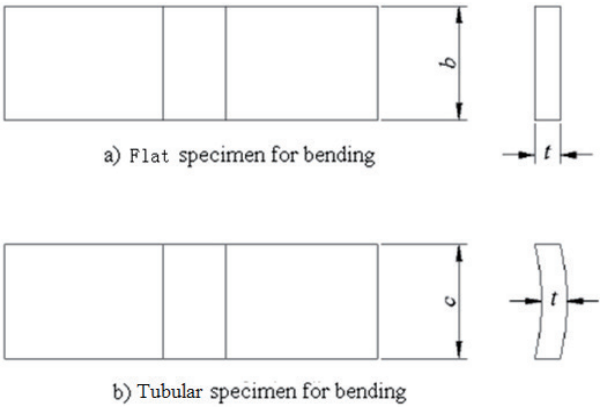
Figure 1.2.3.2(1)



a) $25 < t \leqslant 50$ b) $t > 50$

Figure 1.2.3.2(2)

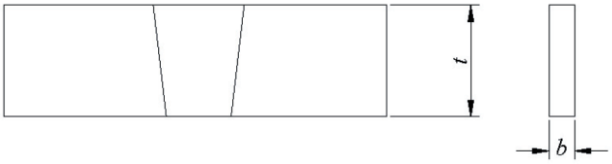
1.2.3.3 Butt weld face and root bend test specimens are to be machined to the dimensions as shown in Figure 1.2.3.3. The upper and lower surfaces of the weld are to be filed, ground or machined flush with the surface of the plate. The edges on the tension side may be rounded to a radius of 1 mm to 2 mm. For tubular specimens, the compression side may be machined to a plane.



t – Thickness of specimen, to be taken as the thickness of parent plate. Where the thickness exceeds 25 mm, the specimens may be machined on the compression side to reduce the thickness to 25 mm. For aluminum alloys, thickness reduction is not to be applied; b – Breadth of flat specimen, to be taken as 30 mm; c – Breadth of tubular specimen, taken as $t + 0.1d$, but neither less than 10 mm, nor more than 30 mm, where d is the outside diameter of tubular specimen, in mm.

Figure 1.2.3.3

1.2.3.4 Butt weld side bend test specimens are to be machined to the dimensions as shown in Figure 1.2.3.4. The upper and lower surfaces of the weld are to be machined flush with the surface of the plate. The edges on the tension side may be rounded to a radius of 1 to 2 mm.



t – Thickness of the test plate, in mm. When t is greater than 40 mm, the specimen may be divided into several portions with t equal to 20 mm ~ 40 mm; b – Thickness of specimen, to be taken as 10 mm.

Figure 1.2.3.4

1.2.3.5 Longitudinal butt-weld face and root bend specimens are to be machined to the dimensions as shown in Figure 1.2.3.5 and Table 1.2.3.5. The welds of upper and lower surfaces of the specimen are to be machined flush with the surface of the plate. If the joint thickness is more than 20 mm or the capacity of the test machine is insufficient, the compression side of the specimen may be machined to 20 mm. The edges on the tension side may be rounded to a radius of 1 to 2 mm. The radius of the former is to be as required for high strength of base metal.

Dimensions of Longitudinal Bend Specimen **Table 1.2.3.5**

a	b	L
$a \leq 6$	20	180
$6 < a \leq 10$	30	200
$10 < a \leq 20$	50	250

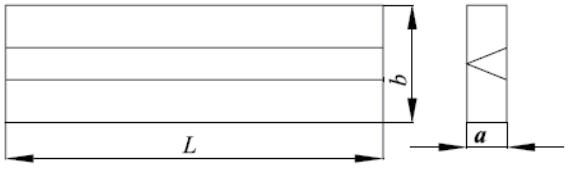


Figure 1.2.3.5 Longitudinal Bend Specimen

1.2.3.6 Charpy V-notch impact test specimens are to be machined to the dimensions as specified in PART ONE of the Rules, and the position of the V-notch is to comply with the relevant requirements of this PART. Unless otherwise specified, the notch is to be perpendicular to specimen surface and weld axis.
1.2.3.7 Macro specimens are to be taken by fracturing the test plate at the weld joint in a direction perpendicular to the weld, having a length including at least 10 mm unaffected base metal. The complete cross section of the fractured surface in way is to be ground, polished and acid-etched for examination.
1.2.3.8 Hardness test specimens may be taken using the method specified for macro specimens in 1.2.3.7 of this Section, and the complete cross section of the fractured surface in way is to be ground and polished.

1.2.4 Testing

1.2.4.1 The procedures used for tensile and impact tests are to comply with the relevant requirements of Sections 2 and 3 of Chapter 2, PART ONE of the Rules.
1.2.4.2 Bend tests are generally to be carried out at ambient temperature. A former, having a specified diameter and with its axis perpendicular to the center of the weld, is to be used to push and bend the specimen. Where the yield strength of the weld and parent metal, or of two parent metals, differs significantly (such as aluminium alloy, dissimilar steel joint), wrap around method bend test as indicated in Figure 1.2.4.2 is recommended. The face, root or side bend test is to be such that the bend test specimen is tested with the face, root or side of the weld in tension respectively. Unless otherwise specified, the diameter of the former and the bending angle are to be as follows:

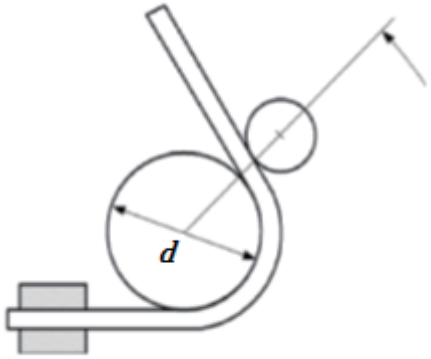


Figure 1.2.4.2 Wrap Around Method Bend Test

(1) Bend tests of structural steels are to comply with the requirements of Table 1.2.4.2(1).

Requirements for Bend Tests of Structural Steels **Table 1.2.4.2(1)**

Purpose of test	Specified yield strength of test material (N/mm^2)	Diameter d of former	Bending angle α
For approval of welding consumables	$R_{eH} \le 400$ $400 < R_{eH} \le 500$ $500 < R_{eH} \le 690$	$3t$ $4t$ $5t$	120°
For approval of welding procedures	$R_{eH} \le 400$ $400 < R_{eH} \le 500$ $500 < R_{eH} \le 690$	$4t$ $5t$ $6t$	180°

Notes: ① t is the thickness of the specimen.
② For approval test of welding procedures for boilers and pressure vessels, the former diameter is to comply with Table 7.2.3.4 of this PART.

(2) The bend tests of aluminum alloy welds are to comply with the following requirements:

a. Tests for approval of welding consumables are to comply with the requirements of Table 2.9.3.7 of this PART.
b. The bending angle for approval tests of welding procedures is to be 180°, and the diameter of the former is not to be greater than the value obtained from the following formula:

$$d = \frac{(100 \times t_s)}{A} - t_s$$

where: d – maximum former diameter, in mm;
t_s – thickness of bend test specimens (including side bend specimens), in mm;

A – minimum tensile elongation required by the alloy grade, temper condition and thickness (for combinations of different alloys, the lowest individual value is to be used), in %.

(3) The bend tests of austenitic and duplex stainless steel welds are to comply with the following requirements:

a. Tests for approval of welding consumables are to comply with the requirements of Table 2.8.4.3 of this PART.

b. The bend tests for approval of welding procedures are to comply with the requirements of Table 1.2.4.2(3) of this PART.

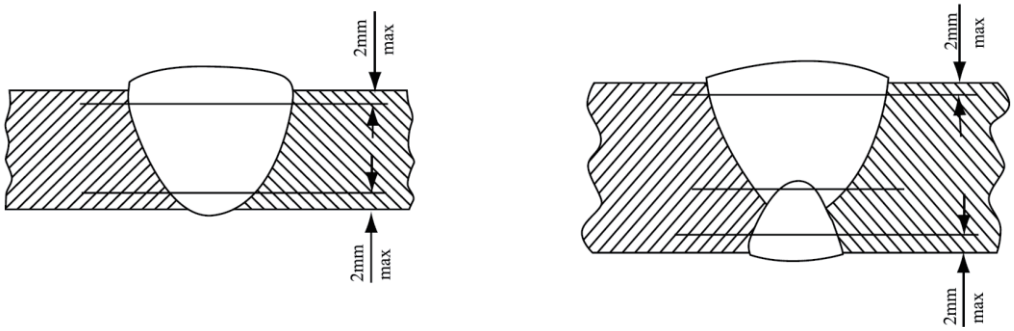
Requirements for Bend Test of Austenitic and Duplex Stainless Steel Welds

Table 1.2.4.2(3)

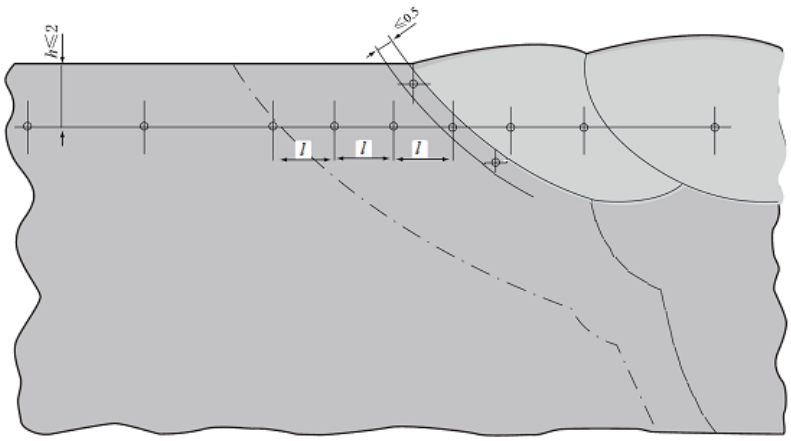
Test material		Diameter of the former, d	Bending angle, a
Austenitic stainless steel		4t	180°
Duplex stainless steel	S22253 S22053	4t	180°
	S25554 S25073	6t	180°

Note: t is the thickness of the specimen.

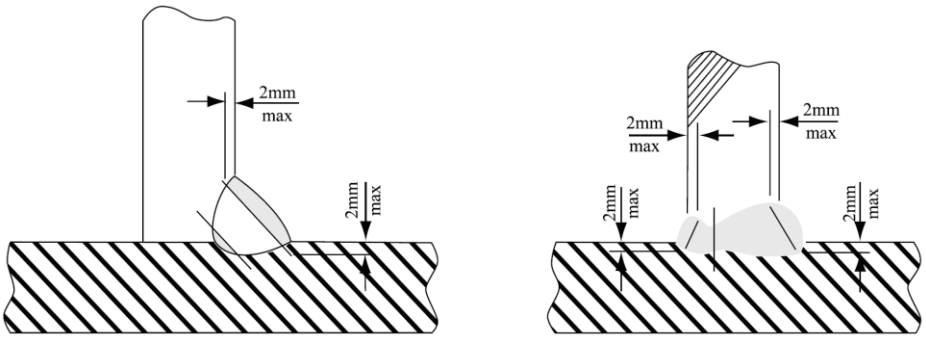
1.2.4.3 Unless otherwise specified in this PART, hardness measurements are to be carried out by means of a Vickers hardness tester along the rows as shown in Figure 1.2.4.3, normally applying a force of 98 N. A minimum of 3 individual points in each area of the weld metal, the fusion line, the heat affected zone and the base metal are to be measured and the distance between measuring points is to be such that they will not interfere with each other (the recommended distance l between indentations for hardness test in the heat affected zone is 1 mm).



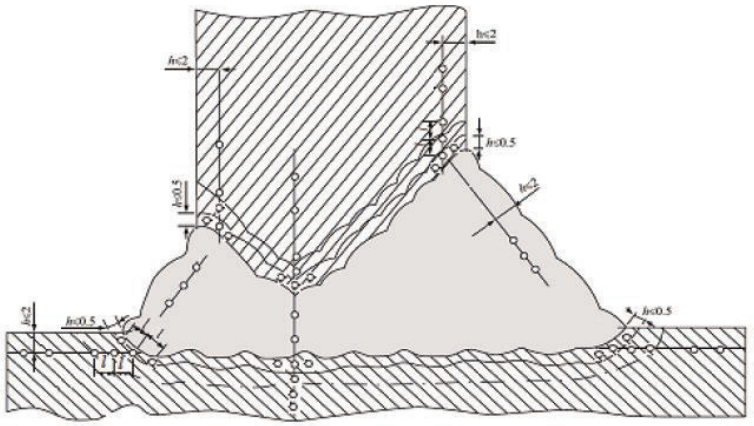
(1) Hardness Measuring Rows of Butt Weld



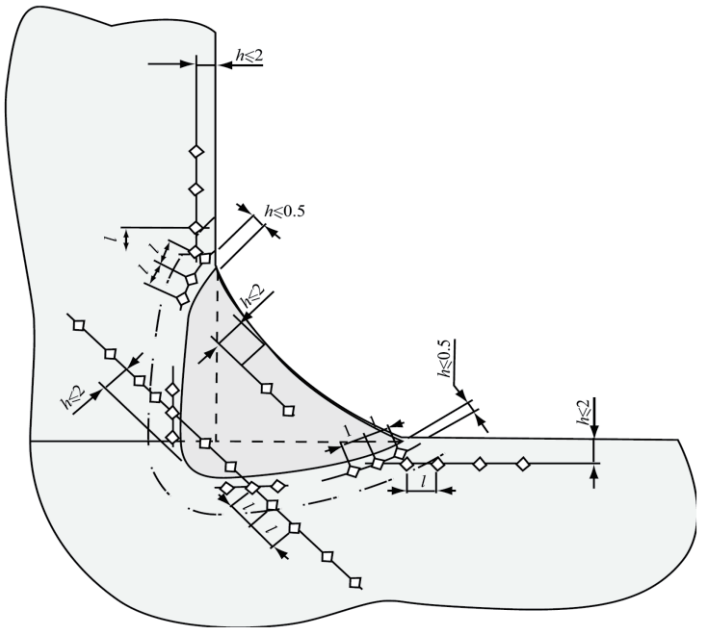
(2) Example Showing Positions of Measuring Points in Each Area of Butt Weld



(3) Hardness Measuring Rows of Fillet Weld



(4) Example Showing Positions of Measuring Points in Each Area of Full Penetration Fillet Weld



(5) Example Showing Positions of Measuring Points in Each Area of Fillet Weld

Figure 1.2.4.3 Weld Hardness Test

1.2.4.4 Fillet weld fracture tests are to be carried out as shown in Figure 1.2.4.4. A force is applied to the top of the abutting plate, with the root of the weld in tension and then fractured. If fracturing is unlikely, the surface of weld may be grooved to a depth not greater than 20% of the throat thickness.

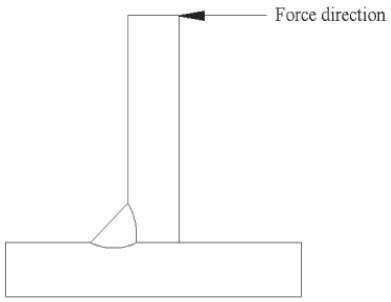


Figure 1.2.4.4

1.2.5 Acceptance and re-tests

1.2.5.1 All results are to comply with the relevant requirements of this PART. For impact tests, the average energy value of the results from one set of 3 specimens is taken for acceptance purposes, in which one individual value may be less than the required average value provided that it is not less than 70% of this value. On butt weld specimens, the values of tensile strength are to be recorded together with the position of fracture.

1.2.5.2 Where the result of any specimen, except for impact tests, is unacceptable, duplicate test specimens of the same type may be prepared from the original welded assembly or from a new assembly rewelded with the same procedure and using welding consumables from the same batch, and the results of all re-tests are to be satisfactory.

1.2.5.3 Where the results from a set of 3 impact test specimens do not comply with the requirements, an additional set of 3 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 value, which, for acceptance, is not to be less than the required 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 the average value.

1.2.5.4 If there is a single hardness value above the maximum values allowed, additional hardness tests are to be carried out (on the reverse of the specimen or after sufficient grinding of the tested surface).

1.2.5.5 If the above re-tests again fail, further re-tests may be made, which are to be made on a new welded assembly and to include all tests required for the original assembly.

1.2.5.6 All test results are to be recorded in the test report.

CHAPTER 2 WELDING CONSUMABLES

Section 1 GENERAL PROVISIONS

2.1.1 Application

2.1.1.1 This Chapter applies to welding consumables such as electrodes, wires and fluxes intended for use in the welding of metallic structures as specified in the Rules.

2.1.1.2 Sections 1 to 7 of this Chapter mainly apply to consumables for welding structural steels, Section 8 applies to consumables for welding stainless steels and Section 9 applies to consumables for welding aluminum alloys.

2.1.1.3 For welding consumables other than those specified in this Chapter, details of the technical specification are to be submitted to CCS and such welding consumables can only be used upon verification by relevant tests.

2.1.2 Works approval

2.1.2.1 Welding consumables are to be made at works which have been approved by CCS, and the steels used for making the welding consumables are also to be supplied by steelmakers which have been approved by CCS.

2.1.2.2 Manufacturers of welding consumables are to have good conditions of production, mature manufacturing procedures and a perfect quality management system so as to ensure stable and reliable quality of products.

2.1.2.3 Builders of ships and offshore installations as well as manufacturers of marine products are to use the welding consumables approved by CCS.

2.1.3 Approval tests

2.1.3.1 All types of welding consumables are to be subjected to approval tests in accordance with the requirements detailed in this Chapter. CCS Surveyor may require, in any particular case, additional tests as may be necessary.

2.1.3.2 Unless otherwise specified in this Chapter, the specimens, test requirements and re-test conditions for the approval tests are to comply with the relevant requirements of Section 2 of Chapter 1 of this PART.

2.1.3.3 During approval tests, the preparation and testing of the test specimens are to be carried out in the presence of CCS Surveyor. It is recommended that the welded test assembly be examined by radiographic testing to ascertain that no defect exists in the welds that will affect the accuracy of test results. Welded test assemblies and test specimens are not to be subjected to any heat treatment after welding, except longitudinal deposited metal tensile test specimens. Heat treatment for hydrogen removal is not to be applied to longitudinal deposited metal tensile test specimens of low hydrogen welding consumables.

2.1.3.4 The manufacturer of welding consumables is to submit a test report to CCS Surveyor, containing the following items:

(1) test date, ambient conditions and pre-treatment of welding consumables;

(2) grade as approved, brand, type and size of welding consumables;

(3) material (brand), grade, mechanical properties and chemical composition (including grain refining elements) of test plates;

(4) welding positions;

(5) welding current, voltage, rate of deposit, the model of welding machines and composition of shielding gas;

(6) all test results.

2.1.3.5 For all grades of welding consumables, the grade of steels used for the preparation of test assemblies may be selected from those listed in Table 2.1.3.5, and a toughness grade lower than that required in the Table may also be selected. For testing the deposited weld metal, any steel grade may be selected for welding consumables of grade Y40 and below; steels compatible with the properties of the weld metal may be selected for grade Y42 and above, or prepared edges of the base metal is to be built up with welding consumables which are to be approved; and for low-alloy steel containing nickel and stainless steel, the side walls of the weld are in general to be buttered with a weld metal of the same composition. When the building-up method is to be used, it is recommended that one or two layers be built up using appropriate welding consumables before the test assembly is fitted.

Grade of Steel for Approval Test **Table 2.1.3.5**

Grade of welding consumables	Grade of steel for test	Grade of welding consumables	Grade of steel for test	Grade of welding consumables	Grade of steel for test
1	A	3Y42	D420	5Y55	F550
2	B, D	4Y42	E420	3Y62	D620
3	E	5Y42	F420	4Y62	E620
1Y	AH32, AH36	3Y46	D460	5Y62	F620
2Y	DH32, DH36	4Y46	E460	3Y69	D690
3Y	EH32, EH36	5Y46	F460	4Y69	E690
4Y	FH32, FH36	3Y50	D500	5Y69	F690
2Y40	DH40	4Y50	E500	1.5Ni	1.5Ni
3Y40	EH40	5Y50	F500	3.5Ni	3.5Ni
4Y40	FH40	3Y55	D550	5Ni	5Ni
5Y40	FH40	4Y55	E550	9Ni	9Ni

2.1.3.6 The plate edges are generally to be processed by machining or plasma cutting. Steel may also be processed using the oxy-acetylene method or other appropriate automatic cutting methods. If a hot work method is applied, any remaining scale is to be removed from the beveled edges.

2.1.3.7 The welding current, arc voltage and travel speed, etc., are to be in accordance with the manufacturer's recommendations. Where a type of welding consumables is stated to be suitable for both alternating current (AC) and direct current (DC), AC is to be used for the preparation of the test assemblies.

2.1.4 Maintenance of approval

2.1.4.1 Welding consumables which have been approved are to be subjected to annual inspection and tests so as to maintain the approval of the welding consumables.

2.1.4.2 Where any alteration to the manufacturing processes or procedures of the approved welding consumables is proposed by the manufacturer, CCS is to be notified of this alteration, and CCS will consider, according to the particular circumstances of such an alteration, whether the approval will be maintained or a new approval test is to be made.

2.1.4.3 In the following cases, CCS will inform the manufacturer that the approval of the welding consumables is revoked:

(1) where the consumables fail to meet the requirements at the annual inspection and testing; or

(2) where the manufacturer fails to receive annual inspection and testing without acceptable reasons; or

(3) where the results of any random check indicate that the quality of the welding consumables is remarkably worse than that at the approval test.

2.1.5 Markings and instructions for use

2.1.5.1 Each box or package of welding consumables approved by CCS is to be clearly marked with CCS approval logo.

2.1.5.2 For the approved welding consumables, a copy of instructions for use, containing the storing, baking and welding parameters recommended by the manufacturer is to be attached to each package or box of the consumables.

Section 2 MECHANICAL PROPERTIES OF WELDING CONSUMABLES

2.2.1 General requirements

2.2.1.1 In addition to the requirements of this Section, welding consumables are, depending on their usage, to be subjected to approval tests and annual tests in accordance with the relevant requirements of this Chapter.

2.2.2 Consumables for welding structural steels

2.2.2.1 Consumables for welding structural steels are graded into nine levels of yield stress, and each of which is further subdivided into several levels in respect of notch toughness. Designations of different grades are shown in Table 2.1.3.5. The notch toughness is indicated by the numerals 1 to 5, and the letter Y stands for high-strength welding consumables. Where the yield stress of welding consumables is greater than 400 N/mm^2, Y is to be followed by a numeral from 40 to 69. Consumables for the nickle alloy steel are divided into four levels of 1.5Ni, 3.5Ni, 5Ni and 9Ni in respect of the content of nickel in the base metal.

2.2.2.2 For each grade of consumables for welding structural steels, the consumables which have satisfied the requirements for a higher toughness grade are considered as complying with the requirements for a lower toughness grade.

2.2.2.3 The mechanical properties of consumables for welding structural steels are to comply with the requirements given in Table 2.2.2.3.

Mechanical Properties of Consumables for Welding Structural Steels **Table 2.2.2.3**

Grade of welding consumables			1, 2, 3	1Y, 2Y 3Y, 4Y①	2Y40 3Y40 4Y40 5Y40	3Y42 4Y42 5Y42	3Y46 4Y46 5Y46	3Y50 4Y50 5Y50	3Y55 4Y55 5Y55	3Y62 4Y62 5Y62	3Y69 4Y69 5Y69	1.5Ni	3.5 Ni	5 Ni	9Ni
Deposited metal test	Yield strength⑦ R_{eH} (N/mm^2)		≥305	≥375	≥400	≥420	≥460	≥500	≥550	≥620	≥690	≥375			
	Tensile strength⑧ R_m (N/mm^2)		400-560	490-660	510-690	530-680	570-720	610-770	670-830	720-890	770-940	≥460	≥420	≥500	≥600
	Elongation A(%)		≥22			≥20		≥18			≥17	≥22	≥25		
	Charpy V-notch impact test	Test temp. (℃)	②									-80	-100	-120	-196
		Average impact energy⑥(J)	≥47③			≥47		≥50	≥55	≥62	≥69	≥34			
Butt weld test	Transverse tensile strength (N/mm^2)		≥400	≥490	≥510	≥530	≥570	≥610	≥670	≥720	≥770	≥490	≥450	≥540	≥640
	Charpy V-notch impact test	Test temp. (℃)	②									-80	-100	-120	-196
		Average impact energy⑥(J)	≥47④			≥47		≥50	≥55	≥62	≥69	≥34			
	Bend test		After testing, the test specimens are not to reveal any open defects in any direction greater than 3 mm⑤												

Notes: ① Manual arc welding electrodes are to comply with Grade 2Y and above.

② The temperature of impact test for welding consumables of Grade 1 and Grade 1Y is to be 20℃;
for those of Grades 2, 2Y, 2Y40 to be 0℃;
for those of Grades 3, 3Y, 3Y40, 3Y42, 3Y46, 3Y50, 3Y55, 3Y62, 3Y69 to be -20℃;
for those of Grades 4Y, 4Y40, 4Y42, 4Y46, 4Y50, 4Y55, 4Y62, 4Y69 to be -40℃;
for those of Grades 5Y40, 5Y42, 5Y46, 5Y50, 5Y55, 5Y62, 5Y69 to be -60℃.

③ The average impact energy of deposited metal test of submerged arc automatic welding is not to be less than 34 J for welding consumables with R_{eH} < 400 N/mm^2; not to be less than 39 J for those with R_{eH} ≥ 400 N/ mm^2.

④ The average impact energy of butt joints of vertical welding and submerged arc automatic welding is not to be less than 34 J for welding consumables with R_{eH} < 400 N/mm^2; not to be less than 39 J for those with R_{eH} ≥ 400 N/mm^2.

⑤ Except for 5Ni and 9Ni steel specimens to be bend tested with a former of diameter four times the plate thickness, the diameter of former is to comply with the requirements of 1.2.4.2 of this PART.

⑥ Energy values from individual impact test specimens are not to be less than 70% of the specified values.

⑦ In case of no marked yield stress, the proof stress $R_{P0.2}$ is to be reported.

⑧ Where the tensile strength exceeds the specified maximum value, special consideration is to be given by CCS.

2.2.2.4 Where the bend test results of welding consumables with the yield stress of 420 N/mm^2 or above do not comply with Table 2.2.2.3, except that the elongation within the gauge length L_0 of bend specimens complies with that required for the deposited metal test, the test may be considered satisfactory. The gauge length L_0 of the bend specimen is shown in Figure 2.2.2.4.

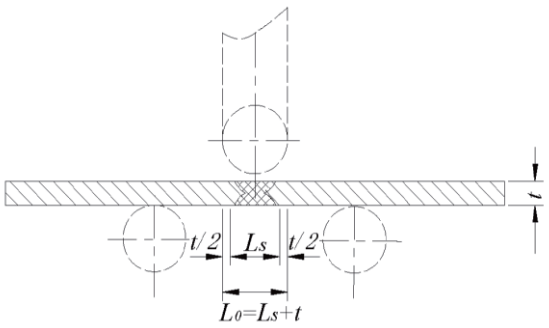


Figure 2.2.2.4

Section 3 ELECTRODES FOR MANUAL ARC WELDING

2.3.1 General requirements

2.3.1.1 For electrodes which have satisfied the requirements for mechanical properties as given in Section 2 of this Chapter and passed the hydrogen test according to 2.3.6.3 of this Section, the suffix “H15”, “H10” or “H5” will be added after the grade mark to indicate compliance with the requirements for low hydrogen electrodes. The diffusible hydrogen content for electrodes of different grades is at least to comply with Table 2.3.1.1.

Required Hydrogen Content for Welding Consumables Table 2.3.1.1

Grade of welding consumables	Diffusible hydrogen content
1, 2, 3, 1Y, 2Y, 3Y	Not mandatory
4Y, 2Y40, 3Y40, 4Y40	H15
3Y42, 4Y42, 5Y42, 3Y46, 4Y46, 5Y46, 3Y50, 4Y50, 5Y50	H10
3Y55, 4Y55, 5Y55, 3Y62, 4Y62, 5Y62, 3Y69, 4Y69, 5Y69	H5

2.3.1.2 Where electrodes for welding structural steels have deep penetration properties, the suffix “DP” will be added after the appropriate grade mark for normal penetration welding. Only grade 1 electrodes can be approved as deep penetration electrodes.

2.3.1.3 Where an electrode is to be used in contact welding using automatic gravity or similar welding devices, tests similar to those for normal manual electrodes are to be carried out using the devices and processes for which the electrode is recommended by the manufacturer.

2.3.2 Tests

2.3.2.1 All electrodes are to be subjected to the deposited metal test.

2.3.2.2 Butt weld test assemblies are to be prepared for the welding positions for which the electrode is recommended by the manufacturer, e.g. downhand, horizontal, vertical (vertical-upward or vertical-downward) and overhead positions.

Electrodes satisfying the requirements for both downhand and vertical-upward positions will be considered as also complying with the requirements for the horizontal position. Where the electrode is recommended for welding in all positions, the test assemblies are to be prepared for the down hand, vertical and overhead positions.

2.3.2.3 In addition to the requirements of 2.3.2.1 and 2.3.2.2, for normal electrodes having fillet welding properties, one fillet weld test in the horizontal position is to be made. Where an electrode is solely used for fillet welding, in addition to the deposited metal test, fillet weld tests are to be made in the welding positions as recommended by the manufacturer, such as downhand, vertical and overhead positions.

2.3.2.4 Electrodes requiring the control of diffusible hydrogen (e.g. low hydrogen or ultra-low hydrogen electrodes) are, in addition to compliance with the requirements of mechanical properties for the appropriate grade, to be subjected to a hydrogen test.

2.3.2.5 Where grade 1 electrodes are submitted for approval for deep penetration welding, in addition to compliance with the requirements for grade 1 electrodes, tests for deep penetration welding of downhand butt joints and horizontal-vertical fillets are to be carried out. Where an electrode is submitted only for the deep penetration welding of downhand butt joints and horizontal-vertical fillets, in addition to the deposited metal test as required by 2.3.3, deep penetration welding tests are to be carried out in accordance with the requirements of 2.3.7 and 2.3.8 of this Section.

2.3.2.6 Where an electrode is submitted solely to approval for use in contact welding using automatic gravity or similar welding devices, deposited metal tests, fillet weld tests and, where appropriate, butt weld tests similar to those for normal manual electrodes are to be carried out using the process for which the electrode is recommended by the manufacturer. Where a covered electrode is submitted to approval for use in contact welding using automatic gravity or similar welding devices in addition to normal manual welding, fillet weld and, where appropriate, butt weld tests, using the gravity of other contact device as recommended by the manufacturer, are to be carried out in addition to the normal approval tests.

In the case of a fillet welding electrode using automatic gravity or similar contact welding devices, the fillet welding is to be carried out using the welding process recommended by the manufacturer, with the longest size of the electrode manufactured. The manufacturer’s recommended current range is to be reported for each electrode size.

Where approval is requested for the welding of both normal strength and higher strength steel, the assemblies are to be prepared using higher strength steel.

2.3.3 Deposited metal tests

2.3.3.1 In general, two deposited metal test assemblies are to be prepared, 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.

2.3.3.2 Two test plates and one backing plate are to be prepared for each deposited metal test assembly. The plates are to be 20 mm in thickness, not less than 100 mm in width and about 300 mm in length, with the edge being beveled to an angle of 10°. The backing plate is to be 10 mm in thickness, 30 mm in width and of a length equal to that of the test plates.

2.3.3.3 The test assembly is to be fitted up as shown in Figure 2.3.3.3. The weld metal is to be deposited in downhand single-run or multi-run layers according to normal practice, and the direction of deposition of each layer is 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. After completion of each run, the flux and welding slag are to be removed, and the assembly is to be left in still air until it has cooled to less than 250℃, but not below 100℃ (the temperature being taken in the centre of the weld on the surface of the weld), then the next run is to start.

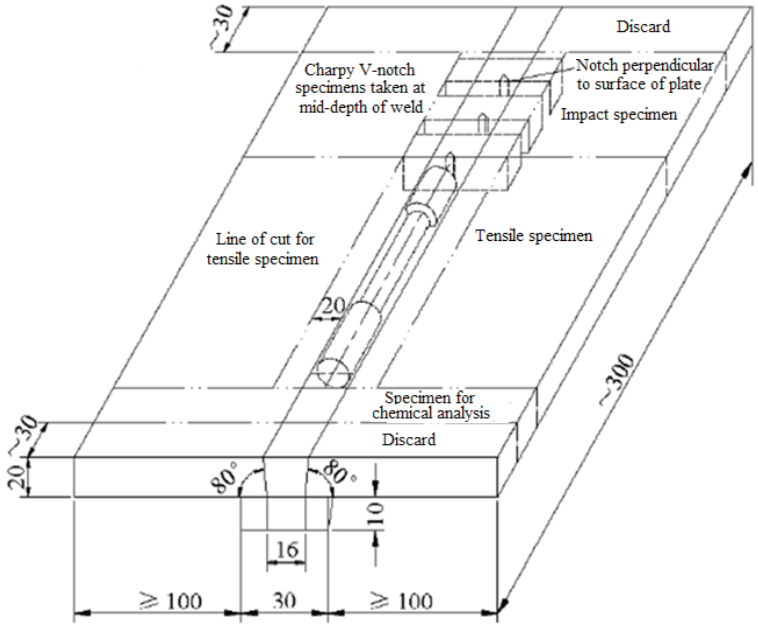


Figure 2.3.3.3

2.3.3.4 One longitudinal tensile test specimen and a set of three V-notch impact test specimens are to be taken from each test assembly as shown in Figure 2.3.3.3. The results of tensile and impact tests are to comply with the relevant requirements of Section 2 of this Chapter. The axis of the tensile test specimen is to coincide with the centre of the weld and the mid-thickness of the plates as far as possible. The axes of the impact test specimens are to coincide with the mid-thickness of the plates, perpendicular to the centre of the weld. The V-notch is to be positioned in the centre of the weld and perpendicular to the surface of the plate.

2.3.3.5 In addition to the requirements of 2.3.3.4, the chemical composition of the deposited metal is to be analyzed for each test assembly. The analysis report is to be submitted to CCS and the content of all significant alloying elements is to be included in the report. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer.

2.3.4 Butt weld tests

2.3.4.1 One butt weld test assembly is to be prepared for each welding position, and the electrodes employed for different positions are to be as follows:

(1) Downhand: the first run with 4 mm diameter electrode, remaining runs (except the last two layers) with 5 mm diameter electrodes. The runs of the last two layers with the largest diameter of electrode manufactured for the same type for which approval is requested.

(2) Horizontal-vertical: the first run with 4 mm or 5 mm diameter electrode, remaining runs with 5 mm

diameter electrodes.
(3) Vertical-upward and overhead: the first run with 3.2 mm diameter electrode, remaining runs with 4 mm diameter electrodes or possibly with 5 mm if this is recommended by the manufacturer for the positions concerned.
(4) Vertical-downward: using electrode diameters as recommended by the manufacturer.
Where only one or two sizes are available for the same type of electrode, then in the welding positions mentioned above, the first run is to be applied with the small diameter electrode and the remaining runs with the larger.
2.3.4.2 Where the electrode is to be approved only for the downhand position, in addition to the test assembly as required by 2.3.4.1(1) of this Section, another test assembly is to be prepared in that position. The first run is to be made with 4 mm diameter electrode, next run with 5 mm or 6 mm diameter electrode, and remaining runs with the largest diameter of electrode manufactured for the same type for which approval is requested.
2.3.4.3 Each butt weld test assembly is to be made by welding together two plates of equal thickness (15 to 20 mm), not less than 100 mm in width and of sufficient length to allow the cutting out of test specimens of the prescribed number and size. The plate edges are to be beveled to an angle of 30°.
2.3.4.4 The test plates are to be fitted and welded together as shown in Figure 2.3.4.4. The interpass temperature is to be neither more than 250℃ nor less than 100℃ (the temperature being taken in the center of the weld on the surface of the seam). For all butt weld test assemblies, the back sealing runs are to be made with 4 mm diameter electrodes in the welding position appropriate to each test sample, after cutting out the root run to clean metal.
In order to keep the test assembly smooth and straight after welding, preset backward deformation may be applied prior to welding.

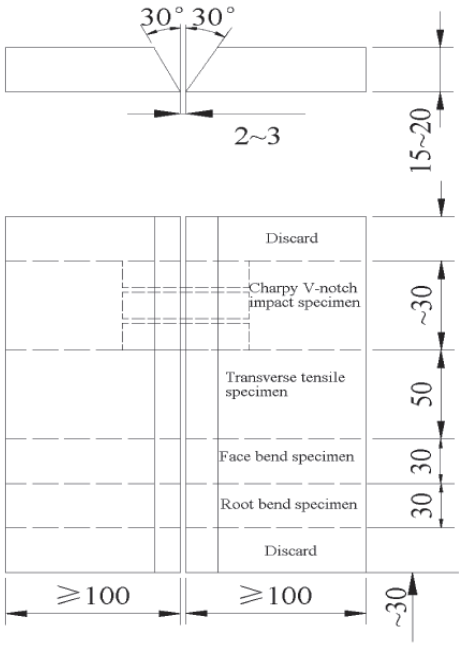


Figure 2.3.4.4

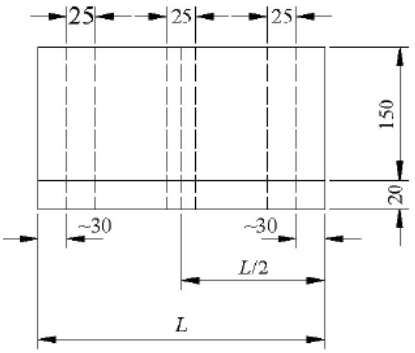
2.3.4.5 One transverse tensile specimen, two bend specimens and a set of three impact test specimens are to be prepared from each test assembly (the axis of the specimen being at the middle of plate thickness) as shown in Figure 2.3.4.4 for tensile, face and root bend and impact tests respectively. The results of all tests are to comply with the relevant requirements of Section 2 of this Chapter.

2.3.5 Fillet weld tests

2.3.5.1 One fillet weld test assembly is to be prepared for each welding position. The first side is to be welded using the maximum diameter and the second side the minimum diameter of electrode manufactured. The fillet size will in general be determined by the electrode size and the welding current employed during testing.
2.3.5.2 Each fillet weld test assembly is to be made by welding together two plates of 20 mm in thickness, 150 mm in width and of a length sufficient to allow at least the deposition of the entire length of the largest

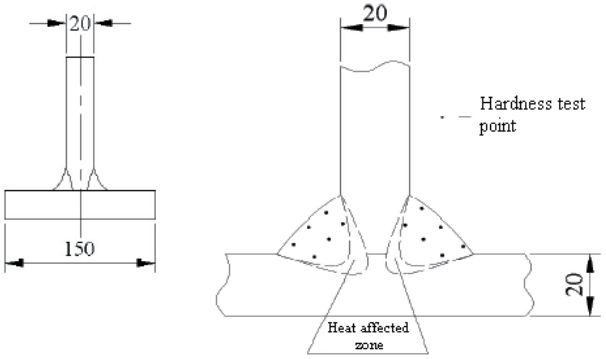
diameter electrode being tested.

2.3.5.3 As shown in Figure 2.3.5.3(1), three macro-sections, each about 25 mm thick, are to be taken from the test assembly and examined for root penetration, satisfactory profile, freedom from cracking and reasonable freedom from porosity, and slag inclusions. The central macro-section is to be polished for hardness tests as shown in Figure 2.3.5.3(2), for the purpose of determining the hardness of the welded joint. One of the two remaining sections is to have the weld on the first side gouged or machined. On the other remaining section, the weld on the second side is to be gouged or machined. The two sections are then to be subjected to fracture tests in accordance with the requirements given in 1.2.4.4 of this PART. The fractured surfaces are to show satisfactory penetration, freedom from cracks and porosity.



a)

Figure 2.3.5.3(1)



b)

Figure 2.3.5.3(2)

2.3.6 Hydrogen test

2.3.6.1 The diffusible hydrogen test is to adopt mercury method or heat conduction method specified in ISO 3690. Four weld assemblies are to be prepared. For heat conductivity detector method, the minimum holding time at different test temperature is to comply with the provisions of Table 2.3.6.1. For welding consumables with level of hydrogen content of H10 and H15, glycerin method specified in 2.3.6.2 may also be adopted.

Relationship between Test Temperature and Minimum Holding Time where Thermal Conductivity Detector Method is Used **Table 2.3.6.1**

Measuring Method		Test Temperature (℃)	Minimum Holding Time (h)
Thermal Conductivity Detector Method①	Gas Chromatography (hydrogen collection method)	45	72
		150	6

① Thermal conductivity detector method includes gas chromatography method ((hydrogen collection method)) and hot carrier gas extraction method. The use of hot carrier gas extraction method may be considered subject to verification of the testing procedure to confirm that collection and measurement of the hydrogen occurs continuously until all of the diffusible hydrogen is quantified.

2.3.6.2 The procedure for hydrogen test with glycerin method is as follows:

(1) Four plates of any grade of hull structural steel are to be prepared as hydrogen test specimens. The specimens are to be 12 mm in thickness, 25 mm in width and 125 mm in length.

(2) Before welding, the specimens are to be cleaned and weighed to the nearest 0.1 g.

(3) Prior to welding, the electrodes are to be baked according to the drying process recommended by the manufacturer, so as to fully dry the electrodes. On the 25 mm surface of each test specimen, a single bead of welding about 100 mm in length is to be deposited with a 4 mm electrode, using about 150 mm of the electrode. The welding is to be carried out with as short an arc as possible and with a current of about 150 A.

(4) Within 30 s of the completion of the welding of each specimen, the slag is to be removed and the specimen quenched in water having a temperature of approximately 20℃. After a further 30 s, the specimens are to be cleaned and placed in an apparatus suitable for the collection of hydrogen by displacement of glycerin. All four specimens are to be welded and placed in the hydrogen collecting apparatus within 30 min by a single operator.

(5) The specimens are to be kept immersed in the glycerin having a temperature of 45℃ for a period of 48 h and, after removal, are to be cleaned in water and spirit, dried and weighed to the nearest 0.1 g to

determine the amount of weld deposited.

The amount of gas evolved is to be measured to the nearest 0.05 cm^3 and corrected for temperature and pressure to 0℃ and 101.325 kPa.

2.3.6.3 The individual and average diffusible hydrogen contents of the four specimens are to be reported, and the average value of diffusible hydrogen per 100 g is not to exceed the values in Table 2.3.6.3.

Average value of diffusible hydrogen **Table 2.3.6.3**

Mark	Diffusible Hydrogen Contents	Measuring Method
H15	15$cm^3$①	Mercury Method Thermal Conductivity Detector Method Glycerin Method ③
H10	10$cm^3$②	
H5	5cm^3	Mercury Method Thermal Conductivity Detector Method

Notes: ① 10 cm^3 per 100 grams where the glycerin method is used.
② 5 cm^3 per 100 grams where the glycerin method is used.
③ The glycerin method is not to be used for the welding consumables with H 5 mark.

2.3.7 Deep penetration butt weld tests

2.3.7.1 Two test plates are to be prepared for each deep penetration butt weld test assembly. The test plates are to have a thickness equal to twice the diameter of the core of the electrode plus 2 mm, a width of not less than 100 mm and a length appropriate to the size and number of specimens. The joint edges are to be prepared square and smooth without being beveled.

2.3.7.2 The test plates are to fit well and, after tacking, the gap is not to exceed 0.25 mm. The test plates are to be butt welded together with one downhand run of welding from each side, using the largest diameter electrode manufactured, and the welding current and the procedure employed are to be as recommended by the manufacturer for the electrodes. Between runs, root gouging is not needed.

2.3.7.3 Two transverse tensile specimens, two bend specimens and a set of three impact test specimens (with the notch positioned at the centre of the weld) are to be prepared from each test assembly (the axis of the specimen being at the middle of plate thickness) as shown in Figure 2.3.7.3 for tensile, bend and impact tests respectively. The results of all tests are to comply with the relevant requirements of Section 2 of this Chapter.

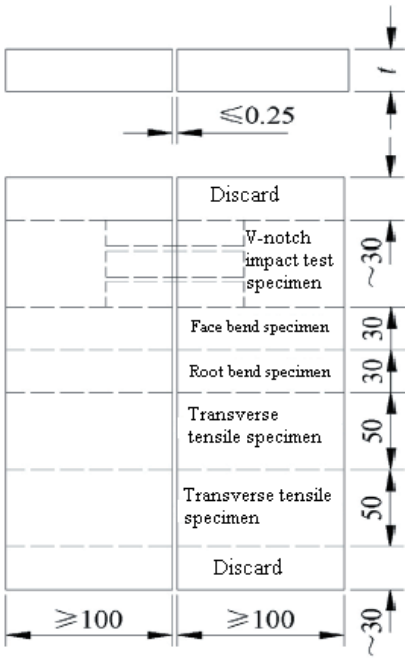


Figure 2.3.7.3

2.3.7.4 During the preparation of test specimens, the weld is to be examined for root penetration. The discards at the end of the welded assemblies, which are to be about 30 mm wide, are to be prepared as macro-section test specimens in accordance with the requirements of 1.2.3.7 of this PART. The cross sections of these specimens are to show complete fusion and interpenetration of the weld beads.

2.3.8 Deep penetration fillet weld tests

2.3.8.1 Two test plates about 12.5 mm in thickness, 100 mm in width and 180 mm in length are to be prepared for each deep penetration fillet weld test assembly. The joint edge of the abutting plate is to be prepared square.
2.3.8.2 The test plates are to be joined to form a T-connection with a gap between the plates of not more than 0.25 mm, as shown in Figure 2.3.8.2. The welding on one side is to be carried out with a 4 mm diameter electrode, and that on the other side with the maximum diameter electrode manufactured. The welding current used is to be within the range recommended by the manufacturer. The length of the fillet on each side is not to be less than 160 mm.

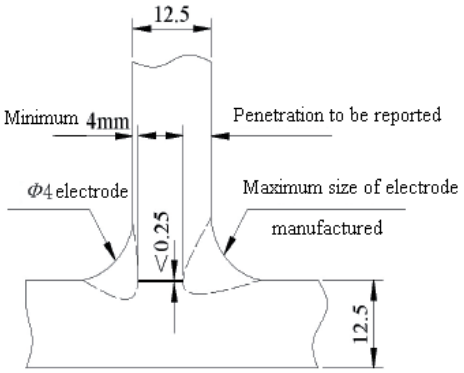


Figure 2.3.8.2

2.3.8.3 Macro specimens are to be taken from the welded assembly by cutting within 35 mm of the ends of the fillet welds and examined for root penetration. The welding of the fillet made with a 4 mm diameter electrode is to show a penetration of not less than 4 mm and the corresponding penetration of the fillet made with the maximum diameter electrode manufactured is to be reported.

2.3.9 Annual inspections

2.3.9.1 Electrodes which have been approved by CCS are, in general, to be subjected to annual inspections and tests in the presence of the Surveyor.
2.3.9.2 The annual tests of the electrodes are to consist of the following:
(1) For normal penetration electrodes, two deposited metal test assemblies are to be prepared and tested in accordance with 2.3.3 of this Section. If electrodes are available in one diameter only, one test assembly is sufficient.
(2) Where an electrode is approved solely for deep penetration welding, one butt welded test assembly is to be prepared and tested in accordance with 2.3.7 of this Section.
(3) Where an electrode is approved for both normal and deep penetration welding, the test assemblies are to be prepared and tested as detailed in (1) and (2) above.
(4) Where an electrode is approved solely for gravity welding, at least one deposited metal test assembly is to be prepared and tested using the gravity or similar welding device as recommended by the manufacturer. If this electrode is approved also for normal welding the tests are to be performed according to (1) of this paragraph.

Section 4
WIRE-FLUX COMBINATIONS FOR SUBMERGED ARC AUTOMATIC WELDING

2.4.1 General requirements

2.4.1.1 For wire-flux combinations used with the two-run technique, the suffix “T” is to be added after the grade mark.
2.4.1.2 For wire-flux combinations used with the multi-run technique, the suffix “M” is to be added after the grade mark.
2.4.1.3 For wire-flux combinations used with both two-run and multi-run techniques, the suffix “TM” is to be added after the grade mark.

2.4.2 Tests

2.4.2.1 Where wire-flux combinations are intended for use with the multi-run technique, deposited metal

and butt weld tests are to be carried out.

2.4.2.2 Where wire-flux combinations are intended for use with the two-run technique, butt weld tests for the two-run technique are to be carried out.

2.4.2.3 Where particular wire-flux combinations are intended for use with both techniques, tests are to be carried out for each technique.

2.4.2.4 Where wire-flux combinations are intended for use with multiple electrode submerged-arc welding, separate approval tests for are to be carried out, normally in accordance with the requirements of this Section.

2.4.2.5 Where welding consumables are intended to be used for high strength steel used for welding structures with a yield strength of 420 N/mm^2 and above, a hydrogen test is to be carried out in accordance with the method approved by CCS, and the test results are to comply with the requirements of Table 2.3.1.1 in Section 3 of this Chapter.

2.4.3 Deposited metal tests for multi-run technique

2.4.3.1 Two test plates and one backing plate are to be prepared for a deposited metal test assembly for the multi-run technique. The test plates are to be 20 mm in thickness, about 200 mm in width and of sufficient length to allow the cutting out of test specimens of the prescribed number and size. The plate edges are to be beveled to an angle of 10°. The backing plate is to be 12 mm in thickness, 50 mm in width and of a length equal to that of the test plates.

2.4.3.2 The test assembly is to be as shown in Figure 2.4.3.2 and welded in the downhand position using the maximum diameter of wire for which approval is requested. The direction of deposition of each run is to alternate from each end of the plate. After completion of each run, the flux and welding slag are to be removed, and the assembly is to be left in still air until it has cooled to less than 250℃, but need not be below 100℃ (the temperature being taken in the centre of the weld on the surface of the seam), and then the next run is to start. The thickness of the layer is to be not less than the diameter of the wire not less than 4 mm.

2.4.3.3 Two longitudinal tensile specimens (one if approved as wire-flux combinations for two-run technique at the same time) and a set of three impact test specimens are to be taken from each test assembly as shown in Figure 2.4.3.2 for tensile and impact tests respectively. The test results are to comply with the relevant requirements of Section 2 of this Chapter. Particulars for cutting the specimens are to be the same as specified in 2.3.3.4 of this Chapter. The chemical composition of the deposited weld metal in each test assembly, including the content of all significant alloying elements, is to be submitted to CCS for examination. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer.

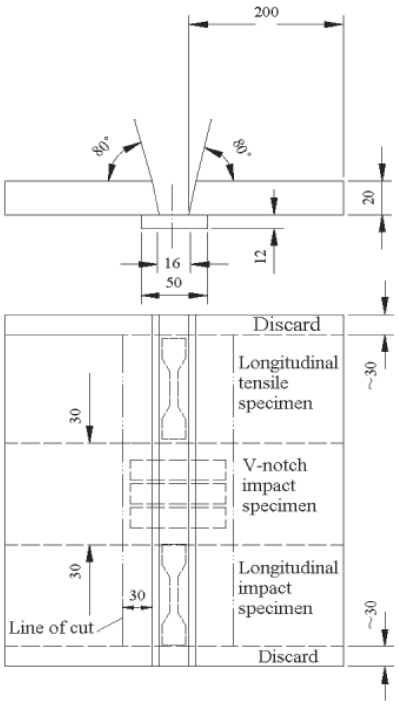


Figure 2.4.3.2

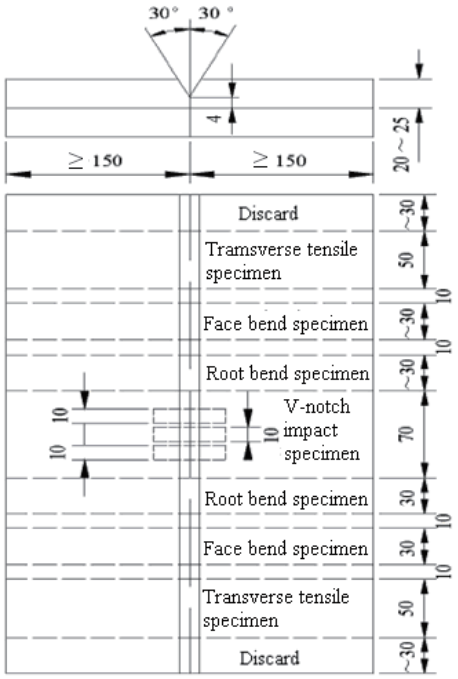


Figure 2.4.4.3

2.4.4 Butt weld tests for multi-run technique

2.4.4.1 Two test plates are to be prepared for a butt weld test assembly for the multi-nm technique. The test plates are to be 20 to 25 mm in thickness, not less than 150 mm in width and not less than 400 mm in length. The plate edges are to be beveled to an angle of 30°, with the root face being 4 mm.

2.4.4.2 The test plates are to be butt welded by the multi-run technique in the downhand position. The welding conditions are to be the same as those described in 2.4.3.2 of this Section. On completion of welding the first side, the back sealing run is to be applied in the downhand position after cutting out the root run to clean metal.

2.4.4.3 As shown in Figure 2.4.4.3, two transverse tensile specimens, four bend specimens and a set of three impact test specimens (with the notch positioned at the centre of the weld) are to be taken from the test assembly (the axis of specimen being at the middle of plate thickness) for tensile, face and root bend, and impact tests respectively. The results of all tests are to comply with the relevant requirements of Section 2 of this Chapter.

2.4.5 Butt weld tests for two-run technique

2.4.5.1 Two butt weld test assemblies for the two-run technique are to be made respectively from a pair of plates of different thicknesses and having an appropriate strength level according to the grades of wire-flux combinations for which approval is required. The thicknesses of test plates are shown in Table 2.4.5.1. Each test plate is not to be less than 150 mm in width and of sufficient length to allow the cutting out of test specimens of the prescribed number and size.

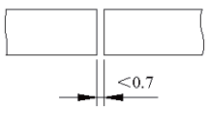
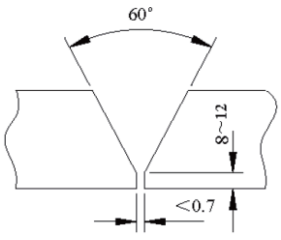
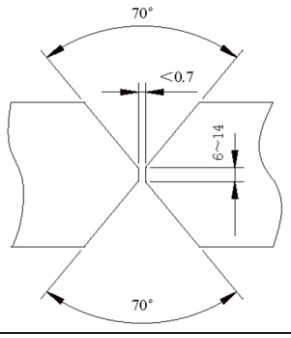
Butt Weld Test Plate Thicknesses Required for Different Grades of Welding Consumables in Respect to Two-Run Technique **Table 2.4.5.1**

Grade of welding consumables	Thickness of thinner test plate (mm)	Thickness of thicker test plate (mm)
1, 1Y	12 ~ 15	20 ~ 25
2, 2Y, 3, 3Y, 4Y, 2Y40, 3Y40, 4Y40	20 ~ 25①	30 ~ 35①

Note: ① A limitation of the approval to the medium range (up to the maximum welded plate thickness) may be agreed to by CCS. Test assemblies are then to be welded using plates of 12 to 15 mm and 20 to 25 mm irrespective of the grade for which the approval is requested. This is applicable to thicknesses up to 25 mm only.

2.4.5.2 The maximum diameter of wire and the edge preparation that may be used to prepare test assemblies of different thicknesses are to comply with Table 2.4.5.2. Small deviations in the edge preparation may be allowed.

Thickness and Edge Preparation of Butt Weld Test Plates for Two-Run Technique **Table 2.4.5.2**

Plate thickness (mm)	12 ~ 15	20 ~ 25	30 ~ 35
Max. diameter of wire (mm)	5	6	7
Forms and dimensions of edge preparation (mm)			

2.4.5.3 Each butt weld is to be welded in two runs, one from each side. After completion of the first run, the flux and welding slag are to be removed and the assembly is to be left in still air until it has cooled to less than 100℃, the temperature being taken in the centre of the weld on the surface of the seam and then the second run is applied.

2.4.5.4 As shown in Figure 2.4.5.4(1), two transverse tensile specimens, two bend specimens and a set of three impact test specimens are to be cut from each assembly, and one longitudinal tensile specimen cut from the thicker assembly. The impact test specimens are to be cut in positions as shown in Figure

2.4.5.4(2). The above test specimens are to be subjected to tensile, bend and impact tests respectively. The results of all tests are to comply with the relevant requirements of Section 2 of this Chapter. The edges of the discards are to be polished and etched for macro-section examination.

2.4.5.5 Where the combination is to be approved for the two-run technique only, in addition to the specimens required by 2.4.5.4, the chemical composition of the deposited metal is to be analyzed for the thicker assembly. The chemical analysis report is to include the content of all significant alloying elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer.

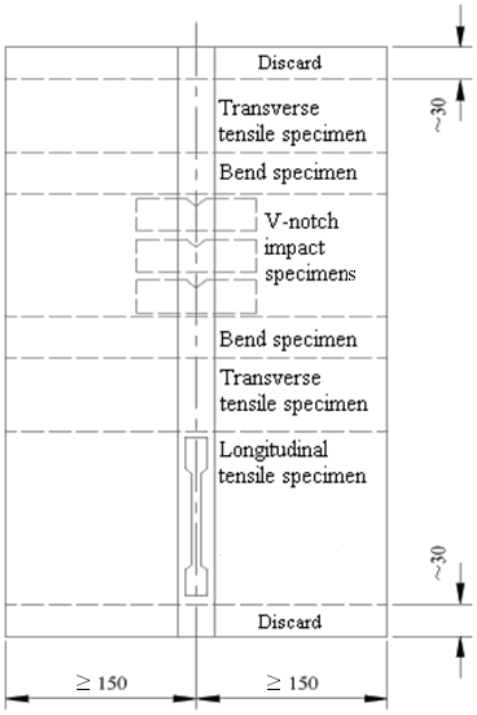


Figure 2.4.5.4(1)

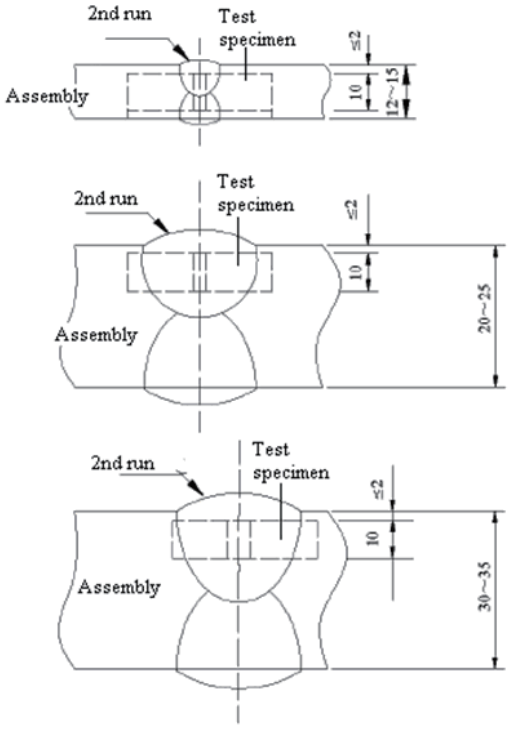


Figure 2.4.5.4(2)

2.4.6 Annual inspections

2.4.6.1 Wire-flux combinations which have been approved by CCS are, in general, to be subjected to annual inspections and tests in the presence of the Surveyor.

2.4.6.2 The annual tests of the wire-flux combinations are to consist of the following:

(1) for wire-flux combinations for use with the multi-run technique, one deposited metal test assembly is to be prepared;

(2) for wire-flux combinations for use with the two-run technique, one butt weld test assembly is to be prepared, using plate material at least 20 mm in thickness.

2.4.6.3 The deposited metal test assemblies are to be prepared and tested in accordance with the requirements of 2.4.3 of this Section, except that only one longitudinal tensile specimen and a set of three V-notch impact test specimens are required.

2.4.6.4 One butt weld test assembly with a thickness of not less than 20 mm is to be prepared in accordance with 2.4.5 of this Section, from which only one transverse tensile specimen, two bend specimens and a set of three V-notch impact test specimens are to be cut. One longitudinal tensile test specimen is additionally to be taken where the wire-flux combination is approved solely for the two-run technique.

2.4.6.5 Where a wire-flux combination is used for welding both normal strength and higher strength steels, the latter steel is to be used for the preparation of the butt weld assembly required by 2.4.6.2(2) of this Section.

Section 5 WIRES AND WIRE-GAS COMBINATIONS FOR SEMI-AUTOMATIC AND AUTOMATIC WELDING

2.5.1 General requirements

2.5.1.1 Wires (for use with or without a shielding gas) and wire-gas combinations may be divided into the following categories according to the process used:

(1) for wires and wire-gas combinations used in semi-automatic multi-run welding, the suffix "S" is to be added after the grade mark;

(2) for wires and wire-gas combinations used in single electrode automatic multi-run welding, the suffix "M" is to be added after the grade mark;

(3) for wires and wire-gas combinations used in single electrode automatic two-run welding, the suffix "T" is to be added after the grade mark;

(4) for wires and wire-gas combinations used in both two-run and multi-run welding, the suffix "TM" is to be added after the grade mark;

(5) for wires and wire-gas combinations used in both semi-automatic and automatic welding, the suffix "SM" is to be added after the grade mark.

2.5.1.2 Flux-cored wires are to be subjected to the deposited metal hydrogen test with the method approved by CCS, and the test results are to satisfy the requirements of Table 2.3.6.3 of this Chapter. An appropriate low hydrogen suffix will be added after the grade mark of welding consumables which have satisfied low hydrogen requirements. The low hydrogen requirements for different grades of welding consumables are given in Table 2.3.1.1 of this Chapter.

2.5.1.3 The composition of the shielding gas used in the approval test is to be reported, and the group and composition limits of shield gas are given in Table 2.5.1.3. When a wire is used in composition with grouped shielding gases, they are to be subjected to an approval test respectively.

Compositional Limits of Designated Groups of Gas Types and Mixtures **Table 2.5.1.3**

Group	Gas composition (Vol. %)			
	Argon (Ar)	Carbon dioxide (CO_2)	Oxygen (O_2)	Hydrogen (H_2)
M11	Residual①②	0 ~ 5	−	0 ~ 5
M12	Residual①②	0 ~ 5	−	−
M13	Residual①②	−	0 ~ 3	−
M14	Residual①②	0 ~ 5	0 ~ 3	−
M21	Residual①②	5 ~ 25	−	−
M22	Residual①②	−	3 ~ 10	−
M23	Residual①②	5 ~ 25	0 ~ 8	−
M31	Residual①②	25 ~ 50	−	−
M32	Residual①②	−	10 ~ 15	−
M33	Residual①②	5 ~ 50	8 ~ 15	−
C1	−	100	−	−
C2	−	Residual	0 ~ 30	−

Notes: ① 95% of the content of argon gas may be substituted by helium gas.
② The content of helium gas used is to be greater than or equal to that of argon gas.

2.5.1.4 Wires and wire-gas combinations for multiple electrode automatic welding are, in general, to be approval tested in accordance with the relevant requirements of this Section.

2.5.2 Tests for wires and wire-gas combinations

2.5.2.1 Deposited metal, butt weld and fillet weld tests are to be carried out for the wires and wire-gas combinations for use in semi-automatic multi-run welding.

2.5.2.2 Deposited metal and butt weld tests are to be carried out for the wires and wire-gas combinations for use in multi-run automatic welding.

2.5.2.3 Butt weld tests are to be carried out for the wires and wire-gas combinations for use in automatic two-run welding.

2.5.2.4 Wires or wire-gas combinations approved for semi-automatic and automatic multi-run welding may be tested according to the requirements of 2.5.2.1 when semi-automatic and automatic multi-run welding are performed in the same conditions of welding current and energy, without additional tests for automatic multi-run welding.

2.5.3 Deposited metal tests for semi-automatic multi-run technique

2.5.3.1 The deposited metal tests for the semi-automatic multi-run technique are to be carried out in accordance with the requirements of 2.3.3 of this Chapter, except that two test assemblies are to be prepared in accordance with the requirements of 2.5.3.2 of this Section.

2.5.3.2 One deposited metal test assembly is to be prepared using wires of the smallest diameter manufactured, and the other using wires of the largest diameter manufactured. Where only one diameter is manufactured, only one deposited metal test assembly is to be prepared. During welding, the thickness of each layer of weld metal is to be between 2 mm and 6 mm.

2.5.4 Butt weld tests for semi-automatic multi-run technique

2.5.4.1 For approval of wires and wire-gas combinations for the semi-automatic multi-run technique, one butt weld test assembly is to be prepared for each welding position (downhand, horizontal, vertical and overhead) for which the wire is recommended by the manufacturer. The butt weld tests are to be carried out in accordance with the requirements of 2.3.4 of this Chapter, except that the assemblies are to be welded according to the requirements of 2.5.4.2 of this Section.

2.5.4.2 The downhand assembly is to be welded using, for the first run, wires of the smallest diameter manufactured and, for the remaining runs, wires of the largest diameter manufactured. Where approval is requested only in the downhand position, an additional butt weld assembly is to be prepared in that position using wires of a different diameter from those required above.

The butt weld assemblies, in positions other than downhand, are to be welded using, for the first run, wires of the smallest diameter manufactured, and for the remaining runs, wires of the largest diameter recommended by the manufacturer for the position concerned.

2.5.5 Fillet weld tests for semi-automatic multi-run technique

2.5.5.1 Fillet weld tests for the semi-automatic multi-run technique are to be carried out in the downhand position. The tests are to be carried out in accordance with the requirements of 2.3.5 of this Chapter, except that the test assembly is not less than 300 mm in length and both sides are to be welded using respectively wires of the smallest and the largest diameters for which approval is requested.

2.5.6 Deposited metal and butt weld tests for automatic multi-run technique

2.5.6.1 Deposited metal tests for automatic multi-run welding are to be carried out in accordance with the requirements of 2.4.3 of this Chapter, except that the thickness of each layer is not to be less than 3 mm. Butt weld tests for automatic multi-run welding are to be carried out in accordance with the requirements of 2.4.4 of this Chapter.

2.5.7 Butt weld tests for automatic two-run technique

2.5.7.1 Butt weld tests for the automatic two-run technique are to be carried out in accordance with the requirements of 2.4.5 of this Chapter, except that two test assemblies are to be prepared in accordance with the requirements of 2.5.7.2 to 2.5.7.4 of this Section.

2.5.7.2 Two butt weld test assemblies are in general to be prepared, using plates 12 mm to 15 mm and 20 mm to 25 mm in thickness respectively. Each assembly consists of two plates. Where the welding consumables are suitable for welding plates thicker than 25 mm, one assembly is to be prepared using plates of 20 mm in thickness and the other using plates of the maximum thickness for which the consumables are suitable.

2.5.7.3 The edge preparation of the test assemblies is to be as shown in Figure 2.5.7.3. Small deviations in the edge preparation may be allowed, if requested by the manufacturer. Where plates over 25 mm in thickness are used, dimensions of the edge preparation are to be stated in the test report.

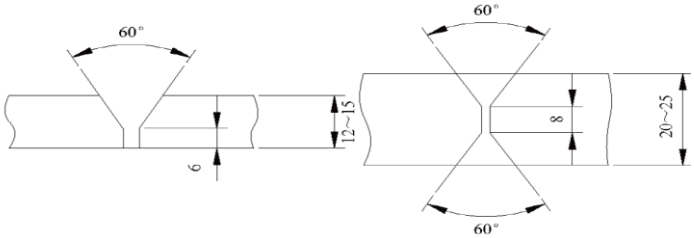


Figure 2.5.7.3

2.5.7.4 Wire diameters recommended by the manufacturer may be used and are to be reported.

2.5.8 Annual inspections

2.5.8.1 Wires and wire-gas combinations for semi-automatic and automatic welding which have been approved by CCS are, in general, to be subjected to annual inspections and tests in the presence of the Surveyor.

2.5.8.2 The annual tests for wires and wire-gas combinations are to consist of the following:

(1) for wires and wire-gas combinations approved for semi-automatic or for both semi-automatic and automatic multi-run welding, one deposited metal test assembly is to be prepared in accordance with the requirements of 2.5.3 of this Chapter for deposited metal tests using wires of a diameter within the range approved;

(2) for wires and wire-gas combinations approved solely for automatic multi-run welding, one deposited metal test assembly is to be prepared in accordance with the requirements of 2.5.6 of this Section for deposited metal tests, except that only one longitudinal tensile test specimen is required;

(3) for wires and wire-gas combinations approved for two-run automatic welding, one butt weld test assembly is to be prepared in accordance with the requirements of 2.5.7 of this Section for butt weld tests, using plates 20 mm to 25 mm in thickness, except that only one transverse tensile test specimen is required.

Section 6
CONSUMABLES FOR USE IN ELECTRO-SLAG OR ELECTRO-GAS VERTICAL WELDING

2.6.1 General requirements

2.6.1.1 Unless otherwise specified in this Section, the requirements for the two-run technique in Section 4 of this Chapter are also applicable to consumables used for electro-slag or electro-gas vertical welding with or without consumable nozzles.

2.6.1.2 For welding consumables of Grades 1Y, 2Y, 3Y, 4Y, 2Y40, 3Y40 and 4Y40 used for electro-slag or electro-gas vertical welding, the approval may be restricted for use only with specific types of higher strength steel. This is in respect of the content of grain refining elements and if general approval is required, a niobium treated steel is to be used for approval tests.

2.6.1.3 For technical reasons, the special high-ductility welding consumables as mentioned in this Section may not be entirely suitable to the welding of low-ductility steels. Where approval is requested for the welding of both normal strength and higher strength steels, two test assemblies are in general to be prepared using higher strength steel. Where deemed necessary by CCS, two additional assemblies prepared using normal strength steel may be required.

2.6.2 Butt weld tests

2.6.2.1 Two butt weld test assemblies are to be prepared, one with plates 20 mm to 25 mm in thickness and the other with plates 35 mm to 40 mm in thickness. Each plate is not to be less than 250 mm in width and of sufficient length to allow the cutting out of test specimens of the number and size as specified in 2.6.2.3 of this Section.

2.6.2.2 The welding conditions and the edge preparation for the test assemblies are to be those recommended by the manufacturer and reported. The chemical composition of the plate, including the content of grain refining elements, is also to be reported.

2.6.2.3 Two longitudinal tensile, two transverse tensile, two bend, two macro specimens and two sets of three Charpy V-notch impact test specimens are to be cut from each assembly for tensile, bend and impact tests respectively, as shown in Figure 2.6.2.3(1). The results of all tests are to comply with the relevant requirements of Section 2 of this Chapter. The positions of the two sets of Charpy V-notch impact test specimens are to be as shown in Figure 2.6.2.3(2).

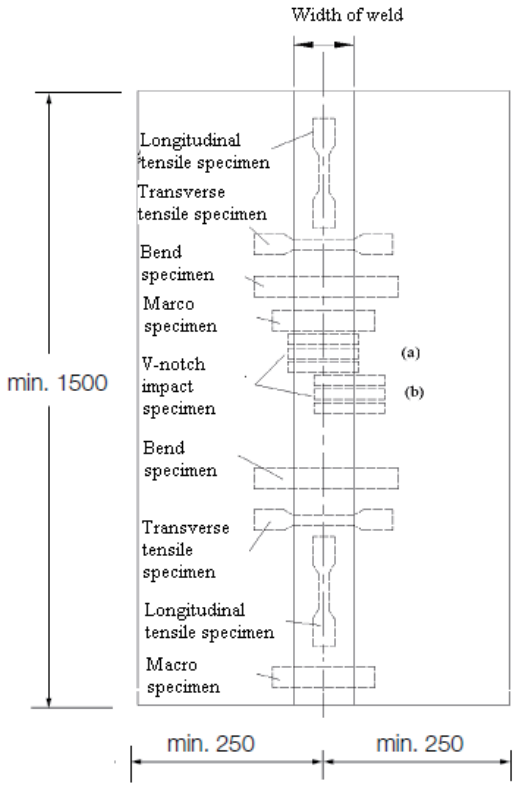
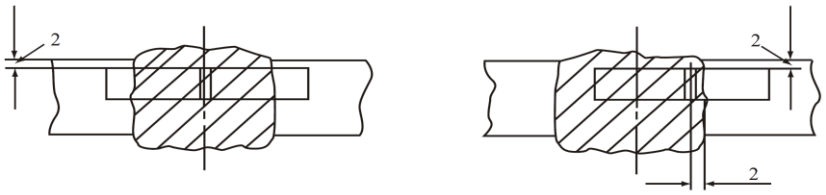


Figure 2.6.2.3(1)



a) Notch in the center of the weld b) Notch within 2 mm of fusion line

Figure 2.6.2.3(2)

2.6.3 Annual inspections

2.6.3.1 Consumables for use in electro-slag and electro-gas vertical welding which have been approved by CCS are, in general, to be subjected to annual inspections and tests in the presence of the Surveyor.

2.6.3.2 The annual tests are to consist of at least one butt weld test assembly prepared using plates of 20 mm to 25 mm in thickness according to the requirements of 2.6.2 of this Section. And one longitudinal tensile, one transverse tensile, two bend specimens, two sets of impact test specimens (the notch of impact specimens positioned in the centre the weld and at 2 mm from the fusion line of the weld respectively) and one macro specimen are to be taken from the assembly for tensile, bend, impact tests and macro examination respectively.

Section 7 CONSUMABLES FOR USE IN ONE-SIDE WELDING WITH TEMPORARY BACKING MATERIALS

2.7.1 General requirements

2.7.1.1 The tests for approval of wire-flux (or wire-gas) combinations for use in automatic one-side welding with temporary backing materials are generally to be carried out in accordance with the requirements of Sections 4 and 5 of this Chapter and this Section.

2.7.1.2 The requirements for approval of electrodes or wire-flux combinations for use in manual or semi-automatic one-side welding with temporary backing materials will be specially considered by CCS.

2.7.2 Butt weld tests

2.7.2.1 For the consumables for use in one-side welding with temporary backing materials, two butt weld test assemblies are to be prepared, one with plates 20 mm to 25 mm in thickness and the other with plates 30 mm to 35 mm in thickness. Each plate is not to be less than 150 mm in width and of sufficient length to allow the cutting out of test specimens of the prescribed number and size.

2.7.2.2 Two longitudinal tensile, two transverse tensile and two bend specimens, one macro specimen and the Charpy V-notch impact test specimens specified in 2.7.2.3 of this Section are to be cut from each assembly for tensile, bend and impact tests respectively. The results of all tests are to comply with the relevant requirements of Section 2 of this Chapter.

2.7.2.3 As shown in Figure 2.7.2.3, two sets of three impact test specimens are to be taken from the assembly prepared using plates 20 mm to 25 mm thick, and three sets of three Charpy V-notch impact specimens are to be taken from the assembly prepared using plates 30 mm to 35 mm thick.

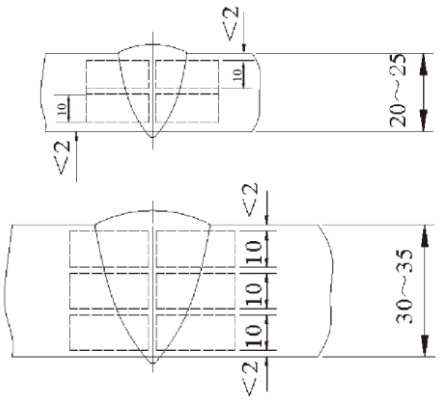


Figure 2.7.2.3

2.7.3 Annual inspections

2.7.3.1 Consumables for use in one-side welding with temporary backing materials which have been approved by CCS are, in general, to be subjected to annual inspections and tests in the presence of the Surveyor.

2.7.3.2 The annual tests are to consist of at least one butt weld test assembly prepared using plates of 20 mm to 25 mm in thickness according to the requirements of 2.7.2 of this Section. And one longitudinal tensile, one transverse tensile, two bend specimens and one set of three Charpy V-notch impact test specimens (cut from the root of the weld) are to be taken from the assembly, as shown in Figure 2.7.2.3, for tensile, bend and impact tests respectively.

Section 8 WELDING CONSUMABLES FOR STAINLESS STEEL

2.8.1 Application

2.8.1.1 This Section applies to welding consumables for austenitic and austenitic/ferritic duplex stainless steels (unless expressly indicated otherwise, hereinafter referred to as stainless steel(s)) specified in Section 8 of Chapter 3 and Section 6 of Chapter 4, PART ONE of the Rules.

2.8.2 General requirements

2.8.2.1 Welding consumables for stainless steels are graded according to applicable parent stainless steel. Detailed grades are as follows: 304, 304L, 304LN, 316, 316L, 316LN, 317, 317L, 317LN, 309, 309L, 347, 2205, 2550 and 2750.

2.8.2.2 For welding consumables suitable to different welding procedures, a suffix showing technological applicability is to be added after the grade mark according to 2.4.1 or 2.5.1 of this Chapter.

2.8.2.3 Unless expressly provided otherwise in this Section, approval tests for welding consumables are to be carried out based on the type of welding consumables and according to the applicable requirements in Sections 3, 4 and 5 of this Chapter.

2.8.3 Deposited metal tests

2.8.3.1 Plates used in the test assembly for deposited weld metal tests may be of stainless steel compatible with welding consumables, or of normal strength carbon steel or carbon-manganese steel provided that the prepared edges are built up by means of low heat input with two layers of insulation from welding consumables to be tested. The thickness of insulation is not to be less than 3 mm after processing.
2.8.3.2 The deposited weld metal is to be subjected to chemical analysis, mechanical test and metallographic examination.
2.8.3.3 The chemical composition of the deposited weld metal, including all significant elements, is to be reported. The analysis results are to comply with recognized standards or the manufacturer's specifications.
2.8.3.4 The mechanical properties of the deposited weld metal is to comply with the relevant requirements in Table 2.8.3.4.

Mechanical Properties of Deposited Metal of Welding Consumables for Stainless Steel

Table 2.8.3.4

Grade of welding consumables		Austenitic stainless steel			Austenitic/ferritic duplex stainless steel		
		304L 316L 317L 309L	304LN 316LN 317LN 347	304 316 317 309	2205	2550	2750
Proof strength (N/mm^2)	$R_{p0.2}$	≥270	≥290	≥290	≥450	≥550	≥550
	$R_{p1.0}$ ①	≥310	≥330	≥330	≥490	≥590	≥590
Tensile strength R_m (N/mm^2)		≥500	≥550	≥550	≥620	≥690	≥790
Elongation A_5 (%)		≥25	≥22	≥25	≥25	≥15	≥15
Charpy V-notch impact test	Test temperature (℃)	-20/-196②			-20		
	Average impact energy (J)	≥29					

Notes: ① Unless otherwise agreed, the value of proof strength $R_{p1.0}$ is generally not to be used as a criterion for acceptance;
② Austenitic stainless steel is to be subjected to impact test at -20℃. When used in deep cold condition, austenitic stainless steel is to be subjected to impact test at -196℃. If required by an agreement, impact test may also be carried out as agreed.

2.8.3.5 Specimens are to be taken at the center of the deposited metal, and the ferrite content of the deposited metal is to be measured by metallographic or magnetic means. For welding consumables for austenitic stainless steels, the ferrite content is to comply with the manufacturer's specifications. For welding consumables for austenitic/ferritic duplex stainless steels, the ferrite content is to be within the range of 35% to 65%.

2.8.4 Butt weld tests

2.8.4.1 Test plates for butt weld tests are to be of stainless steel compatible with welding consumables.
2.8.4.2 Butt joints are to be subjected to mechanical and intergranular corrosion tests.
2.8.4.3 The mechanical properties of butt joints are to comply with the relevant requirements in Table 2.8.4.3.

Mechanical Properties of Butt Joints of Welding Consumables for Stainless Steel

Table 2.8.4.3

Grade of welding consumables		Austenitic stainless steel			Austenitic/ferritic duplex stainless steel		
		304L 316L 317L 309L	304LN 316LN 317LN 347	304 316 317 309	2205	2550	2750
Tensile strength R_m (N/mm^2)		≥480	≥550	≥520	≥620	≥690	≥790
Charpy V-notch impact test	Test temperature (℃)	-20/-196①			-20		
	Average impact energy (J)	≥27					
Bend test	Former diameter	3t			6t		
	Bending angle	120°					
	Requirement	After test, length of crack or other defects on specimen surface is not to be more than 3 mm.					

Note: ① Austenitic stainless steel is to be subjected to impact test at -20℃. When used in deep cold condition, austenitic stainless steel is to be subjected to impact test at -196℃. If required by an agreement, impact test may also be carried out as agreed.

2.8.4.4 Stainless steel butt joints are to be sampled for intergranular corrosion test according to Section 7, Chapter 2, PART ONE of the Rules.
2.8.4.5 In addition to the requirements mentioned above, duplex stainless steels butt joints are to be sampled for pitting corrosion test according to Section 9, Chapter 2, PART ONE of the Rules.

2.8.5 Annual inspections
2.8.5.1 Annual tests of welding consumables for stainless steels are to be carried out based on the type of welding consumables and according to the requirements of 2.3.9, 2.4.6 or 2.5.8 of this Chapter.
2.8.5.2 All test results are to comply with the relevant requirements of 2.8.3 and 2.8.4.

Section 9 WELDING CONSUMABLES FOR ALUMINUM ALLOYS

2.9.1 Application
2.9.1.1 This Section applies to welding consumables intended for welding aluminum alloys to be used for hull construction and marine structures according to Chapter 8, PART ONE of the Rules.
2.9.1.2 Unless otherwise specified in this Section, welding consumables for aluminum alloys are to be subjected to approval and test based on types of welding consumables and according to approval procedures and test methods in Sections 1 and 5 of this Chapter.

2.9.2 General requirements
2.9.2.1 The welding consumables for aluminum alloys are graded as A, B, C and D in accordance with the alloy type and strength level of the base materials used for the approval tests.
2.9.2.2 For wires and wire-gas combinations used in metal-arc inert gas welding (MIG), tungsten inert gas arc welding (TIG) and/or plasma arc welding, the letter “W” is to be added before the grade mark, e.g. “WC”.
2.9.2.3 For rod-gas combinations used in tungsten inert gas arc welding (TIG) and/or plasma arc welding, the letter “R” is to be added before the grade mark, e.g.“RB”.
2.9.2.4 Approval of a wire or a rod will be granted in conjunction with a specific shielding gas according to Table 2.9.2.4 or defined in terms of composition and purity of “special” gas to be designated with group sign “S”. The composition of the shielding gas is to be reported. The approval of a wire or rod with any particular gas can be applied or transferred to any combination of the same wire or rod and any gas in the same numbered group as defined in Table 2.9.2.4, subject to agreement of CCS.

Compositional Limits of Shielding Gases and Mixtures to be Used **Table 2.9.2.4**

Group	Gas composition (Vol. %))	
	Argon	Helium
I−1	100	−
I−2	−	100
I−3	Remainder	$0 < He \leq 33$
I−4	Remainder	$33 < He \leq 66$
I−5	Remainder	$66 < He \leq 95$
S	Gases of other chemical composition (mixed gases) may be considered as “special gases” and covered by a separate test	

2.9.2.5 Approval on higher strength AlMg base materials covers also the lower strength AlMg grades and their combination with AlSi grades.

2.9.3 Requirements for tests
2.9.3.1 For approval of welding consumables for aluminum alloys, deposited metal tests and butt weld tests are in general to be carried out.
2.9.3.2 One deposited weld metal test assembly may be prepared according to Figure 2.9.3.2. The base metal used is to be compatible with the weld metal in respect of chemical composition. The size depends on the type of the welding consumables (and on the welding process) and is to give a sufficient amount of pure weld metal for chemical analysis.

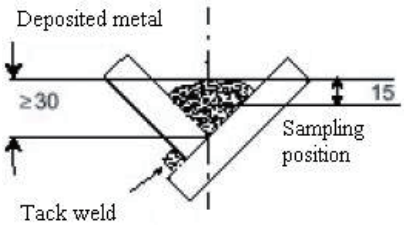
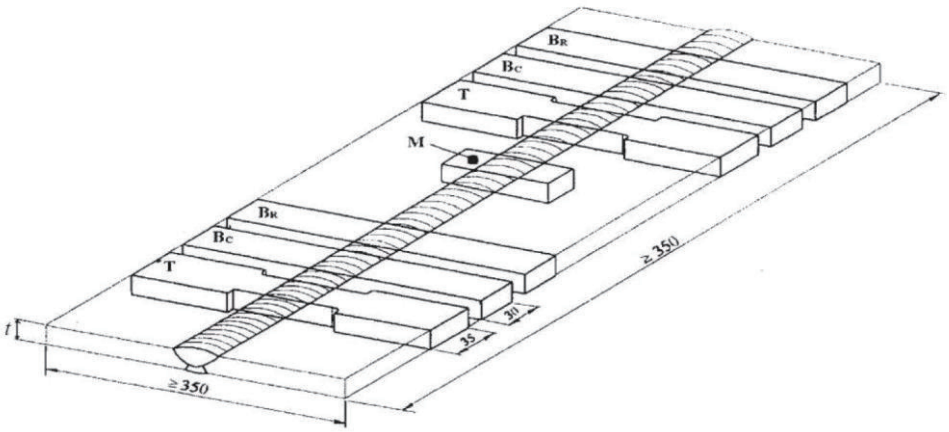


Figure 2.9.3.2 Deposited weld metal test assembly

2.9.3.3 A report of chemical analysis of the deposited weld metal, including contents of all significant elements, is to be submitted. The test results are not to exceed the limit values specified by the manufacturer.

2.9.3.4 Butt weld test assemblies according to Figure 2.9.3.4 with a thickness of 10 mm to 12 mm are to be prepared for each welding position (downhand, horizontal-vertical, vertical-upward and overhead) for which the consumable is recommended by the manufacturer. Consumables satisfying the requirements for downhand and vertical-upward positions may be exempted from testing for the horizontal-vertical position, subject to agreement of CCS. Additionally, one test assembly according to Figure 2.9.3.4 with a thickness of 20 mm to 25 mm is to be welded in the downhand position only (edge preparation is to be a single V with 70° angle).



T – Flat tensile test specimen B_C – Face bend test specimen B_R – Root bend test specimen
M – Macrographic section t = 10 ~ 12 mm or 20 ~ 25 mm

Notes: 1 Edge preparation is to be single V or double V with 70° angle.
2 Back sealing runs are allowed in single V weld assemblies.
3 In case of double V assembly, both sides are to be welded in the same welding position.

Figure 2.9.3.4 Butt Weld Test Assembly for Positional Welding

2.9.3.5 Welding may be carried out according to the requirements of 2.5.4 or 2.5.6 of this Chapter. On completion of welding, 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 naturally ageing for a minimum period of 72 h from the completion of welding before testing is carried out.

2.9.3.6 As shown in Figure 2.9.3.4, two flat tensile test specimens, four bend test specimens (two face bend ones and two root bend ones) and one macrographic section are to be taken from each butt weld test assembly for tests.

2.9.3.7 The results of tensile tests and bend tests are to comply with the relevant requirements of Table 2.9.3.7. The position of the fractures of tensile specimens is to be stated in the report. The macrographic specimen is to be examined for imperfections such as visible flaws, lack of fusion, pores and inclusions.

Mechanical Properties of Welding Consumables for Aluminum Alloys Table 2.9.3.7

Grade of welding consumables		A		B	C				D
Brand of base material used for test		5754	5454	5086	5083	5383 5456	5A01	5059	6061, 6005A, 6082
Tensile test	Tensile strength (N/mm^2)	190	215	240	275	290	325	330	170
Bend test	Former diameter	3*t*	4*t*	6*t*					
	Minimum bending angle	180°							
	Test requirements	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 are to be ignored in the evaluation, unless there is evidence that they result from lack of fusion.							

2.9.4 Annual inspections

2.9.4.1 For annual inspections of welding consumables for aluminum alloys, one deposited metal test assembly and one downhand butt weld test assembly for chemical analysis of the deposited metal and for mechanical tests of butt joints are to be prepared according to the type of welding consumables.

2.9.4.2 All test results are to comply with the relevant requirements of 2.9.3.3 and Table 2.9.3.7.

CHAPTER 3 APPROVAL OF WELDING PROCEDURES

Section 1 GENERAL PROVISIONS

3.1.1 Application

3.1.1.1 This Chapter applies to the approval of welding procedures prior to the commencement of production welding of structures of normal weldable steels and aluminum alloys at building yards of ships and offshore installations, and manufacturing works of marine products.

3.1.1.2 The requirements for approval of aluminum alloy welding procedures in this Chapter apply only to metal-arc inert gas welding (MIG), tungsten inert gas arc welding (TIG) and plasma arc welding.

3.1.1.3 For welding procedures of other materials not specified in this Chapter, relevant information is to be provided by the yards or works and the procedures are to be assessed and approved by CCS (approval test is to be carried out when necessary). Corresponding approval range will be considered by CCS, as appropriate.

3.1.1.4 The approval of welding procedures of cargo tanks and process pressure vessels of liquefied gas carriers is to comply with the relevant requirements of Chapter 6 of CCS Rules for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk.

3.1.2 Welding procedure documents

3.1.2.1 A preliminary welding procedure specification (pWPS) is to be prepared by the shipyard or manufacturer prior to welding procedure approval tests so as to guide completion of technical documents for welding procedure approval tests. The preliminary welding procedure specification is to include all technical parameters in the welding procedure specification. Relevant technical parameters can be modified and amended according to test results during approval tests.

3.1.2.2 The welding procedure qualification report (WPQR) is a technical document properly describing and precisely recording technical parameters which are actually used and obtained in welding procedure approval tests as basis for approval of the welding procedure specification. The results of each test involved in the report (including retest results) are to be assessed.

3.1.2.3 The welding procedure specification (WPS) is a technical document prepared by the shipbuilder or manufacturer in modifying and amending the preliminary welding procedure specification according to a satisfactory welding procedure qualification report, and formally approved by CCS to guide production welding.

3.1.3 Approval

3.1.3.1 It is the shipbuilder's or manufacturer's responsibility to establish and document whether a welding procedure specification is suitable for the particular application. Prior to the commencement of construction, the shipbuilder or manufacturer is to prepare a summary table of welding procedures in combination with their own technical conditions and production experiences and submit it to the Surveyor for approval. The name and number of the welding procedure specification intended for use are to be indicated in the summary table according to different positions, types and sizes of welds at structures and connections.

3.1.3.2 Welding procedure approval tests are generally required to verify that a manufacturer is adequately qualified to perform welding operations using a particular procedure when a new material or new welding procedure is adopted. The shipbuilder or manufacturer is to prepare a detailed preliminary welding procedure specification. The preliminary welding procedure specification submitted for approval is to include the following:

(1) type, grade, thickness and delivery condition of the parent metal;
(2) designation, grade and size of the welding consumables (electrode, wire, flux and shielding gas);
(3) type and main performance parameters of welding equipment;
(4) design of and requirements for edge preparation; backing material (if any);
(5) number and order of welding metal disposition and welding sequence;
(6) welding positions (downhand, horizontal, vertical and overhead);
(7) rule welding parameters (electric polarity, welding current, arc voltage, travel speed and shielding gas flow);
(8) pre-heating, interpass temperatures, post-weld heat treatment and post-weld stress-relieving;
(9) welding site conditions (at site or in the shop);
(10) other special requirements.

3.1.3.3 The welding of test assemblies and the testing of test specimens are to be witnessed by the Surveyor.
3.1.3.4 During test, the test parameters and results are to be recorded in the welding procedure qualification report and the report is to be signed by the Surveyor witnessing the test.
3.1.3.5 A complete welding procedure specification is to be prepared by the manufacturer based on test results and submitted together with test report to CCS for approval.
3.1.3.6 If test results do not comply with the relevant requirements, and additional tests carried out in accordance with 1.2.5.2 to 1.2.5.4, Chapter 1 of this PART still fail, the preliminary welding procedure specification (pWPS) is to be adjusted by the shipyard or manufacturer. The new pWPS is to be prepared and the test pieces welded in accordance with the new pWPS.
3.1.3.7 Any changes to the approved welding procedure specification are to be submitted to CCS for approval. CCS will decide whether a new welding procedure test is necessary depending on the nature and extent of such changes.
3.1.3.8 The welding procedure specification qualified at a manufacturer is valid for welding in workshops under the same technical and quality management.

3.1.4 Application of approved welding procedures
3.1.4.1 All the conditions of validity stated below are to be met independently of each other. Changes outside of the ranges specified are to require a new welding procedure test.
3.1.4.2 The approval is, in general, valid only for the welding process(es) used in the welding procedure test. It is not permitted to change from a multi-run to a single run and in respect to the welding of aluminum alloys, it is also not permitted to change from a single run to a multi-run. For the welding procedure approval of multi-process procedures, multi-process procedure tests are in general to be carried out. The approval of such a test is only valid for the process sequence carried out during the multi-process procedure test. For hull structure steel, the welding procedure approval may be carried out with separate welding procedure tests for each welding process.
3.1.4.3 The application of a welding procedure specification to steel is specified as follows:
(1) For each strength level, welding procedures are considered applicable to the same and lower toughness grades as that tested.
(2) For each toughness grade where the minimum value of the specified yield strength of steel is not more than 390 N/mm^2, welding procedures are considered applicable to the same and two lower strength levels as that tested. For high strength quenched and tempered steel, welding procedures are considered applicable to the same and one lower strength level as that tested.
(3) For high heat input processes above 50 kJ/cm, the welding procedure is only applicable to that toughness grade tested and one strength level below.
(4) For steel forgings and castings (carbon steel and carbon-manganese steel), welding procedures are considered applicable to the same or lower strength level as that tested.
(5) For steels with delivery conditions other than those tested, unless specified below, CCS will put forward test requirements as appropriate:
① the approval of quenched and tempered steels does not qualify steels with other delivery conditions and vice versa;
② in general the approval of normalized, as rolled and controlled rolling steels qualifies TMCP steels but not vice versa.
3.1.4.4 The application of a welding procedure specification to aluminum alloys is to comply with the following requirements:
(1) Welding procedures to be approved for aluminum alloys may be grouped as follows according to the chemical composition of their parent metal:
Group A: aluminum-magnesium alloys with Mg content < 4% (alloys 5754, 5454)
Group B: aluminum-magnesium alloys with 4% ≤ Mg ≤ 7% (alloys 5059, 5083, 5086, 5383, 5456 and 5A01)
Group C: aluminum-magnesium-silicon alloys (alloys 6005A, 6061 and 6082).
(2) The welding procedure qualified for one alloy is applicable to the other alloys with an equal or lower strength level in the same Group. The welding procedures qualified for Group B alloys are applicable to Group A alloys.
3.1.4.5 The application of welding procedures in respect to thickness is to comply with the following requirements:
(1) The application of the thickness of steels and aluminum alloys is to comply with the requirements of Tables 3.1.4.5a and 3.1.4.5b respectively.

Application of Steel Thickness **Table 3.1.4.5a**

Thickness of test piece① t (mm)	Range of approval	
	Butt and T-joint welds with single run or single run from both sides	Butt and T-joint welds with multi-run and fillet welds②
$t \leq 3$	(0.7 ~ 1.1) t	(1 ~ 2) t
$3 < t \leq 12$	(0.7 ~ 1.1) t	3 mm ~ 2 t
$12 < t \leq 100$	(0.7 ~ 1.1) t③	(0.5 ~ 2) t (maximum 150 mm)
$t > 100$	not applicable	50 mm ~ 2t

Notes: 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 base metals.
③ For high heat input processes over 50 kJ/cm, the upper limit of the range of approval is to be 1.0 × t.

Application of Aluminum Alloy Thickness **Table 3.1.4.5b**

Thickness of test piece①② t (mm)	Range of approval③
$t \leq 3$	(0.5 ~ 2) t
$3 < t \leq 20$	3 mm ~ 2t
$t > 20$	$\geq 0.8t$

Notes: 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 In the case of fillet joints between dissimilar thicknesses, t is the thickness of the thicker material.
③ For automatic single-run procedures, the approved maximum penetration is the maximum penetration during test.

(2) In addition to the requirements of (1), the application of the throat thickness of fillet welds is to comply with the following requirements:

Steel: a value of 0.75 ~ 1.5 times the throat thickness for test is to be required for single run fillet welds and that of 0.5 ~ 2 times for multi-run fillet welds.

Aluminum alloys: a value of 0.75 ~ 1.5 times the throat thickness for test is generally required, except that a tested throat thickness of 10 mm or more qualifies all throat thicknesses not less than 7.5 mm.

(3) For the vertical-down welding, the test piece thickness "t" is always taken as the upper limit of the range of application.

(4) For butt welds between plates having unequal thicknesses, the lesser thickness in Table 3.1.4.5 is the ruling dimension.

(5) Notwithstanding the above, the approval of maximum thickness of base metal for any technique is to be restricted to the thickness of the test assembly if three of the hardness values in the heat affected zone are found to be within 25 HV of the maximum permitted.

3.1.4.6 The application of welding procedures in respect to the external diameter of pipes is to comply with the requirements of Table 3.1.4.6.

Application of Welding Procedure in Respect to External Diameter of Pipes

Table 3.1.4.6

External diameter of test pipe D (mm)	Application d (mm)
$D \leq 25$	$0.5D \leq d \leq 2D$
$D > 25$	$d \geq 0.5D$ (minimum 25 mm)

3.1.4.7 The application of welding consumables and auxiliary materials:

(1) Steels: except high heat input processes over 50 kJ/cm, welding consumables cover other approved welding consumables having the same grade mark (including all suffixes) as the welding consumables tested.

(2) Aluminums: approved welding consumables cover other approved welding consumables having the strength equal to or higher than that of the welding consumables tested.

(3) Any variation of the composition of the shielding gas or the mixing ratio of mixed gases is to be restricted to the groups listed in Table 2.5.1.3 or Table 2.9.2.4 of this PART.

3.1.4.8 Approval for a test made in any position is restricted to that position. To qualify a range of positions, test assemblies are to be welded for the highest heat input position (generally vertical upward) and the lowest heat input position (generally horizontal-vertical), and all applicable tests are to be made on those assemblies, except for welding in the vertical downward position. Butt weld joints of pipes with an external diameter more than 25 mm apply to butt weld joints of plates at corresponding positions.
3.1.4.9 The upper limit of heat input approved is 25% greater than that used in the test or 55 kJ/cm, whichever is smaller. For high heat input processes over 50 kJ/cm, the upper limit is 10% greater than that used in the test.
3.1.4.10 Changes to the type (AC, DC, pulsed) and polarity (DCSP or DCRP) of the welding current normally require a new welding procedure qualification.
3.1.4.11 In production welding, the minimum preheating temperature is not to be less than that used in the qualification test. The maximum interpass temperature is not to be higher than that used in the qualification test.
3.1.4.12 The post-weld heat treatment or aging used in the qualification test is to be maintained during manufacture. Artificial ageing for 6000 series alloys may substitute for prolonged natural ageing.
3.1.4.13 The range of approval for the type of welded joints is to be in accordance with Table 3.1.4.13. In general, qualified butt weld procedures are also applicable to fillet welds for corresponding thicknesses. For aluminum alloys and for steels with yield strength not less than 355 N/mm^2, however, the fillet weld test is to be carried out according to structural requirements.

Range of Approval for Type of Welded Joint **Table 3.1.4.13**

Type of welded joint for test assembly				Range of approval	
Welding process		Name	Code	Structural steel	Aluminum alloy
Butt weld	Both sides	With gouging	C	C	C
		Without gouging	D	D, C	D, C, A
	Single side	With backing	A	A, C	A, C
		Without backing	B	B, A, C, D	B, A, C, D

3.1.4.14 Welding procedure qualification with shop primer qualifies welds without primer, but not vice versa.
3.1.4.15 The range of approval relating to other variables not covered above may be taken according to the relevant standards subject to agreement of CCS.

Section 2 WELDING PROCEDURE APPROVAL TESTS FOR BUTT WELDS

3.2.1 General requirements
3.2.1.1 This Section applies to welding procedure approval tests for butt welds of plates and pipes.
3.2.1.2 The welding procedure approval tests for butt welds are to be carried out for different welding processes and welding positions respectively.

3.2.2 Test assemblies
3.2.2.1 The base metals and welding consumables selected for test assemblies are to comply with the requirements of the preliminary welding procedure specification.
3.2.2.2 The direction in which test pieces are cut from rolled steel is to be determined as required for impact tests (see Figure 3.2.2.2). For normal and higher strength hull structural steel plates, the butt weld of the test piece is to be perpendicular to the rolling direction (longitudinal impact) of the two plates, and for other rolled plates the butt weld of the test piece is to be parallel to the rolling direction (transverse impact) of the two plates.
For aluminum alloys, the butt weld of the test piece is to be parallel to the rolling direction of the two plates.

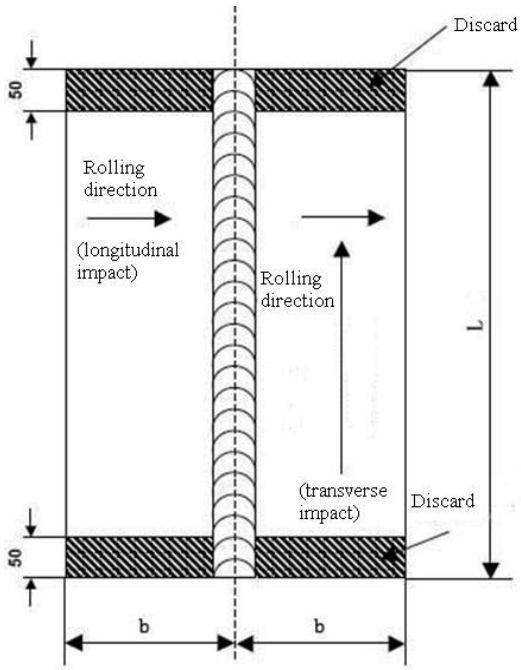


Figure 3.2.2.2 Test Assembly for Butt Weld

3.2.2.3 The test plate is to be of a size sufficient to ensure a reasonable number of specimens and at least the following requirements are to be complied with:
(1) Dimensions of butt weld test plates are to comply with the requirements of Table 3.2.2.3.

Dimensions of Butt Weld Test Plates **Table 3.2.2.3**

Welding process	Size of test plate (mm)	
	Length L	Breadth b
Manual and semi-automatic welding	$\geq 350\ (6t)$①	$\geq 150\ (3t)$①
Automatic welding	≥ 1000	$\geq 200\ (4t)$①

Note: ① The greater is to be taken (t being the thickness of test plate, in mm). Where the thickness of test plate exceeds 100 mm, appropriate reduction of the dimensions of test plate may be carried out as agreed by CCS.

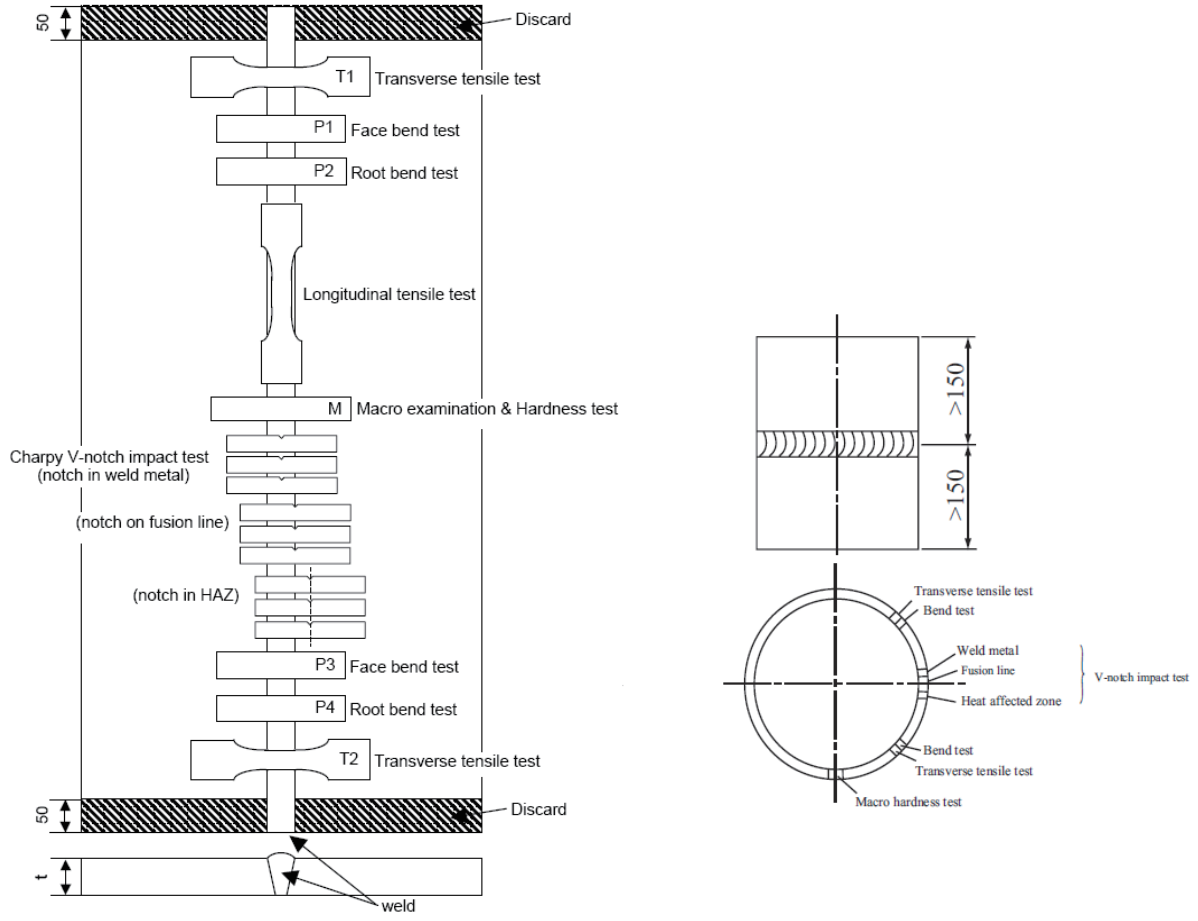
(2) The test length L of pipes is not to be less than 150 mm. Where the diameter of a pipe is over 600 mm, a test plate may be substituted as the pipe for butt welding at the corresponding position.
3.2.2.4 The preparation of test plates, the beveling of plate edges, tacking, welding and heat-treatment procedures are to comply with the preliminary welding procedure specification.
3.2.2.5 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 assemblies.

3.2.3 Sampling

3.2.3.1 Test assemblies are to be examined by 100% visual testing and by 100% non-destructive surface and internal testing prior to the cutting of test specimens. In case any post-weld heat treatment or aging is required or specified, the non-destructive testing is to be performed after the heat treatment or aging. For high strength quenched and tempered steels with specified minimum yield strength of 420 N/mm^2 and above, the non-destructive testing is to be delayed for a minimum of 48 h, unless the heat treatment has been carried out. NDT procedures are to be agreed with CCS.
3.2.3.2 The visual inspection and non-destructive testing of steel and aluminum alloy test sample are to be respectively in accordance with the requirements for level B of ISO 5817 and ISO 10042 (excess weld metal, excessive convexity and excess penetration for which level C applies) or other equivalent standards.
3.2.3.3 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 preliminary welding procedure specification is to be modified and the relevant approval test is to be carried out.

3.2.4 Butt welding procedure test items

3.2.4.1 For butt welding procedure tests regarding steels, the following specimens are generally to be taken from the test assembly as shown in Figure 3.2.4.1 and the dimensions of specimens are to comply with the relevant requirements in Section 2, Chapter 1 of this PART:
(1) two transverse tensile test specimens;
(2) two transverse face and two transverse root bend specimens. They may be substituted by four side-bend specimens where the thickness of the test assembly is not less than 12 mm. For butt joints in heterogeneous steel plates, face and root longitudinal bend test specimens may be used instead of the transverse bend test specimens;
(3) several sets of impact specimens (three specimens each set) are to be taken at positions shown in Figure 3.2.4.1(3) based on heat input range, welding procedure and plate thickness of the test assembly and according to the requirements of Table 3.2.4.1(3);
(4) one specimen for macro examination and one specimen for hardness test (usually cut at welded joints). Steels with specified yield strength less than 355 N/mm^2 may be exempted from hardness test;
(5) one longitudinal tensile test specimen of weld metal (only where the welding consumable is not approved). Where more than one welding process or type of consumables has been used to make the test weld, test specimens are to be taken 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.



Sampling positions of test plate assembly

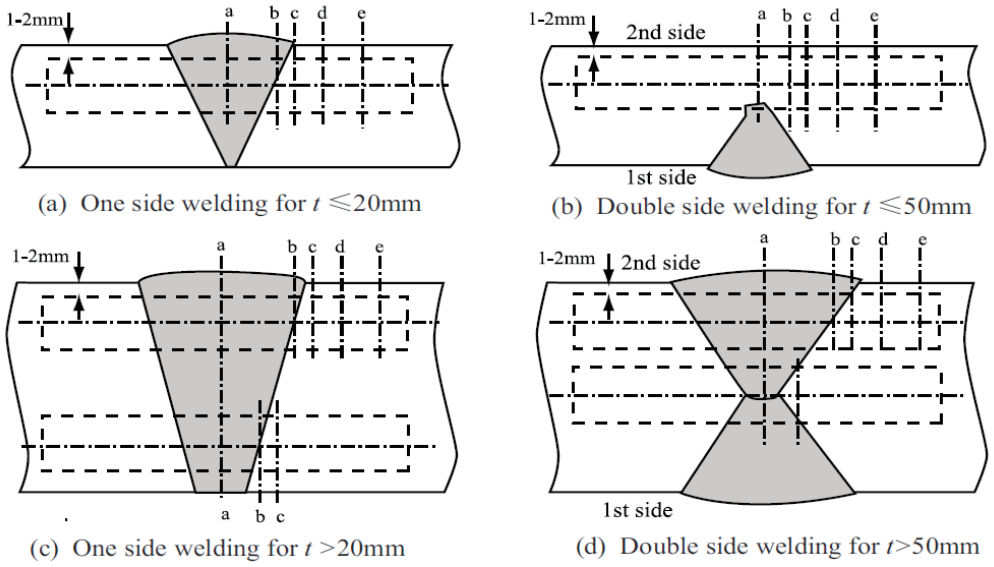
Sampling positions of test pipe assembly

Figure 3.2.4.1 Sampling Positions of Test Assemblies

Sampling Positions of Impact Specimens **Table 3.2.4.1(3)**

Heat input range (kJ/cm)	Welding procedure	Thickness of test assembly (mm)	Sampling position of impact specimen	
			Surface①	Root
≤ 50②	One side	$t \leq 20$	a, b, c, d	–
		$20 < t \leq 50$	a, b, c, d	a
		$t > 50$	a, b, c, d	a, b
	Double side	$t \leq 50$	a, b, c, d	–
		$t > 50$	a, b, c, d	a
> 50③	One side	$t \leq 20$	a, b, c, d, e	–
		$t > 20$	a, b, c, d, e	a, b, c
	Double side	$t \leq 50$	a, b, c, d, e	–
		$t > 50$	a, b, c, d, e	a, c

Notes: ① For double side welding, the 2nd side is to be taken.
② Only when the approved procedure is to be used for joining primary parts of offshore engineering facilities, a specimen at position d is to be additionally taken.
③ Only when the heat input is more than 200 kJ/cm, a specimen at position e is to be additionally taken.
④ When butt welds are made between different steel grades/types, the test specimens are to be taken from the side of the joint with lower toughness of steel. Temperature and absorbed energy results are to be in accordance with the requirements for the lower toughness steel.
⑤ Where more than one welding process or type of consumables has been used to make the test weld, impact test specimens are to be taken from the respective areas where each was employed. This is not to apply to the process or consumables used solely to make the first weld run or root deposit.
⑥ When the thickness of the test assembly or the pipe diameter is not enough to make impact specimen of 5 mm, impact tests may be exempted.



In the Figure, a, b, c, d and e are notch locations of impact specimens where: a – center of weld, b – fusion line, c – heat affected zone, 2 mm from fusion line, d – heat affected zone, 5 mm from fusion line, e – heat affected zone, 7 ~ 10 mm from fusion line (to be determined according to heat input).

Figure 3.2.4.1(3) Sampling Positions of Impact Specimens

3.2.4.2 For butt welding procedure tests regarding aluminum alloy structures, the following specimens are generally to be taken from the test assembly as shown in Figure 3.2.4.2:
(1) Four transverse bend test specimens (two face bend ones and two root bend ones). They may be substituted by four side-bend specimens where the thickness of the test assembly is not less than 12 mm.
(2) Two transverse tensile test specimens and one macro-specimen (which may be prepared from the discard).

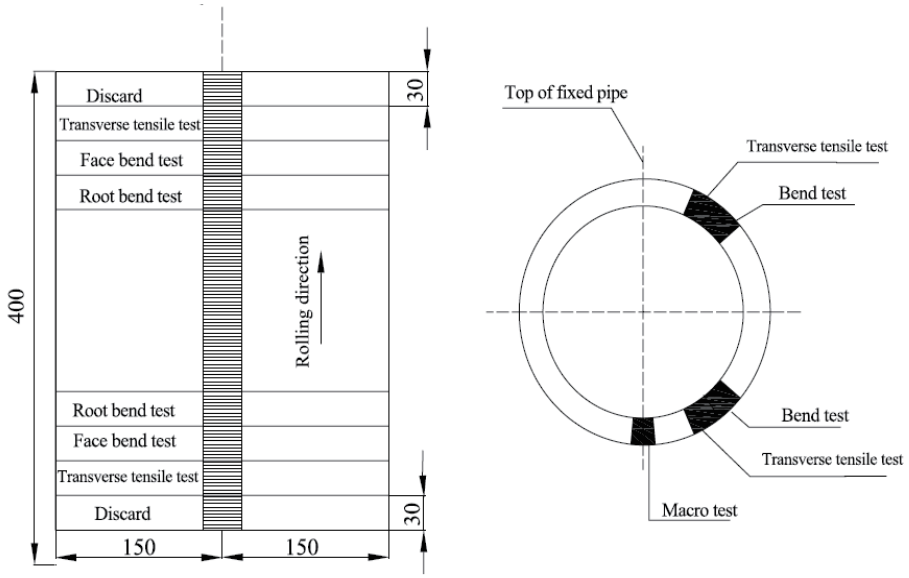


Figure 3.2.4.2

3.2.4.3 In addition to the tests required in 3.2.4.1 and 3.2.4.2 of this Section, the following examinations and test items may be required when deemed necessary by the Surveyor according to the actual situation:
(1) chemical analysis of deposited weld metal;
(2) chemical analysis of parent plate;
(3) micro-structure of the whole joint.
3.2.4.4 The specimens are to be prepared in accordance with the requirements in Section 2, Chapter 1 of this PART and the tests are to be carried out in accordance with the requirements in Section 2, Chapter 1 of PART ONE of the Rules.

3.2.5 Welding procedure test results for steel structures

3.2.5.1 The tensile strength of butt welds is not to be less than the minimum specified for the base metal. 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 requirements relating to the steel grade having lower strength.
3.2.5.2 The tensile test results of weld metal are generally to meet the minimum requirements for approval level of applicable welding consumables specified in Chapter 2 of this PART. If the welding consumables used are not within the range specified in Chapter 2, the properties are not to be lower than the specified minimum value of parent metal.
3.2.5.3 After bending, the test specimens are not to reveal any open defect in any direction exceeding 3 mm in length on the outer surface.
3.2.5.4 The temperature for Charpy V-notch impact tests is to comply with Table 3.2.5.4(a) and the test results are to comply with Table 3.2.5.4(b).

Temperature for Impact Test **Table 3.2.5.4(a)**

Grade of steel	A, AH32, AH36, AH40	B, D, DH32, DH36, DH40, AH420, AH460, AH500, AH550, AH620, AH690, AH890, AH960	E, EH32, EH36, EH40, DH420, DH460, DH500, DH550, DH620, DH690, DH890, DH960	FH32, FH36, FH40, EH420, EH460, EH500, EH550, EH620, EH690, EH890, EH960	FH420, FH460, FH500, FH550, FH620, FH690
Test temperature (℃)	20	0	-20	-40	-60

Ductility for Impact Test[①] **Table 3.2.5.4(b)**

Grade of steel	A, B[②], D, E	AH32, DH32, EH32, FH32	AH36, DH36, EH36, FH36	AH40, DH40, EH40, FH40	AH420, DH420, EH420, FH420	AH460, DH460, EH460, FH460	AH500, DH500, EH500, FH500	AH550, DH550, EH550, FH550	AH620, DH620, EH620, FH620	AH690, DH690, EH690, FH690	AH890, DH890, EH890	AH960, DH960, EH960
Average energy (J)	47[③]			47[④]	28	31	33	37	41	46		

Notes: ① For thicknesses above 50 mm, impact test requirements are to be agreed by CCS.
② For Grades A and B steels, average absorbed energy on fusion line and in heat affected zone is to be minimum 27 J.
③ The average energy may be 34 J for vertical welding of manually or semi-automatically welded joints and for automatic welding. For manually or semi-automatically welded joints, the average energy is to be 47 J for downhand welding, horizontal welding and overhead welding.
④ The average energy may be 39 J for vertical welding of manually or semi-automatically welded joints and for automatic welding. For manually or semi-automatically welded joints, the average energy is to be 47 J for downhand welding, horizontal welding and overhead welding.
⑤ Except for hull structural steels listed in the Table, the impact test temperature and impact energy for welded joints of normal strength steel are to comply with the requirements for parent material.

3.2.5.5 The macro examination is to reveal a regular weld profile, full penetration and the absence of defects such as cracks and lack of fusion.
3.2.5.6 The results from the hardness test are given in Table 3.2.5.6.

Requirements for Hardness Test Results of Weld Joints

Table 3.2.5.6

Steel with a specified minimum yield strength R_{eH} (N/mm^2)	Allowable maximum hardness value of welded joints
$R_{eH} \leq 420$	HV350
$420 < R_{eH} \leq 690$	HV420
$690 < R_{eH} \leq 960$	HV450

3.2.6 Welding procedure test results for aluminum alloys

3.2.6.1 The tensile strength of joints is to comply with the requirements of Table 3.2.6.1.

Requirements for Tensile Strength of Aluminum Alloy Joints Table 3.2.6.1

Designation	Minimum tensile strength R_m (N/mm^2)
5754	190
5454	215
5086	240
5083	275
5383 5456	290
5059	330
5A01	325
6005A 6061 6082	170

3.2.6.2 After bending, the test specimens are not to reveal any crack or other open defect exceeding 3 mm in length on the outer surface.
3.2.6.3 The macro examination is to reveal a regular weld profile, full penetration and the absence of defects such as cracks and lack of fusion.

3.2.7 Additional requirements for welding procedures approval tests of stainless steels

3.2.7.1 For austenitic stainless steel, in addition to the relevant requirements of 3.2.4.1 and 3.2.5 above, the following requirements are to be complied with:
(1) generally only the center of the weld is subject to the impact test (test temperature is -20℃). In deep cold condition, the center of the weld, fusion line and heat affected zone 2 mm from the fusion line are to be subject to the impact test individually (test temperature is -196℃). The impact energy is not to be less than 27 J;
(2) the hardness test may be omitted;
(3) the intergranular corrosion test of welds is to be carried out in accordance with the requirements of Section 7, Chapter 2, PART ONE of the Rules (for austenitic stainless steel used in non-corrosive medium, it may be omitted).
3.2.7.2 For duplex stainless steel, in addition to the relevant requirements of 3.2.4.1 and 3.2.5 above, the

following requirements are to be complied with:
(1) the center of the weld, fusion line and heat affected zone 2 mm from the fusion line are to be subject to the impact test individually (test temperature is -20℃). The impact energy is not to be less than 27 J;
(2) the result of the hardness test is not to be greater than HV420;
(3) the pitting corrosion test of welds is to be carried out in accordance with the requirements of Section 9, Chapter 2, PART ONE of the Rules (except connection to other stainless steels or carbon steels);
(4) micro examination of welds and heat affected zones is to exhibit no grain boundary carbides and intermetallic precipitates;
(5) the ferritic content of the welds and the heat affected zone of the final and root runs are measured separately. The content is to be within the range from 30% to 70%.

Section 3 WELDING PROCEDURE APPROVAL TESTS FOR FILLET WELDS

3.3.1 General requirements

3.3.1.1 This Section applies to welding procedure approval tests for plate-to-plate, pipe-to-pipe and pipe-to-plate fillet welds.
3.3.1.2 The welding procedure approval tests for fillet welds are to be carried out for different welding processes and welding positions respectively.

3.3.2 Test assemblies

3.3.2.1 The base metals and welding consumables selected for test assemblies are to comply with the requirements of the preliminary welding procedure specification.
3.3.2.2 The test assembly is to be of a size sufficient to ensure a reasonable heat distribution, normally in accordance with Table 3.3.2.2.

Size of Fillet Weld Test Plate **Table 3.3.2.2**

Size of test plate / Welding process	Length *L*	Breadth *b*
Manual and semi-automatic welding	≥350 ($6t$)①	150 ($3t$)①
Automatic welding	≥1000	150 ($3t$)①

Note: ① The greater of the two is to be taken (t being thickness of the test plate, in mm).

For pipe-to-plate assemblies, the length of sides of the plate is to be at least 100 mm greater than the outside diameter of the test pipe.
For pipe-to-plate assemblies, the length of the test pipe is to be more than 150 mm.
3.3.2.3 The preparation, tacking and welding of test plates are to comply with the requirements of the preliminary welding procedure specification.
3.3.2.4 The test assembly is to be welded on one side only. For single run manual and semi-automatic welding, at least one stop/restart is to be included in the test length and its position is to be clearly marked for subsequent macro examination. If tack welding will be kept in the production procedure, tack welds are to be kept during test for fusion into the joint.

3.3.3 Test items

3.3.3.1 After welding, test assemblies are to be examined by visual testing and by dye penetrant or magnetic particle testing. For test assemblies with specified minimum yield strength of 420 N/mm^2 and above, the non-destructive testing is to be delayed for a minimum of 48 h, unless heat treatment has been carried out.
3.3.3.2 For fillet welds in plates, the specimens are to be taken as shown in Figure 3.3.3.2. Both ends of the test assembly are to be discarded for a length about 50 mm, then two macrosections about 25 mm in length are to be taken, one at the mid-length of the test assembly and the other at stop/restart points. For steels with specified minimum yield strength not less than 355 N/mm^2(including duplex stainless steel), the specimen with stop/restart points is also used for hardness test. Fracture tests are to be carried out on the longer part of the remainder of the test assembly.

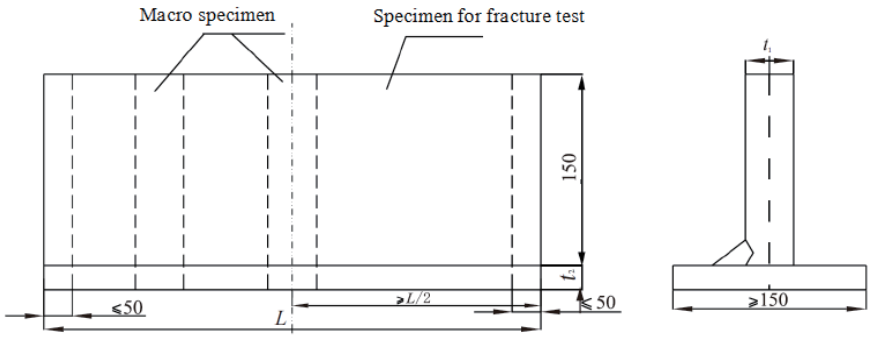
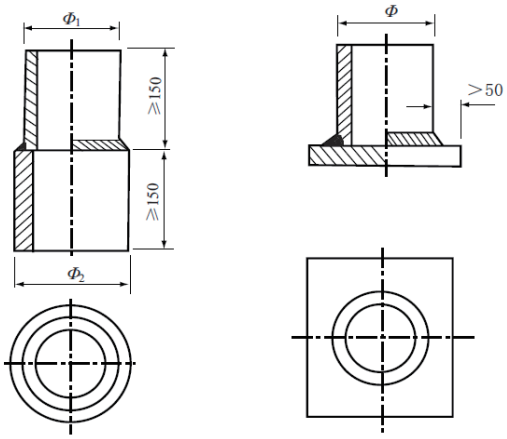


Figure 3.3.3.2

3.3.3.3 Unless otherwise specified, the pipe-to-pipe and pipe-to-plate fillet weld assemblies are to be cut into four equal parts as shown in Figure 3.3.3.3(1) or (2). Each weld is to be subjected to macro examination (at least one cross section is to include stop/restart points). For steels with specified minimum yield strength not less than 355 N/mm^2, the specimen with stop/restart points is also used for hardness test.



(1) Pipe to fillet weld assembly (2) Pipe to plate fillet weld assembly

Figure 3.3.3.3

3.3.3.4 Hardness tests and fillet weld fracture tests are to be carried out in accordance with the relevant requirements in Section 2, Chapter 1 of this PART.

3.3.4 Test results

3.3.4.1 The macro examination is to reveal a regular weld profile, sufficient root penetration and the absence of defects such as cracks, lack of fusion.

3.3.4.2 The fractured surfaces of fracture test specimens are to show welds without cracks and lack of fusion. Slag inclusions or pores are to be assessed in accordance with level B of ISO 5817 or ISO 10042.

3.3.4.3 The results from the hardness test of steel structures are given in Table 3.2.5.6, Section 2 of this Chapter.

3.3.4.4 The visual inspection and non-destructive testing of steel and aluminum alloy test sample are to be respectively in accordance with the requirements for level B of ISO 5817 and ISO 10042 (excess weld metal, excessive convexity and excess penetration for which level C applies) or other equivalent standards.

Section 4 FULL-PENETRATION WELDING PROCEDURE APPROVAL TESTS FOR INCLINED OR T-SHAPED TUBULAR JOINTS

3.4.1 General requirements

3.4.1.1 The full-penetration welding procedure approval tests for inclined or T-shaped tubular joints of steel offshore structures are to be carried out for different welding processes and positions respectively.

3.4.1.2 In addition to the test items specified in this Section, butt weld tests in the same welding conditions are to be carried out according to Section 2 of this Chapter.

3.4.2 Test assemblies

3.4.2.1 Unless otherwise specified, test assemblies for inclined or T-shaped tubular joints are to be prepared as shown in Figure 3.4.2.1.

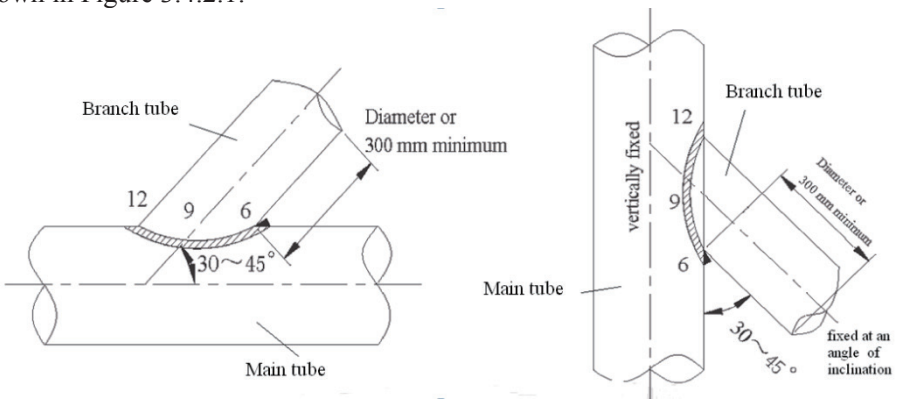


Figure 3.4.2.1

3.4.2.2 The parameters concerning diameter, wall thickness, inclined angle, etc. of main and branch tubes are to be determined according to their structures as appropriate. The inclined angle is usually 30° to 45°, or the minimum possible inclined angle in the actual structures. The minimum length of the branch tube is to be taken as its diameter, but does not need to be more than 300 mm. Shape of grooves, edge preparation, assembly and welding procedures are to be as required by the actual structures.

3.4.2.3 Where the diameter of the main tube exceeds 600 mm, the tube may be replaced by a plate of the same thickness and steel grade, but the plate is to be of sufficient size.

3.4.2.4 The welding of tubular joints may be divided into two kinds: welding in shop (rotating) and on site (fixed), with a test assembly being prepared for each kind. The length of the test weld is to be the full weld length of the joint and where this length is 800 mm, half of it may be taken as the test weld.

3.4.3 Test items

3.4.3.1 Dye penetrant test or magnetic particle examination and ultrasonic detection are to be carried out for the welds.

3.4.3.2 Impact tests: 4 sets (3 specimens for each set) (when the wall thickness of the main tube allows). The specimens are to be taken from the positions near “9 o’clock” point as shown in Figure 3.4.2.1. The notches are to be positioned in the center of the weld, on fusion line and 2 mm and 5 mm from fusion line within the HAZ respectively. V-notches are to be perpendicular to the wall of the branch tube.

3.4.3.3 Macro examination: Two specimens are to be respectively taken from the positions of “6 o’clock” and “12 o’clock”. Where the specified minimum yield strength of the steel is 355 N/mm^2 and above, hardness tests are also to be carried out at the above positions of two sections.

3.4.4 Test results

3.4.4.1 The temperature for Charpy V-notch impact tests is to comply with Table 3.2.5.4(a) and the test results are to comply with Table 3.2.5.4(b).

3.4.4.2 The macro examination is to reveal a regular weld profile, full penetration and the absence of defects such as cracks and lack of fusion.

3.4.4.3 The results from the hardness test are given in Table 3.2.5.6, Section 2 of this Chapter.

3.4.4.4 Non-destructive testing is to be in accordance with the requirements for level B of ISO 5817 (excess weld metal, excessive convexity and excess penetration for which level C applies) or other equivalent standards.

CHAPTER 4 QUALIFICATION TESTS OF WELDERS

Section 1 GENERAL PROVISIONS

4.1.1 Application

4.1.1.1 The requirements of this Chapter apply to the qualification tests of welders intended to be engaged in the fusion welding (including shielded metal arc welding, semi-automatic welding and TIG welding) of ship structures, offshore structures, machinery, boilers and pressure vessels as well as piping with carbon steels, carbon-manganese steels, alloy steels or aluminum alloys as the base metal.[Notes]

Notes: ① The requirements of this Chapter apply to applications for welder or welding operator qualification (initial or renewal) dated on or after 1 January 2018.

② The requirements of this Chapter do not invalidate welder's qualifications issued and accepted by CCS before 1 January 2018. These qualifications are to be renewed in accordance with the requirements of this Chapter latest by 31 December 2020.

③ Certificates that expire after 1 January 2018 are to be renewed in accordance with the requirements of this Chapter.

④ The welder's or welding operator's qualifications which have not been required before 1 January 2018, are to be initially issued in accordance with the requirements of this Chapter by the 31 December 2020 at the latest.

4.1.1.2 The requirements of this Chapter do not apply to welders engaged in oxy-acetylene welding.

4.1.1.3 For base metals, welding consumables and welding processes other than those specified in this Chapter, the requirements for the qualification tests of welders are to be submitted to CCS for approval.

4.1.1.4 The method of qualification tests of welders engaged in special product welding is to be specially considered by CCS.

4.1.1.5 The welding operator responsible for setting up and/or adjustment of fully mechanized and automatic equipment, such as submerged arc welding, gravity welding, electro-gas welding and MAG welding with auto-carriage, etc., must be qualified whether he operates the equipment or not. However a welding operator, who solely operates the equipment without responsibility for setting up and/or adjustment, does not need qualification provided that he has experience of the specific welding work concerned and the production welds made by the operators are of the required quality.

For the qualification test and approval range of the welding operator, refer to ISO 14732.

4.1.2 General requirements

4.1.2.1 Those welders intended to be engaged in welding specified in 4.1.1.1 above in shipyards and manufacturers are to be tested and qualified in accordance with the requirements of this Chapter and issued with a qualification certificate endorsed by CCS.

4.1.2.2 The requirements of this Chapter are applicable to welding of hull structures both during new construction and the repair of ships.

4.1.2.3 The training of welders, control of their qualification and maintenance of their skills are the responsibility of shipyards and manufacturers. The Surveyor is to verify and be satisfied that the welders are appropriately qualified.

4.1.2.4 Welders or welding operators qualified in accordance with national or international welder qualification standards may also be engaged in welding of hull structures and relevant products at the discretion of CCS provided that the qualification testing, range of approval and revalidation requirements are considered equivalent to the requirements of this Chapter.

4.1.2.5 A Qualification Test Committee may be individually or jointly set up by manufacturers/training providers concerned to take the responsibilities for carrying out the qualification tests in compliance with the requirements of this Chapter. The Qualification Test Committee, which is to be approved by CCS, is in general to consist of a technical manager, welding engineers or technicians, welding quality inspectors, and experienced welders of the manufacturer.

4.1.3 Requirements for test applicants

4.1.3.1 Applicants satisfying one of the following requirements may submit an application to the Qualification Test Committee and take part in the tests upon approval:

(1) holding a graduation certificate of welder training of a technical school and being engaged in welding work;

(2) being capable of welding independently with adequate skill and being engaged in welding work;

(3) having been trained in basic knowledge and operational skill;

(4) additionally for applicants for qualification tests of underwater welders: holding a valid diver's certificate or a graduation certificate of a diving school and possessing a certain skill in underwater welding.

4.1.4 Categorization of qualification test items

4.1.4.1 According to types of products, welders are categorized as those qualified for the welding of ships and offshore structures(S) and those qualified for the welding of marine boilers and pressure vessels(B).

4.1.4.2 Welders may choose to have butt weld and/or fillet weld tests according to their actual needs.

4.1.4.3 For welders engaged in the welding of marine boilers and pressure vessels, special tests of tube-to-plate fillet welding are to be carried out when necessary.

4.1.5 Re-tests and new tests

4.1.5.1 When a welder fails a qualification test, the following is to apply.

(1) In cases where the welder fails to meet the requirements in part of the tests, a retest may be welded immediately, consisting of another test assembly of each type of welded joint and position that the welder failed. In this case, the test is to be done for duplicate test specimens of each failed test. All retest specimens are to meet all of the specified requirements.

(2) In cases where the welder fails to meet the requirements in all parts of the required tests or in the retest prescribed in 4.1.5.1(1), the welder is to undertake further training and practice.

4.1.5.2 When there is specific reason to question the welder's ability or the period of effectiveness has lapsed, the welder is to be re-qualified in accordance with the tests specified in Section 2 of this Chapter.

4.1.5.3 Where any test specimen does not comply with dimensional specifications due to poor machining, a replacement test assembly is to be welded and tested.

4.1.6 Certificates

4.1.6.1 Qualification certificates are normally issued when the welder has passed the qualification test by CCS. Each Shipyard and Manufacturer are to be responsible for the control of the validity of the certificate and the range of the approval.

4.1.6.2 The following items are to be included in the Certificate:

(1) Range of qualification for base metal, welding processes, filler metal type, types of welded joint, plate thicknesses (wall thickness and pipe diameter for pipes) and welding positions as well as water depth (for underwater welding only).

(2) Expiry date of the validity of the qualification.

(3) Name, date of birth, identification and the photograph of the welder.

(4) Name of shipbuilder / manufacturer.

4.1.6.3 When a certificate is issued, the relative documents such as test reports and/or revalidation records are to be archived as annexes to the copy of certificate.

4.1.6.4 The status of approvals of each individual qualification is to be demonstrated to CCS when requested.

4.1.7 Validity of the qualification

4.1.7.1 Normally the validity of the welder's approval begins from the issue date of qualification certificate when all the required tests are satisfactorily completed.

4.1.7.2 The certificate is to be signed at six-month intervals by the shipyards/manufacturers personnel who is responsible for production weld quality (e.g. personnel in charge of the quality inspection department) provided that all the following conditions are fulfilled:

(1) the welder is to be engaged with reasonable continuity on welding work within the current range of approval. An interruption for a period no longer than six months is permitted;

(2) the welder's work is in general to be in accordance with the technical conditions under which the approval test is carried out;

(3) there is to be no specific reason to question the welder's skill and/or knowledge.

4.1.7.3 If any of these conditions is not fulfilled, CCS is to be informed and the certificate is to be cancelled. The validity of the certificate may be maintained in agreement with CCS if the maintenance scheme of qualification is in accordance with either one of 4.1.7.4.

4.1.7.4 Except that the Qualification Certificate of Welder for tact welding is valid for an unlimited period, revalidation is to be carried out by CCS for the Qualification Certificate of all welders. The skill of the welder is to be periodically verified by one of the following:

(1) The welder is to be tested every 3 years.

(2) Every 2 years, two welds made during the last 6 months of the 2 years validity period are to be tested by radiographic or ultrasonic testing or destructive testing and are to be recorded. The welds tested are to reproduce the initial test conditions except for the thickness. These tests revalidate the welder's

qualifications for an additional 2 years.
4.1.7.5 CCS has to verify compliance with the above conditions and sign the maintenance of the welder's qualification certificate.

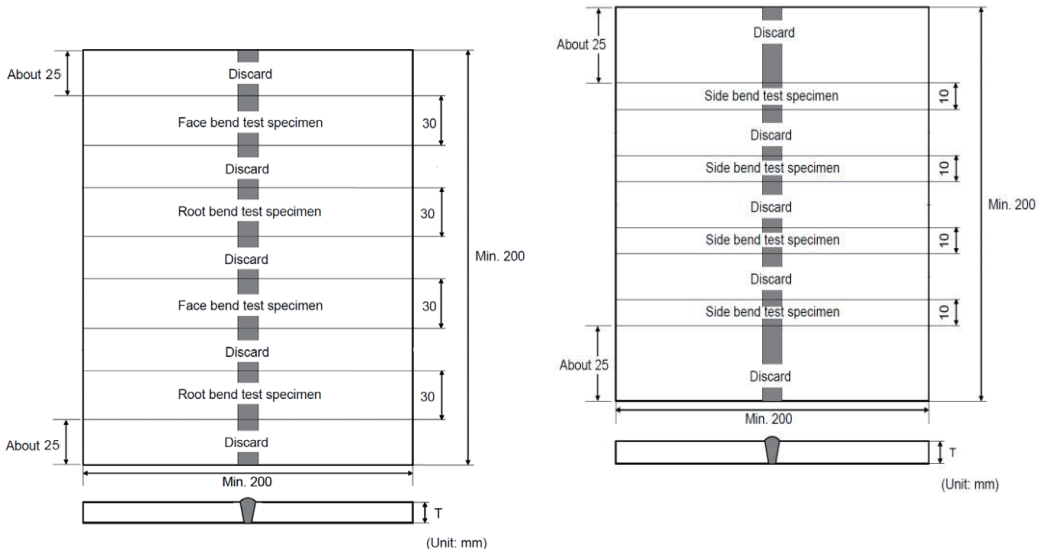
Section 2 QUALIFICATION TESTS AND EVALUATION OF WELDERS

4.2.1 General requirements

4.2.1.1 Welding of the test assemblies and testing of test specimens are to be witnessed by the Surveyor.
4.2.1.2 Prior to the welder qualification test, the Qualification Test Committee is to submit the intended welding positions, material groups, thicknesses of test assemblies (pipe diameters), joint types and edge preparation dimensions to CCS for confirmation.
4.2.1.3 For the test of welder qualification, on-site record of the test is to be made by the person in charge of the test and confirmed by the Surveyor. The Test Committee is to complete a summary table of test evaluation and submit it to CCS.
4.2.1.4 The plates, pipes and welding consumables for the tests are to comply with the relevant requirements specified in 4.2.3 of this Chapter.

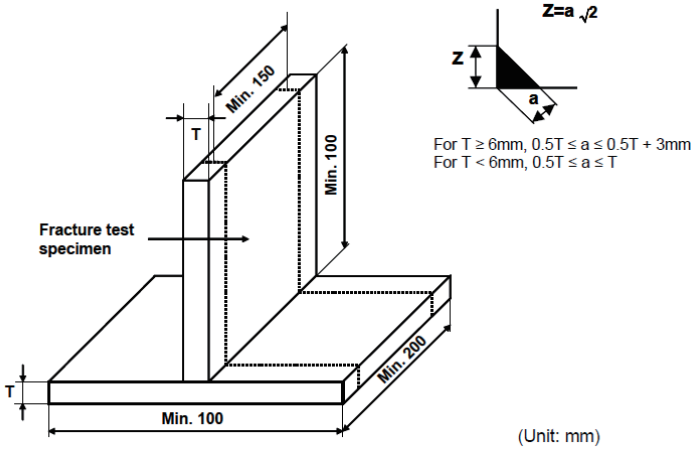
4.2.2 Type and dimensions of test assemblies

4.2.2.1 Dimensions for butt and fillet welds in plates, butt welds in pipes and pipe-to-plate fillet welds are shown in Figures 4.2.2.1(a), (b), (c) and (d) respectively.

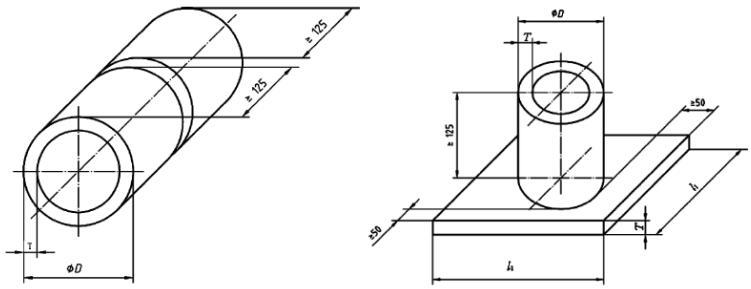


T<12 mm T≥12 mm

(a) Butt welds



(b) Fillet welds



(c) Butt welds in pipes (d) Pipe-to-plate fillet welds (insertion) (in mm)

Figure 4.2.2.1 Dimensions of Test Assemblies

4.2.2.2 For butt welds in pipes, a minimum examination length of 150 mm is required. If the circumference of pipes is less than 150 mm, additional test assemblies are to be required.

4.2.2.3 Specific types of butt welded joints (both sides, one side, with or without backing) and dimensions of edge preparation (included angle, root face, gap) may be determined by the manufacturer according to the actual production.

4.2.2.4 Special requirements for dimensions of the butt welded pipe assembly in the 6GR position are shown in Figure 4.2.2.4.

4.2.2.5 Insertion is to be adopted for pipe-to-plate fillet welds, and the type of joint is shown in Figure 4.2.2.5.

4.2.2.6 Fillet welding is to be adopted for plates, and the throat thickness is shown in Figure 4.2.2.1(b).

4.2.2.7 Dimensions of test assemblies for tack butt welds and tack fillet welds are shown in Figures 4.2.2.7(a) and (b) respectively.

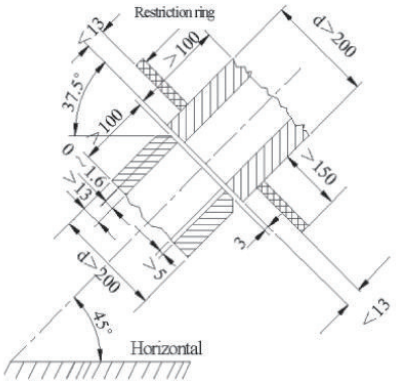


Figure 4.2.2.4 Dimensions of butt welded pipe assembly in the 6GR position

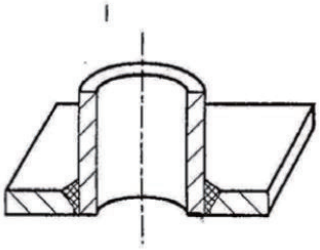
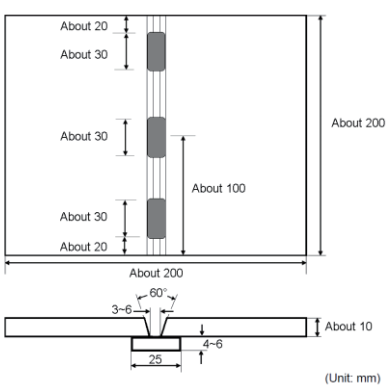
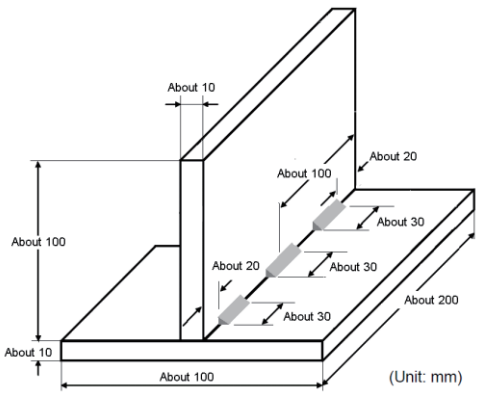


Figure 4.2.2.5 Pipe-to-plate fillet welds



(a) Tack butt welds



(b) Tack fillet welds

Figure 4.2.2.7 Dimensions of test assemblies for tack butt welds and tack fillet welds

4.2.3 Preparation of test assemblies

4.2.3.1 Testing materials are to comply with the relevant provisions of PART ONE of the Rules. Hull structural steels are to conform to one of the following requirements or to be of equivalent grade approved by CCS:

(1) Hull structural steels specified in Sections 2 and 3, Chapter 3, PART ONE of the Rules;

(2) Hull structural forged steels specified in Section 2, Chapter 5, PART ONE of the Rules;

(3) Hull structural cast steels specified in Section 2, Chapter 6, PART ONE of the Rules;

(4) Hull structural steels with specified minimum yield point 460 N/mm^2 specified in CCS Guidelines for Inspection of Thick Higher Strength Steel Plates for Ships.

4.2.3.2 Welding consumables are to match testing materials in performance. Welding consumables for hull structural steels are to conform to one of the following requirements:

(1) Consumables for hull structural steels specified in Sections 1 to 7, Chapter 2 of this PART;

(2) Consumables for H47 steels specified in CCS Guidelines for Inspection of Thick Higher Strength Steel Plates for Ships.

4.2.3.3 The welder qualification test assembly is to be edge prepared, joined, cleaned prior to welding and welded according to a welding procedure specification (WPS or pWPS) simulating the conditions in production, as far as practicable.

4.2.3.4 Each test assembly is to be stamped with the identification number of the welder and the mark of the welding position, and the stamps are to be kept throughout the test. Welding positions for pipes fixed horizontally or at 45° inclination to the horizon are to be expressed by clock hours.

4.2.3.5 Once welding is started, the welding position of the test assembly is not to be changed or altered. The welding direction is to be kept consistent throughout the operation.

4.2.3.6 Root run and capping run need each to have a minimum of one stop and restart. The welders are allowed to remove minor imperfections only in the stop by grinding before restart welding.

4.2.3.7 On completion of welding, there is to be no grinding or repairs on the surface of the weld.

4.2.4 Test or inspection

4.2.4.1 Test or inspection items for different types of test assemblies are shown in Table 4.2.4.1.

Test and Inspection Items Table 4.2.4.1

Type of assembly	Test or inspection items④
Butt welding of plates	1. Visual inspection 2. Bend test①②
Butt welding of pipes	1. Visual inspection 2. Bend test①②
Fillet welding of plates	1. Visual inspection 2. Fracture test or macro examination③
Pipe-to-plate fillet welds	1. Visual inspection 2. Macro examination
Tack welding	1. Visual inspection 2. Fracture test

Notes: ① Radiographic test or fracture test may be carried out in lieu of bend test except the gas-shielded welding processes with solid wire or metal cored wire and aluminum alloy welding.

② Radiographic inspection + bend test for welders engaged in welding of marine boilers and pressure vessels.

③ Two macro sections may be taken in lieu of the fracture test.

④ Additional tests may be required, at the discretion of CCS.

4.2.4.2 The welds are to be visually examined prior to the cutting of the test specimen for the bend test and fracture test. Visual examination is to comply with the following requirements:

(1) The surface of welds is to be in the as-welded state and no machining is to be made. The result of the examination is to show the absence of cracks or other serious imperfections.

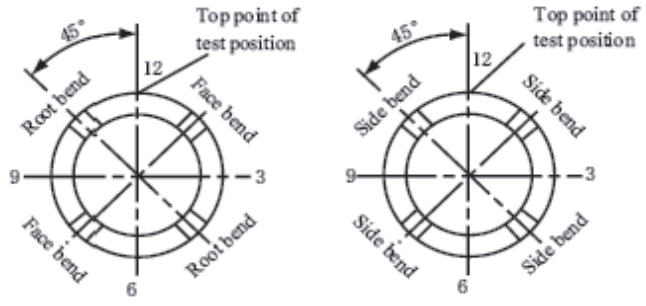
(2) Imperfections detected for steel and aluminum alloy welds are to be assessed respectively in accordance with the requirements for level B of ISO 5817 and ISO 10042 (excess weld metal, excess penetration, excessive convexity and excessive throat thickness for which level C applies), and the acceptance standards for main items are given in Table 4.2.4.2.

Acceptance Standards for Visual Inspection of Welds **Table 4.2.4.2**

Name of defect	Acceptance standards	
	Steel	Aluminum alloy
Crack	Not allowed	Not allowed
Lack of fusion	Not allowed	Not allowed
Root with incomplete penetration	Not allowed	Not allowed
Surface overlap	Not allowed	Not allowed
Surface pore	Not allowed	Concentrated pore and chain pore are not allowed; uniformly distributed porosity rate ≤0.5%, single pore diameter ≤0.2t ①, maximum 1 mm
Local root depression	Depth ≤0.05t①, maximum 0.5 mm	Depth ≤0.05t①, maximum 0.5 mm
Undercut	Depth ≤0.05t①, maximum 0.5 mm	Depth ≤0.1t①, maximum 0.5 mm (continuous undercuts are not allowed)
Excess weld metal (butt weld)	Height ≤1+0.15b②, maximum 7.0 mm	Height ≤1.5+0.15b②, maximum 8.0 mm
Excessive convexity (fillet weld)	Height ≤1+0.15b②, maximum 4.0 mm	Height ≤1.5+0.15b②, maximum 4.0 mm
Excess penetration	Height ≤1+0.6b②, maximum 4.0 mm	Height ≤4.0 mm
Excessive throat thickness	Height ≤1+0.2a③, maximum 4.0 mm	--
Insufficient throat thickness	Not allowed	Height ≤0.1a③
Unsymmetrical fillet weld leg	Difference of weld leg length ≤1.5+0.15a③	Difference of weld leg length≤1.5+0.2a③

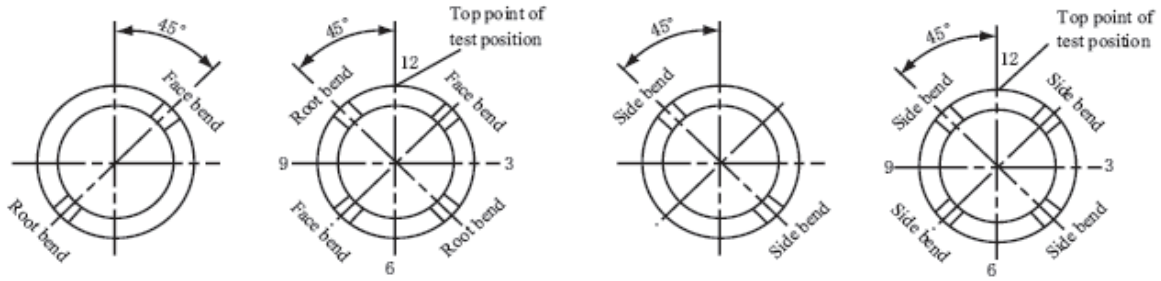
Notes: ① t—plate thickness for butt weld and throat thickness for fillet weld, in mm;
② b—corresponding weld breadth (root weld breadth for excess penetration), in mm;
③ a—throat thickness, in mm.

4.2.4.3 The bend test for butt welding is to comply with the following requirements:
(1) See Figures 1.2.3.3 and 1.2.3.4, Chapter 1 of this PART for the dimensions of and requirements for transverse bend test specimens.
(2) The diameter of the former is to comply with the requirements for welding procedure approval tests in 1.2.4.2 of Chapter 1 of this PART.
(3) For butt weld joints of plates，two face bend test and two root bend test specimens are to be tested for initial qualification test, and one face and one root bend test specimens for extension of approval. For thickness 12 mm and over, four side specimens (two side specimens for extension of approval) with 10 mm in thickness may be tested as an alternative. See Figure 4.2.2.1(a) of this Section for the sampling location of the bend specimen for initial qualification test.
(4) For butt weld joints of pipes, the requirements of test positions at 1G and 2G are the same as those specified in (3) above, however, regardless of initial qualification test or retest, four bend tests are to be carried out for the welders at 5G, 6G and 6GR. The sampling positions for bend specimen are shown in Fig. 4.2.4.3(a) and (b).
(5) At least one bend test specimen is to include one stop and restart in the bending part, for root run or for cap run.
(6) The test specimens are to be bent through 180 degrees. After the test, the test specimens are not to reveal any open defects in any direction greater than 3 mm. Defects appearing at the corners of a test specimen during testing are to be investigated case by case.



$T < 12$ $T \geq 12$

Figure 4.2.4.3(a) Sampling Position of Bend Test Specimen for Butt Weld Joints of Pipes (Initial Qualification Test)



1G, 2G ($T < 12$) 5G, 6G, 6GR ($T < 12$) 1G, 2G ($T \geq 12$) 5G, 6G, 6GR ($T \geq 12$)

Figure 4.2.4.3(b) Sampling Positions of Bend Test Specimens for Butt Weld Joints of Pipes (Re-qualification Test)

4.2.4.4 For steels and aluminum alloys, when radiographic testing is used for butt welds, imperfections detected are to be assessed in accordance with level B of ISO 5817 and ISO 10042 respectively.

4.2.4.5 When fracture test is used for butt welds, full test specimen in length is to be tested in accordance with ISO 9017. Imperfections detected for steel and aluminum alloy welds are to be assessed in accordance with level B of ISO 5817 and ISO10042 respectively.

4.2.4.6 When fracture test is used for butt welds, the test method is to be in accordance with 1.2.4.4, Chapter 1 of this PART. Evaluation is to concentrate on cracks, porosity and pores, inclusions, lack of fusion and incomplete penetration. Imperfections detected are to be assessed in accordance with level B of ISO 5817 and ISO 10042 respectively.

4.2.4.7 When macro examination is used for fillet welds, two test specimens are to be prepared from different cutting positions; at least one macro examination specimen is to be cut at the position of one stop and restart in either root run or cap run. Prepare the specimens according to 1.2.3.7, Chapter 1 of this PART. These specimens are to be etched on one side to clearly reveal the weld metal, fusion line, root penetration and the heat affected zone. Macro sections are to include at least 10mm of unaffected base metal. The examination is to reveal a regular weld profile, through fusion between adjacent layers of weld and base metal, sufficient root penetration and the absence of defects such as cracks, lack of fusion etc.

4.2.4.8 For pipe-to-plate fillet welds, the test assembly is to be cut by mechanical means into four equal parts as shown in Figure 4.2.4.8, from which two parts are to be selected for macro-examination of sections A and B (B being the stop/start location). The specimens are to be prepared and etched as per 4.2.4.7. The examination of macro sections is to reveal a regular weld profile, full root penetration and the absence of defects such as cracks, lack of fusion etc.

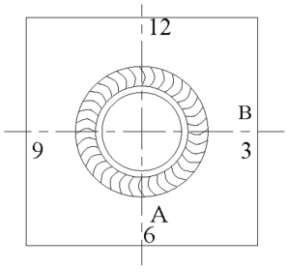


Figure 4.2.4.8 Cutting Position of Macro Sections of Pipe-to-Plate Assembly

4.2.4.9 After fracture testing of tack weld specimens, weld fractures throughout the length of each tack are to show neither lack of fusion on the backing strap or both sides of the groove nor slag inclusions or pores exceeding 2 mm.

Section 3 SCOPE OF APPLICATION OF WELDER'S QUALIFICATION

4.3.1 General requirements

4.3.1.1 A welder is to be qualified in relation to the following variables of welding: welding process, joint type, properties of base metal, plate thickness (wall thickness and pipe diameter for pipes), welding

consumable type and welding position.
4.3.1.2 Welders who passed the qualification test for welding boilers and pressure vessels can be deemed as qualified for welding ships and offshore structures when the welding variables above are same.

4.3.2 Welding processes

4.3.2.1 The welding processes for welder's qualification are to be classified in Table 4.3.2.1. Each testing normally qualifies only for one welding process. A change of welding process requires a new qualification test.

Welding processes for welder's qualification Table 4.3.2.1

Symbol	Welding process in actual welding works		ISO 4063
M	Manual welding	Shielded metal arc welding (SMA W)	111
S	Semi-automatic welding/Partly mechanized welding	Metal inert gas (MIG) welding	131
		Metal active gas (MAG) welding Flux cored arc welding (FCA W)	135, 138① 136②
T	TIG welding	Tungsten inert gas (TIG) welding	141

Notes: Qualification for solid wires, metal cored wires and flux cored wires are as follows:
① A change from MAG welding with solid wires (135) to that with metal cored wires (138), or vice versa is permitted.
② A change from a solid or metal cored wire (135/138) to a flux cored wire (136) or vice versa requires a new welder qualification test.

4.3.2.2 It is permitted for a welder to be qualified for two welding processes, e.g. root run with TIG welding, which are combined by welding a single test piece, applicable to single side welding by root run and double side welding by capping run respectively. The scope of application of thickness is appropriate to the weld thickness.

4.3.3 Types of welds

4.3.3.1 The types of welded joint for welder's qualification are to be classified as shown in Table 4.3.3.1 in accordance with the qualification test.

Types of welded joint for welder's qualification Table 4.3.3.1

Type of welded joint used in the test assembly for the qualification test				Type of welded joint qualified
Butt weld	Single sided weld	With backing	A	A, C, F
		Without backing	B	A, B, C, D, F
	Double sided weld	With gouging	C	A, C, F
		Without gouging	D	A, C, D, F
Fillet weld	----	----	F	F

Note: Welders engaged in full/partial penetration T welds are to be qualified for butt welds for the welding process and the position corresponding to the joints to be welded.

4.3.3.2 For fillet welding, welders who passed the qualification tests for multi-layer technique welding can be deemed as qualified for single layer technique, but not vice versa.
4.3.3.3 Butt welds in pipes greater than 25 mm in outside diameter cover butt welds in plates for appropriate welding positions.
4.3.3.4 Butt welds in plates cover butt welds in pipes of not less than 600 mm in outside diameter for appropriate welding positions and pipes of not less than 150 mm in outside diameter for the horizontally rolling welding position.

4.3.4 Parent material

4.3.4.1 Steels are grouped in Table 4.3.4.1. The welding of any one metal in this group covers qualification of the welder or welding operator for the welding of all other metals within this group.

Steel Groups **Table 4.3.4.1**

Material group	Steel type
W01①	Carbon steel/carbon-manganese steel and low-alloy higher tensile steel with yield strength $R_{eH} \leq 390$ N/mm^2
W02	CrMo steel and creep-resistant CrMoV steel
W03	Higher tensile steel with yield strength $R_{eH} > 390$ N/mm^2, and nickel steel with Ni content < 5%②
W04	Ferritic or martensitic stainless steel with Cr content between 12% and 20%
W05	Nickel steel for low temperature service with Ni content ≥ 5%
W11	Austenitic or duplex stainless steel

Notes: ① Hull structural steels with specified minimum yield point 460 N/mm^2 specified in CCS Guidelines for Inspection of Thick Higher Strength Steel Plates for Ships may be categorized into W01.
② Except for those included in W01.

4.3.4.2 The range of a welder's qualification for parent metals is shown in Table 4.3.4.2.

Range of Welder's Qualification for Parent Metals **Table 4.3.4.2**

Material group of test piece①	Range of qualification					
	W01	W02	W03	W04	W05	W11
W01	*	–	–	–	–	–
W02	×	*	–	–	–	–
W03	×	×	*	–	–	–
W04	×	×	×	*	–	–
W05	–	–	–	–	*	–
W11	–②	–②	–②	–②	–	*

Notes: ① This Table applies only when parent metal indicated by * and filler metal are in the same group, except for W05.
② When using filler metal from group W11.

Key: * indicates the material group for which the welder is approved in the qualification test.
× indicates those material groups for which the welder is also qualified.
– indicates those material groups for which the welder is not qualified.

4.3.4.3 The qualification for welding any type of aluminum alloys in the aluminum-magnesium series (5000 series) or the aluminum-silicon-magnesium series (6000 series) cover all aluminum alloys of both series.

4.3.4.4 When welding with parent or filler materials outside the grouping system in 4.3.4.1 and 4.3.4.3, a separate test is required.

4.3.5 Welding consumables

4.3.5.1 For manual metal arc welding, qualification tests are required using basic, acid or rutile covered electrodes. Welders who have passed the qualification tests for welding with basic electrodes may be deemed as qualified for welding with acid electrodes, but not vice versa. The qualification for welding with cellulose type electrodes does not cover that for welding with other coated electrodes.

4.3.5.2 Welders who have passed the qualification tests with filler material may be deemed as qualified for that without filler material , but not vice versa.

4.3.6 Thickness and pipe diameter

4.3.6.1 For butt and fillet welds in plates and butt welds in pipes, the qualified thickness range for steel and aluminum alloy is shown in Tables 4.3.6.1(a) and 4.3.6.1(b) respectively.

Qualified Thickness Range for Steel **Table 4.3.6.1(a)**

Thickness of test assembly① T (mm)	Qualified thickness range t (mm)
$T \leq 3$	$T \leq t \leq 2T$
$3 \leq T < 12$	$3 \leq t \leq 2T$
$T \geq 12$	$t \geq 3$

Note: ① For multi-process procedure, T is the thickness of deposited metal for each welding process.

Qualified Thickness Range for Aluminum Alloy **Table 4.3.6.1(b)**

Thickness of test assembly① T (mm)	Qualified thickness range t (mm)
$T \leq 6$	$0.5T \leq t \leq 2T$
$T > 6$	$t \geq 6$

Note: ① For multi-process procedure, T is the thickness of deposited metal for each welding process.

4.3.6.2 For butt welds in pipes, the range of qualification for outside pipe diameter is shown in Table 4.3.6.2.

Range of Qualification for Outside Pipe Diameter **Table 4.3.6.2**

Outside pipe diameter of test assembly D (mm)	Range of qualification d (mm)
$D \leq 25$	$D \leq d \leq 2D$
$D > 25$	$D \geq 0.5D$ (25 minimum)

4.3.6.3 The range of qualification for pipe-to-plate fillet welds is as follows:
(1) The qualified range of plate thicknesses is to be in accordance with Tables 4.3.6.1(a) and Table 4.3.6.1(b), regardless of the thickness of pipe wall.
(2) The qualified range of pipe diameters is shown in Table 4.3.6.2.

4.3.7 Welding positions

4.3.7.1 The welding positions qualified as a result of the actual welding position used in a satisfactory welder's qualification test, are shown in Tables 4.3.7.1a, 4.3.7.1b and 4.3.7.1c (Diagrams showing the definitions of weld position used in these Tables are shown in Figure 4.3.7.1 and Table 4.3.7.1d).
A qualification test with fillet welding may be required for welders who are employed to perform fillet welding only. Welders engaged in welding of T joints with partial or full penetration are to be qualified for butt welding.

Qualified welding positions when testing with butt welding of plates **Table 4.3.7.1a**

Qualification Test Position with butt weld of plates	Qualified welding positions in actual welding works	
	Butt welds	Fillet welds
F	F	FF, FH
H	F, H	FF, FH, FHa
Vu	F, Vu	FF, FH, FVu
Vd	Vd	FVd
O	F, H, O	FF, FH, FHa, FO, FOa

Qualified welding positions when testing with fillet welding **Table 4.3.7.1b**

Qualification Test Position with fillet weld	Qualified welding positions in actual welding works
FF	FF
FH	FF, FH
FHa	FF, FH, FHa
FVd	FVd
FVu	FF, FH, FVu
FO	FF, FH, FHa, FO, FOa
FOa	FF, FH, FHa, FO, FOa

Qualified welding positions when testing with butt welding of pipes **Table 4.3.7.1c**

Qualification Test Position with butt weld of pipes	Qualified welding positions in actual welding works			
	Buttt welding of plates①	Butt welding of pipes	Fillet welding of plates①	Pipe-to-plate fillet welding②
1G	F	1G	FF, FH	-
2G	F, H	1G, 2G	FF, FH, FHa	2FG
5G	F, Vu, O	1G, 5G	FF, FH, FVu, FO, FOa	2FG, 4FG, 5FG
2G+5G	F, H, Vu, O	1G, 2G, 5G, 6G	FF, FH, FHa, FVu, FO, FOa	2FG, 4FG, 5FG, 6FG
6G	F, H, Vu, O	1G, 2G, 5G, 6G	FF, FH, FHa, FVu, FO, FOa	2FG, 4FG, 5FG, 6FG
6GR	F, H, Vu, O	1G, 2G, 5G, 6G	FF, FH, FHa, FVu, FO, FOa	2FG, 4FG, 5FG, 6FG

Notes: ① Butt weld joints of pipes with an external diameter more than 25 mm only apply to butt weld joint of plates at corresponding position.
② Not applicable to special pipe-to-plate fillet welds (insertion) in boilers and pressure vessels.

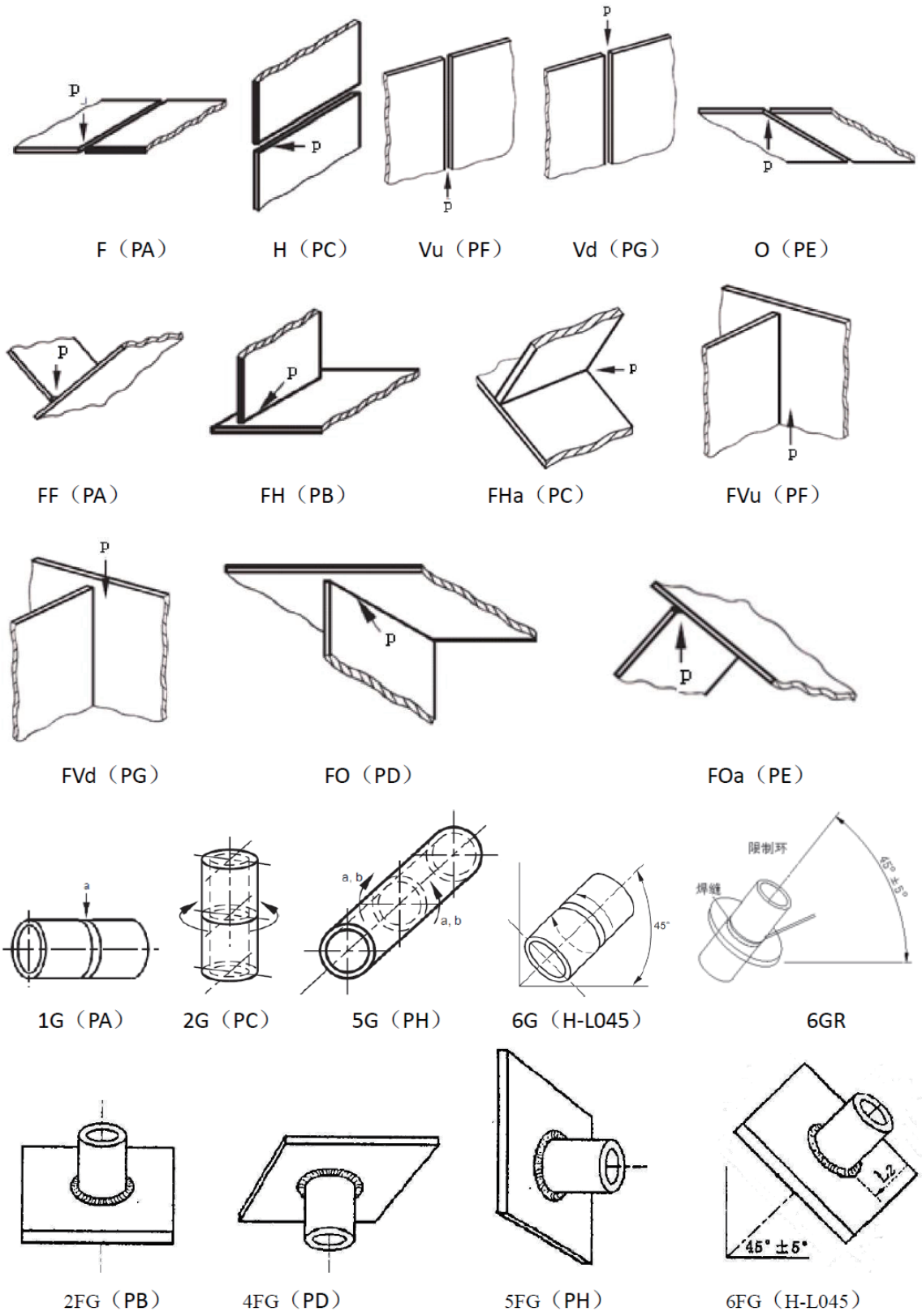


Figure 4.3.7.1 Welding Positions

Code of Welding Positions **Table4.3.7.1d**

Type of assembly	Code of welding position	Welding positions	ISO6947 corresponding code
Butt welding of plates	F	Flat (downhand) welding	PA
	Vu	Vertical upwards welding	PF
	Vd	Vertical downwards welding	PG
	H	Horizontal welding	PC
	O	Overhead welding	PE
Butt welding of pipes	1G	Welding of horizontally rolling pipes	PA
	2G	Welding of vertically fixed pipes	PC
	5G	Welding of horizontally fixed pipes	PH
	6G	Welding of pipes fixed at 45° inclination	H-L045
	6GR	Welding of pipes fixed at 45° inclination with restriction ring	-
Fillet welding of plates	FF	Fillet flat welding	PA
	FH	Fillet horizontal welding	PB
	FHa	Fillet horizontal welding	PC
	FVu	Fillet vertical upwards welding	PF
	FVd	Fillet vertical downwards welding	PG
	FO	Fillet overhead welding	PD
	FOa	Fillet overhead welding	PE
Pipe-to-plate fillet welding	2FG	Fillet horizontal welding of vertically fixed pipe	PB
	4FG	Fillet overhead welding of vertically fixed pipe	PD
	5FG	Fillet welding of horizontally fixed pipe	PH
	6FG	Fillet welding of pipe fixed at 45° inclination	H-L045

4.3.8 Tact welding

4.3.8.1 A welder qualified for butt or fillet welding according to the requirements of Section 2 of this Chapter can be engaged in tack welding for the welding process and position corresponding to those permitted in his certificate.

Alternatively, welders engaged in tack welding only can be qualified on the test assemblies shown in Figure 4.2.2.7(a) or Figure 4.2.2.7(b).

Section 4
QUALIFICATION TESTS AND EVALUATION OF UNDERWATER WELDERS

4.4.1 Test requirements

4.4.1.1 The qualification tests of underwater welders is to be in accordance with the provisions of this Section. Welding of test assemblies and testing of test specimens are to be witnessed by the Surveyor.

4.4.1.2 Prior to the qualification test, the Qualification Test Committee is to submit the intended welding positions, material groups, thickness of test assemblies (pipe diameter), joint types and edge preparation dimensions to CCS for confirmation.

4.4.1.3 The qualification test of underwater welders consists of wet welding and local dry welding.

Wet welding means welding directly carried out by underwater welders in water without any drainage of water. Local dry welding means the welding carried out by underwater welders with drainage of water in the local area to be welded by gas-shielded means.

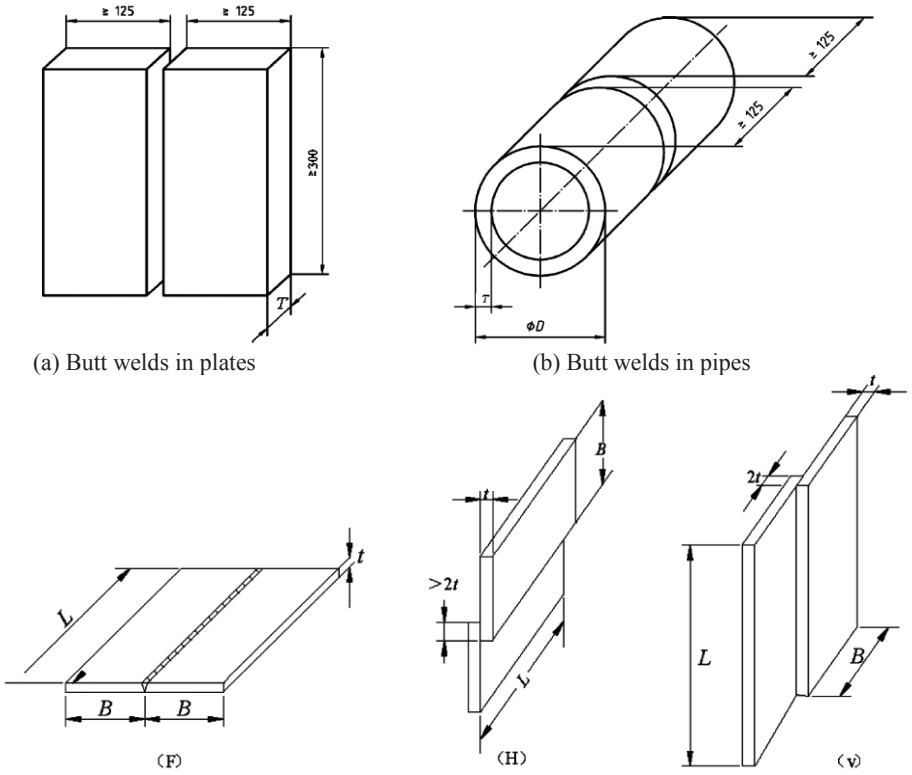
4.4.1.4 Welders who have passed the test of wet welding can only be engaged in wet welding. Welders who have passed the test of local dry welding can only be engaged in local dry welding.

4.4.1.5 Welding consumables for the tests are to be suitable for base metals.

4.4.1.6 The applicant may select a depth of water at his discretion according to the actual working conditions.

4.4.2 Type and dimensions of test assemblies

4.4.2.1 The form and dimensions of test assemblies are as follows (see Figure 4.4.2.1):
(1) butt welds in plates: Length $L \geq 300$ mm, Breadth $B \geq 125$ mm;
(2) butt welds in pipes: Length $L \geq 125$ mm × 2;
(3) Grade T (wet tack welding): Length $L \geq 400$ mm, Breadth $B \geq 100$ mm.
The plate thickness of test assemblies of Grade T is 6 mm, and the plate thickness of other butt welded assemblies may be determined by the applying manufacturer according to actual production.



(a) Butt welds in plates (b) Butt welds in pipes

(c) Test assemblies of Grade T
(in mm)

Figure 4.4.2.1 Dimensions of Test Assemblies

4.4.2.2 One-side welding is generally used for butt joints, which may be carried out with or without backing. Type and edge size of butt joints may be determined by the applying manufacturer according to actual production.

4.4.3 Preparation of test assemblies

4.4.3.1 The test is to be carried out at a designated depth of water or in an equivalently simulated condition.
4.4.3.2 For Grade T, only one run of weld is to be made on each specimen according to the joint type as shown in Figure 4.4.2.1(c).
4.4.3.3 In addition to the above requirements, 4.2.3.1 to 4.2.3.8 of this Chapter are to be complied with.

4.4.4 Test or inspection

4.4.4.1 Test or inspection items and required specimens for different types of test assemblies are shown in Table 4.4.4.1.

Test or Inspection Items and Required Specimens for Qualification Tests of Underwater Welders

Table 4.4.4.1

Type of assembly	Test or inspection items	Required specimens
Butt welding of plates	1 Visual inspection 2 Radiographic inspection 3 Bend test 4 Macro examination	Weld length Examination length of weld① Two for face bend test and two for root bend test② One
Butt welding of pipes	1 Visual inspection 2 Radiographic inspection 3 Bend test 4 Macro examination	Weld length Weld length Two for face bend test and two for root bend test② One
Grade T	Visual inspection	Weld length

Notes: ① The examination length of weld is the length deducted by 25 mm from both ends of the test assembly respectively.
② If the thickness of the test assembly is not less than 12 mm, two side bend specimens may be used instead.

4.4.4.2 For the visual inspection, the surface of welds is to be in the as-welded state and no machining is to be made.
4.4.4.3 Specimens are generally taken by machining. If flame-cutting is applied, surplus metal not less than 5 mm from the line of cut is to be kept on both sides for machining.
4.4.4.4 For preparation of bend test specimens, reinforcement of weld and backing (if any) are to be machined flush with the rolled surface of the base metal. Undercut is not to be removed. Bend test specimens are to be taken as shown in Figures 4.2.4.5(a) and (b). The dimensions of and requirements for specimens are shown in Figures 1.2.3.3 and 1.2.3.4 of Chapter 1 of this PART.
4.4.4.5 The preparation of macro specimens is to comply with the requirements of 1.2.3.7 of Chapter 1 of this PART.

4.4.5 Evaluation of test assemblies

4.4.5.1 The requirements for visual inspection are as follows:
(1) The surface of welds is to be well formed, showing a smooth transition from weld edges to the base metal and a uniform width of welds.
(2) The surface of welds is to be free from cracks, lack of fusion, slag inclusions, pores and overlaps.
(3) The depth of depression on the surface of welds is not to be less than 0.8 mm from the surface of the base metal.
(4) The depth of undercuts is not to exceed 0.8 mm and the aggregate length of undercuts on both sides of the weld is not to exceed 10% of the weld length for plate assemblies or 20% for pipe assemblies.
(5) On completion of welding of assemblies without backing, incomplete penetration is not acceptable. However, local depression may be acceptable provided that it has a depth neither exceeding 0.1 t (t being the thickness of the test assembly), nor greater than 1.5 mm and the aggregate length does not exceed 10% of the weld length.
(6) The height of reinforcement is not to exceed 3 mm for the flat welding position, and 4 mm for other welding positions. The weld width is not to exceed 2.5 mm beyond the groove edge on each side.
(7) Overlaps at the root of welds without backing are not to exceed 3 mm.
4.4.5.2 The radiographic examination is to comply with the requirements for level B of ISO 5817 or other equivalent standards.
4.4.5.3 The bend test is to comply with the following requirements:
(1) The diameter of the former is to be 4 t (t being the thickness of the specimen) and the bending angle 120°.
(2) After testing, the test specimens are not to reveal any crack or other open defect in any direction greater than 3 mm on the surface in tension.
4.4.5.4 The macro examination is to reveal a regular weld profile and the absence of defects such as cracks, lack of fusion, etc.

4.4.6 Application

4.4.6.1 The application of the base metal is limited to the same material group (For steel groups, refer to Table 4.3.4.1, Section 3 of this Chapter).
4.4.6.2 The application of sizes of butt welded materials is shown in Table 4.4.6.2(a) and Table 4.4.6.2(b).

Application of Material Thickness **Table 4.4.6.2(a)**

Thickness of test piece T (mm)	Application of thickness t (mm)
$T \leq 6$	$T \leq t \leq 6$
$T > 6$	$0.5\ T < t \leq 2\ T$ (minimum 6 mm)

Application of Pipe Diameter **Table 4.4.6.2(b)**

External diameter of test pipe D (mm)	Application of external diameter of pipes d (mm)
$D \leq 100$	$0.7\ D \leq d \leq 2\ D$
$100 < D \leq 300$	$0.5\ D \leq d \leq 2\ D$ (minimum 75)
$D > 300$	$d > 0.5\ D$

4.4.6.3 Where any of the following changes of welding consumables occurs, a new qualification test is required:
(1) change of the type (brand) or waterproof coating of electrodes/wires;
(2) change of the diameter of electrodes/wires;
(3) change of the composition of the shielding gas.
4.4.6.4 The range of welding positions are the same as those specified in Table 4.3.7.1a and 4.3.7.1c in this Chapter.
4.4.6.5 Butt welds in pipes cover butt welds in plates for appropriate welding positions.
4.4.6.6 Butt welds in plates cover butt welds in pipes of not less than 600 mm in outside diameter for appropriate welding positions.
4.4.6.7 Welders who have passed the qualification tests with no backing in welding are deemed as qualified for welding with backings in the corresponding grade.
4.4.6.8 The range of approval for water depth is given in Table 4.4.6.8.

Range of Approval for Water Depth **Table 4.4.6.8**

Welding consumables	Applicable maximum water depth① (m)
Carbon and low alloy steels	$X + 10$
Austenitic stainless steel	$X + 3$

Note: ① X is water depth during the qualification test.

4.4.6.9 Grade T welder qualification is applicable only to tack welding and emergency repair welding.

CHAPTER 5 WELDING OF HULL STRUCTURES

Section 1 GENERAL PROVISIONS

5.1.1 Application

5.1.1.1 This Chapter applies to the welding and inspection of hull structural members made of steels, austenitic and duplex stainless steels as well as their clad plates.

5.1.2 Procedure specification and inspection standards

5.1.2.1 Before the commencement of construction, the proposed procedure specification and inspection standards are to be submitted to CCS for approval, and a welding procedure test (where necessary) will be carried out on this account, according to the requirements of Chapter 3 of this PART. Welding construction and inspection are to be carried out in accordance with the plans, procedure specification and inspection standards approved by CCS.

5.1.3 Cutting and forming of marine structural steels

5.1.3.1 Steels may be cut by mechanical shearing or thermal means (e.g. flame cutting, plasma cutting and laser cutting) depending on plate thicknesses. Material which has been cut is to be free from excessive oxides, scale and notches, which are to be removed by mechanical means, if any.

5.1.3.2 For cold formed marine structural plates, the internal bending radius is to be controlled. In general, the internal bending radius is not to be less than 4.5 times the plate thickness. For special components which are subjected to high stresses, however, the internal bending radius is not to be less than 10 times the plate thickness. If the above requirements cannot be met, heat treatment is to be carried out, or an aging impact test in a corresponding straining condition is to be carried out to demonstrate that the impact performance of the material is not affected and surface inspection is required to confirm that there are no such defects as surface cracks.

5.1.3.3 When the forming temperature of steel plates exceeds 650℃ (except for line heating or spot heating), a test of mechanical properties is to be carried out to demonstrate that the forming temperature does not affect tensile performance and impact performance of steels.

5.1.3.4 When line heating or spot heating is used for curve forming or smoothing treatment, the surface heating temperature is to meet the requirements of Table 5.1.3.4.

Maximum Heating Temperature on Steel Surface for Line Heating or Spot Heating

Table 5.1.3.4

Item		Standard
Conventional process AH32-EH32, AH36-EH36 TMCP type AH36-EH36 (C_{eq} >0.38%)	Water cooling just after heating	Under 650℃
	Air cooling after heating	Under 900℃
	Air cooling and subsequent water cooling after heating	Under 900℃(starting temperature of water cooling to be under 500℃)
TMCP type AH32-DH32, AH36-DH36 (C_{eq} ≤0.38%)	Water cooling just after heating or air cooling	Under 1000℃
TMCP type EH32, EH36 (C_{eq} ≤0.38%)	Water cooling just after heating or air cooling	Under 900℃

5.1.4 Selection of welding consumables

5.1.4.1 Welding consumables used for hull structures are to comply with the requirements of Chapter 2 of this PART. The grade of welding consumables selected is to be suitable for the grade of hull structural steel, and is to comply with the requirements of Table 5.1.4.1.

Selection of Welding Consumables **Table 5.1.4.1**

Grade of welding consumables \ Hull structural steel grade	A	B	D	E	AH32 AH36	DH32 DH36	EH32 EH36	FH32 FH36	AH40	DH40	EH40	FH40
1	×											
2	×	×	×									
3	×	×	×	×								
1Y	×				×②							
2Y	×	×	×		×	×						
3Y	×	×	×	×	×	×	×					
4Y	×	×	×	×	×	×	×	×				
2Y40	①	①	①		×	×			×	×		
3Y40	①	①	①	①	×	×	×		×	×	×	
4Y40	①	①	①	①	×	×	×	×	×	×	×	×
5 Y40	①	①	①	①	×	×	×	×	×	×	×	×

Notes: "×" means applicable.

① When joining structural steels of normal strength, it is not recommended to use a much higher grade of welding consumable.

② When using Grade 1Y welding consumables, the material thickness is not to exceed 25 mm.

5.1.4.2 For the joining of steels of different strength levels, the welding consumables in general may be of a type suitable for the lower strength level except at structural discontinuities or areas of stress concentration. For the joining of steels of the same strength level but of different toughness grades, the welding consumables in general may be of a type suitable for the lower toughness grade except for the structural members subjected to complicated forces or severe construction conditions.

5.1.4.3 Unless otherwise specified, low hydrogen type consumables are in general to be used in the following situations:

(1) when joining higher strength structural steel or steel the carbon equivalent of which is over 0.41% to the same or lower strength level;

(2) when welding important structural members.

5.1.5 Preparations before welding

5.1.5.1 The preparation of plate edges, sequence of assembling, alignment of joints and gaps between structural members are to comply with the requirements of the approved procedure specification. Improper assembling is to be avoided so as to reduce internal stresses of structural members. Where excessive gaps exist between surfaces or edges to be joined, the corrective measures adopted are to be agreed by the Surveyor.

5.1.5.2 The surfaces of all parts to be welded are to be clean and dry, and free from rust, scale, grease and other impurities.

5.1.5.3 Where a primer is used to coat steel and not removed prior to welding, the composition of the primer is to be shown as having no significant deleterious effect on the finished weld, and relevant information is to be submitted to CCS for reference.

5.1.5.4 Where welding is required to be carried out in exposed positions in wet, windy or cold weather, adequate cover and protection is to be provided.

For the purpose of preventing the development of excessive stresses or undesirable micro-structures in weldments, suitable measures are to be taken for preheating and/or slow-cooling in the following cases:

(1) where the ambient temperature is lower than 0℃;

(2) where a greater carbon equivalent C_{eq} of the base material is obtained according to the following formula:

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

(3) where excessively rigid structures, thick plates or short beads are employed.

When the carbon equivalent C_{eq} of steel is greater than 0.45%, in addition to preheating, post weld heat treatment is to be considered.

5.1.6 Welding procedures

5.1.6.1 The welds in hull structures are to be made in accordance with the approved welding procedure

specification. For long welds, welding is to be started from a point midway between both ends as far as possible so as to reduce the deformation and internal stress of the structure.

5.1.6.2 Tack welding is to be kept to a minimum. The tack welds are to have a sufficient throat thickness. The length of tack welds is not to be less than 30 mm for normal strength steels, and not to be less than 50 mm for high tensile steels. Tack welds are to be of the same quality as the finished welds. Any defective tack welds are to be cut out before completing the finished welds.
5.1.6.3 Craters at the ends of welds are to be filled to prevent crater cracks. Where automatic welding is employed, run-on and run-off tabs are generally to be used.
Where multi-run welding is employed, slag from the previous run is to be removed before the next run is applied.
5.1.6.4 For welds where full penetration is required, a back sealing run is to be applied after the root run is cut out to clean metal and suitably gouged, unless otherwise specially agreed by CCS.
5.1.6.5 When removing temporary fittings used for assembly, tack welds, defective welds, arc scars and root welds, care is to be taken to ensure that the parent material of the structure is not damaged.

Section 2 WELDING OF HULL STRUCTURAL MEMBERS

5.2.1 General requirements

5.2.1.1 Unless full penetration is entirely ensured, the edges of plates for butt joints are to be beveled on one or both sides to provide an included angle of 40° to 60° in general. The adoption of other forms of edge preparation is subject to agreement of CCS.
5.2.1.2 Where it is impracticable to apply the back sealing run to full penetration butt joints for structural reasons, backing strips may be used as agreed by the Surveyor. The type of bevel and the root gap are to ensure complete fusion between the joints and the backing strips.
5.2.1.3 Where structural members are attached by continuous fillet welds and cross completely finished butt welds of the plates:
(1) the finished butt welds in way of the laying surface are to be made flush; or alternatively, a scallop is to be arranged in the web of the abutting member so as to cross over the butt welds and ensure tight fitting and satisfactory welding;
(2) where the abutting member to be attached by continuous fillet welds is to have butt welds on itself, the butt welds are to be applied first and then made flush prior to the application of fillet welds.

5.2.2 Fillet welds at small included angles

5.2.2.1 Care is to be taken in structure design to avoid the arrangement of fillet welds at a small included angle so as to prevent complicated weldments. In particular cases where the included angle is smaller than 50°, the welding may be carried out as follows:
(1) For the fillet welds of the connection of inner bottom plating to side shell, the edge is to be beveled to not less than 45°, as shown in Figure 5.2.2.1(1). If the included angle is less than 45°, the edge of inner bottom plating may be beveled. Back continuous fillet welds are to be completed after carrying out multi-run continuous fillet welds at the beveled edge. One-side welding with temporary backing materials may be adopted when necessary.

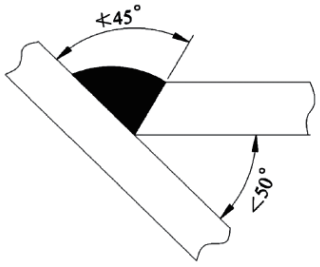


Figure 5.2.2.1(1)

(2) If the included angle is as small as mentioned above for a bracket, the fillet weld may be applied on the side having the obtuse angle provided that welding is carried round the toe end of the bracket to the other

side to an adequate length.

5.2.3 Welding of higher tensile steels

5.2.3.1 For the welding of higher tensile steels, low hydrogen high strength welding consumables suitable for the parent plate and approved by CCS are to be used. During welding, preheating is to be made, and heat input and interpass temperatures are to be controlled.
5.2.3.2 Where higher tensile steel is used for the hull structure, welds are to have a smooth profile without excessive buildup.
5.2.3.3 Where hull structural members, such as stems, stern frames, rudder blades, are of welded higher tensile steel plates, these members are to be annealed so as to relieve the residual stress on completion of the welding. The annealing temperature is to be higher than the critical temperature, and the weldment is then to be cooled slowly.

5.2.4 Welding of hull structural members made from steel castings and forgings

5.2.4.1 Where the hull structural members such as stems, stern frames, rudder stocks and propeller shaft brackets are made from steel castings or forgings, the welding is to comply with the following:
(1) Where the members to be welded have a carbon content not exceeding 0.23% or are highly rigid, due measures are to be taken for preheating and temperature keeping prior to and after the welding.
(2) Where manual arc welding and CO_2 shielded arc welding are employed, stems, stern frames, rudder stocks and propeller shaft brackets are to be subjected to tempering on completion of welding. Where electro-slag welding is employed, stems, stern frames and rudder stocks are to be subjected to normalizing and tempering on completion of welding.
Where stems, stern frames, rudder stocks and propeller shaft brackets are of such dimensions that the whole body cannot be heat-treated at the same time, an efficient local heat treatment process may be accepted.

5.2.5 Welding of sheer strakes to strength deck stringers

5.2.5.1 Where strength deck stringers are fillet welded to sheer strakes with plate thickness being equal to or greater than 15 mm, at least partial full-penetration welding is to be adopted and the edges of the strength deck plates are beveled on one or both sides of the plates, with root face being not greater than $t/3$, and a certain root gap is to be left to ensure deep fusion.
5.2.5.2 Where rounded sheer strakes are butt welded to strength deck stringers, the edges of plates are to be beveled in way of the butt connection to ensure full penetration. Where T-connection is adopted to connect rounded sheer strakes to deck stringers near fore and aft ends of the ship, an adequate length of transition is to be provided. In the transition region, the butt welds for the connection of rounded sheer strakes to deck stringers are to be fully penetrated.

5.2.6 Welding of main engine seatings

5.2.6.1 Where the web thickness of the longitudinal girder of the main engine seating is equal to or greater than 14 mm，the edge of the web plate is to be beveled where it is connected to the horizontal face plate so as to achieve greatest fusion. The size and contour of fillet welds on both sides of the abutting plate are to be uniform and symmetrical.
5.2.6.2 For the fillet welds of other structural members (such as bottom plating, floors, tripping brackets, transverse webs etc.) attached to the main engine seating, the throat thickness is to comply with the relevant requirements of Section 4, Chapter 1, PART TWO of CCS Rules for Classification of Sea-going Steel Ships.

5.2.7 Welding of derrick masts (posts) and crane pedestals

5.2.7.1 The welding of derrick masts (posts) supporting derrick booms and the welding of crane pedestals are to comply with the following requirements:
(1) For derrick masts (posts) and crane pedestals made of steel plates, the circumferential and longitudinal seams of the mast (post) body are to be butt welded with full penetration.
(2) Where the mast (post) or the pedestal passes through the strength deck, the edges of the deck plates connected to it are to be beveled on one side or both sides to ensure full penetration.
(3) Where the mast (post) or the pedestal is directly welded onto the strength deck instead of passing through it, the lower end of the mast or the pedestal is to be fully beveled on one side so as to ensure full penetration.

Section 3 INSPECTION AND REPAIRING OF WELDS

5.3.1 General requirements

5.3.1.1 This Section applies to the inspection and repairing of welds in hull structures of steel ships. Inspection and repairing of other steel structures are to be carried out with prior approval by CCS.

5.3.1.2 The inspection of welds of ships carrying liquefied gases in bulk is to comply with the relevant requirements in Chapters 4 and 6 of CCS Rules for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk in addition to the relevant provisions of this PART.

5.3.2 Inspection

5.3.2.1 On completion of welding of hull structures, visual inspection is to be carried out on all the finished welds. The surface of welds is to be uniform, with a smooth transition to the base metal and free from excessive reinforcements and defects such as cracks, lack of fusion and one-side welds with incomplete root penetration. Surface pores and undercuts are to be limited to the permissible extent.

5.3.2.2 The internal quality of welds may be examined by non-destructive testing such as radiographic examination, ultrasonic inspection or other suitable methods. Some welds are to be subject to a suitable number of additional magnetic particle or dye penetrant examinations where necessary. Non-destructive testing is generally to meet the requirements of Chapter 7 of CCS Guidelines for Inspection of Hull Welds or recognized methods of examination and acceptance criteria.

5.3.2.3 The location and extent of welds to be examined by non-destructive testing are to be agreed between the shipbuilder and CCS Surveyor according to manufacturer's ship type, welding methods used and construction quality records of former days. Additional non-destructive tests may be required by the Surveyor if necessary.

5.3.2.4 The number (n) of non-destructive testing points in the strength deck and shell within 0.6L amidships (except where enhanced testing is required in 5.3.2.6) may be calculated by the following formula:

$$n = 0.16k\,(i + 0.1W_T) + 0.04W_L$$

where: n — the number of non-destructive testing points within 0.6L amidships;

k — average breadth of plates within 0.6L amidships, in m, which may be obtained from the following formula:

$$k = \frac{\text{circumference at transverse midship section (excluding opening)}}{\text{number of strakes seen at transverse section}};$$

i — amount of intersections of butt welds within 0.6L amidships;

W_T — whole length of transverse welds within 0.6L amidships, in m;

W_L — whole length of longitudinal welds joining the blocks within 0.6L amidships, in m.

L is the distance on the summer load waterline from the forward side of the stem to the after side of the rudder post, or to the center of the rudder stock if there is no rudder post. L is not to be less than 96%, and need not be greater than 97%, of the extreme length on the summer load waterline. For pontoon hulls, L is the distance on the summer load waterline from the forward side of the fore end plate to the after side of the after end plate. For ships without rudder stocks, L is 97% of the extreme length on the summer load waterline.

The density of non-destructive testing points is to be decreased in number with the decrease of structure importance and stress.

Where non-destructive testing is carried out at an intersection, the direction of testing is to be paralleled to the direction of the transverse welds.

Testing points are generally to be tested by radiographic method.

5.3.2.5 The number of radiographs for the welds in the strength deck and shell outside 0.6L amidships is to be about 10% to 20% of that specified in 5.3.2.4, and ultrasonic tests of a suitable number may be allowed.

The number of tests in critical areas (such as shaft wrapper plates, stem and stern frame areas, bow wave impact areas and area strengthened for ice) is to be greater than that in other areas.

5.3.2.6 The welds in the essential areas of hull structures are to be subject to non-destructive testing by radiographic or ultrasonic method (unless otherwise specified) according to the following requirements:

(1) For intersection of butt welds on tank watertight bulkhead, inner bottom plate and hopper tank sloping

plate, one in four.

(2) For butt connections of longitudinals and girders at bottom, side and deck,

within 0.4*L* amidships — one in ten;

outside 0.4*L* amidships — one in twenty.

(3) For butt welds at insert plate boundary of strength deck hatch corner, at least 2 non-destructive testing at each corner, as shown in Figure 5.3.2.6(3).

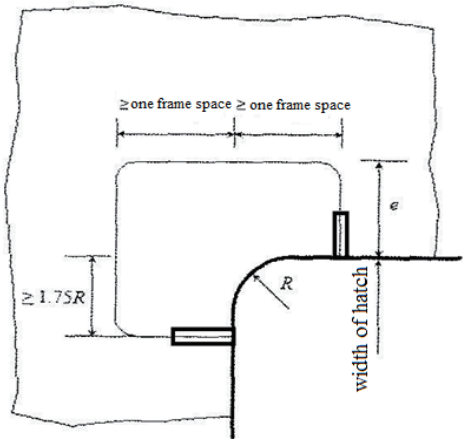


Figure 5.3.2.6(3)

(4) For butt connections 50 mm and above in thickness (such as stern frames, shaft brackets, stabilizer recesses, masts and deck stringers), 100% non-destructive testing.

(5) When full-penetration fillet welds are used at following positions, non-destructive testing is to be carried out according to the following requirements:

a. connection of main engine foundation girders to top plate: 100%;

b. rudder horn and shaft bracket to shell plate of hull structure: 100%;

c. connection of rudder side plating to cast rudder stock: 100%;

d. edge reinforcement or pipe penetration both to strength deck, sheer strake and bottom plating within 0.6*L* amidships, when the dimensions of the opening exceeds 300 mm: 100%;

e. toe connections of longitudinal hatch coaming end bracket to the deck plating: within 0.6*L* amidships: 100%; outside 0.6*L* amidships—one in two;

f. connection of inner bottom with transverse bulkheads, lower stools or transverse floors, or connection of lower stools with transverse bulkheads: 35%;

g. connection of hopper tank sloping plates with inner bottom or inner side: 25%;

h. connection of transverse corrugated bulkheads with topside tanks: 35%;

i. deck stringer/sheer strake joint: 10%, and within 0.6*L* amidships: 1 m increase for the testing at each erection weld.

(6) For welds with large section, especially welds of steel castings and steel forgings as well as welds welded under stress or low temperature, 100% surface crack examination is to be carried out. Other welds with large section beveled on one side or both sides (plate thickness 30 mm or above) and thick fillet welds, such as welds on stern frames, welded mast and bulkhead stool, 100% surface crack examination is to be carried out.

5.3.2.7 Following locations are to be sampled for non-destructive testing:

(1) restart/stop points of automatic butt welds (electro slag, electro gas, submerged arc welding);

(2) butt connections of bilge keel;

(3) butt welds on inner hull and watertight bulkhead of oil tanker;

(4) butt welds on longitudinal continuous hatch coaming and top plate of container ship;

(5) butt connection of longitudinal continuous hatch coaming (including the top plate) more than 0.15*L* in length, of ships other than container ships;

(6) butt welds at structure change near superstructure;

(7) welds of critical locations determined by direct calculation of structural strength or fatigue strength evaluation;

(8) full penetration welds which are inaccessible or very difficult to inspect in service (such as welds at inner sharp angle within bulb bow of ship);

(9) other strength welds which are deemed important, subject to high stress or may have significant impact

after failure.

5.3.2.8 In addition to the requirements of 5.3.2.3 to 5.3.2.7, non-destructive testing is to be carried out on the following locations of cargo tanks of ships carrying dangerous chemicals in bulk:

(1) All crossings of welds of cargo tank bulkhead plating.

(2) Cargo tank boundary welds are to be crack detected for a minimum of 10% of the total weld length.

(3) Where side, bottom longitudinals and longitudinal bulkhead horizontal stiffeners terminate at transverse bulkheads, a minimum of 10% of the bulkhead boundary connections is to be crack detected in addition to the requirements of (2).

(4) Where longitudinals and longitudinal bulkhead horizontal stiffeners are within cargo tanks and continuous through transverse bulkheads, at least 30% each of the bottom and shipside boundaries and at least 20% of the longitudinal bulkhead boundaries are to be crack detected in addition to the requirements of (2).

(5) Where transverse framing members are continuous through the cargo tank longitudinal bulkheads, a minimum of 10% of the boundary connection is to be crack detected.

5.3.2.9 The requirements for non-destructive testing of joints directly connecting hull structure and crane pedestal (derrick post) are as follows:

(1) For fillet welding with full penetration, 100% ultrasonic testing and 100% magnetic particle (or dye penetrant) testing are to be carried out.

(2) For fillet welding with partial penetration or fillet welding, 100% magnetic particle (or dye penetrant) testing is to be carried out.

5.3.2.10 Where none-destructive examination reveals unacceptable defects in the welds and there is the possibility for such defects to develop, additional examinations are to be made along the direction of possible extension of the defective welded seam (one end or both ends) until a sound weld is obtained.

5.3.2.11 When actual testing reveals that less than 80% of welds are satisfactory or any doubt exists regarding the weld quality of certain locations, the number of tests is to be increased at the discretion of the Surveyor.

5.3.2.12 The positions and results of non-destructive testing are to be recorded in the reports, which are to be submitted to CCS Surveyor for confirmation.

5.3.3 Repair of welds

5.3.3.1 Where the examination reveals that the defects in welds are unacceptable, such defective sections are to be cut out and repaired before the acceptance test of hull construction.

5.3.3.2 All surface defects revealed by visual inspection, in general, are to be completely repaired prior to non-destructive testing. Slight surface defects may be ground off.

5.3.3.3 Prior to re-welding, all defects necessitating repairs are to be thoroughly cut out, and non-destructive testing may be necessary to verify that all defects have been thoroughly removed.

5.3.3.4 On completion of repairing, visual inspection and corresponding non-destructive testing are to be carried out on the re-welded portion of welds. The results are to comply with the requirements of the acceptance criteria.

Section 4
WELDING OF STAINLESS STEELS AND STAINLESS STEEL-CLAD PLATES

5.4.1 General requirements

5.4.1.1 This Section applies to the welding of austenitic stainless steels, austenitic/ferritic duplex stainless steels (both hereinafter referred to as “stainless steel(s) ”, unless expressly designated otherwise) and their clad plates. The welding of steel plates with other metallic clad materials will be specially considered by CCS.

5.4.1.2 Unless otherwise specified in this Section, the welding of stainless steels and stainless steel-clad plates is to comply with the requirements of Section 1 of this Chapter.

5.4.1.3 Welders engaged in the welding of stainless steels and stainless steel-clad plates are to have been trained in and certified for the operational technique required for the welding of stainless steels.

5.4.2 Welding consumables

5.4.2.1 Welding consumables basically equivalent to the base material in the chemical composition of their deposited metal are usually to be used for austenitic stainless steel.

5.4.2.2 Welding consumables having more austenitic elements than ferritic ones in the metallurgical structure of their deposited metal are preferably to be used for austenitic/ferritic duplex stainless steel, or austenitic welding consumables appropriate for the duplex stainless steel are to be used.
5.4.2.3 Welding consumables for steel plates clad with stainless steel are to be appropriate to the base and cladding materials respectively.
5.4.2.4 For the welding of stainless steel plates containing nitrogen, the use of inert shielding gas containing a right amount of nitrogen may be considered.

5.4.3 Preparations before welding
5.4.3.1 The joints of austenitic stainless steel and austenitic stainless steel-clad plates are to be so designed and the welding procedure so prepared as to minimize the stress produced by welding. The side of plates facing the corrosive medium is generally to be welded finally.
5.4.3.2 Surfaces of plates are to be thoroughly cleaned to remove oil, paint, dirt and impurities before welding.
5.4.3.3 Surfaces of stainless steel or stainless steel-clad plates adjacent to the weld are to be suitably protected to prevent them from being stained or damaged by spatters or other objects.
5.4.3.4 The edges of stainless steel and stainless steel-clad plates are to be beveled by machining or grinding. Flame cutting is to be avoided.
The form of beveled edges of clad plates is to be specially considered. After beveling, the groove surfaces (including root face) are to be inspected and no cracks and loosened cladding are allowed.
5.4.3.5 Butt welded clad plates are to be aligned using the cladding metal as a datum plane. Tack welds are to be applied to the base material.

5.4.4 Welding
5.4.4.1 Welding of stainless steel plates is preferably to be carried out by means of energy concentration (e.g. metal inert-gas welding, tungsten inert-gas welding, plasma arc welding).
5.4.4.2 For welding of stainless steel, interpass temperatures are to be kept as low as practicable and preferably below 100℃ and as a maximum not to exceed 150℃. Welding parameters are to be in accordance with an approved welding procedure. Welding is generally to be carried out by means of low heat input and short arc. The arc is to be straightly moved in a steady and quick way so as to prevent it from waving.
5.4.4.3 It is recommended that one or two transitional layers be deposited between the weld of the base material and that of the cladding metal, using the consumables made of austenitic stainless steel having an alloy element content higher than that of the cladding metal. The beads of the base material close to the transitional layers are to be deposited with low hydrogen or ultra-low hydrogen welding consumables.
5.4.4.4 In order to keep weld dilution to a minimum, the transitional layers and the subsequent layer are to be deposited for clad plates using electrodes of a small diameter and low welding current.
5.4.4.5 The plate surface facing the corrosive medium is not to be struck for arc and not to be randomly welded with temporary fittings.

5.4.5 Post-weld treatment
5.4.5.1 The surface of both sides of stainless steel and stainless steel-clad plates is not to be straightened by hammering.
5.4.5.2 The post-weld treatment (pickling or passivating) may be carried out according to the instructions of the material manufacturer to achieve sound corrosion resistance in welded areas, if deemed necessary.

5.4.6 Inspection of finished welds
5.4.6.1 All welds are to be visually inspected. The surface of welds is to be uniform with a smooth transition to the parent metal, and is to be free from cracks, pores, unfilled cavities, overlaps, undercuts and other defects.
5.4.6.2 The internal quality of the welds is to be examined by non-destructive testing. The extent and number of non-destructive testing and the procedures and acceptance criteria used are to be in compliance with the standards acceptable to CCS.

5.4.7 Repairing
5.4.7.1 It is recommended that the defects in welds be removed by machining. The repairing processes are to be agreed by CCS Surveyor.

Section 5 WELDING OF NICKEL ALLOY STEELS

5.5.1 General requirements

5.5.1.1 This Section applies to the welding of nickel alloy steels 5Ni and 9Ni of Section 7, Chapter 3, PART ONE of the Rules.

5.5.1.2 The nickel alloy steel components are to be designed to keep their structural continuity and the smooth transition of weld joints to avoid stress concentration.

5.5.1.3 Nickel alloy steels are to be welded according to relevant welding procedure specifications.

5.5.1.4 Welders engaged in the welding of nickel alloy steels are to have been trained in the operational skill and certified accordingly upon qualification tests.

5.5.1.5 Personnel engaged in quality inspection of welding is to be subject to technical training so as to have a correct command of quality assessment standards.

5.5.2 Welding consumables

5.5.2.1 In general, welding consumables with nickel content higher than that of base metal are used to guarantee the low temperature ductibility, such as Ni-base or Fe-Ni base which are used often.

5.5.2.2 When argon-shielded tungsten arc welding is adopted, ferrite nickel alloy steels which are similar to nickel alloy steels in composition may be used as welding consumables.

5.5.2.3 To ensure the quality of weld joints, welding consumables with a coefficient of thermal expansion similar to that of base metal may be used.

5.5.2.4 When nickel alloy steels are welded to hull structure, welding consumables compatible with nickel alloy steels are to be chosen.

5.5.2.5 Impurity elements such as S, P, etc., are to be strictly controlled while sufficient deoxidizing elements are to be guaranteed in welding consumables.

5.5.2.6 The mechanical properties of welding consumables are to be higher than or equal to the specified limits of those of base metals, or in compliance with the specified technical requirements of design documents.

5.5.3 Preparations before welding

5.5.3.1 The plate-cutting and edge preparation of nickel alloy steel plates are to be carried out by machining or thermal cutting (e.g. plasma, laser and flame cutting). The edge of preparation is to be ground off.

5.5.3.2 Before welding, impurities such as water and oil on surfaces of edges and within 20 mm of both sides must be removed.

5.5.3.3 Form of the edge preparation is to be determined by the welding processes used. For argon-shielded tungsten arc welding, relatively small included angle and gap are used.

5.5.3.4 Before welding, the electrodes are to be baked according to the documented procedures of welding process approval to decrease diffusion of hydrogen and prevent cold cracking, in addition to the low hydrogen electrodes of vacuum packaging.

5.5.3.5 As nickel alloy steels are low in carbon and the hardenability tendency is little, they are in general not preheated before welding. Where the plate thickness is over 25 mm and the rigidity is relatively significant, preheating is required before welding. The preheating temperature is determined by factors such as welding processes, ambient temperature and structural constraint, and is in general to be taken in the range of 50℃ to 100℃.

5.5.4 Welding

5.5.4.1 The usual welding processes for nickel alloy steels include manual arc welding, submerged arc automatic welding, argon-shielded tungsten arc welding and gas metal arc welding.

5.5.4.2 To avoid magnetic arc blow during welding, alternating current (AC) as well as electrodes or wire-flux combinations suitable for AC are preferable.

5.5.4.3 The parameters of the welding procedure is to be selected to ensure adequate penetration depth and welding rules requiring small energy input are to be adopted so far as practicable. The electrodes are not to move excessively. Craters at the ends of welds are to be filled to prevent crater cracks, and the interpass temperature is to be controlled below 150℃.

5.5.4.4 Reasonable welding sequences, welding processes or rigid fixing are to be employed to minimize the welding deformation and stresses.

5.5.4.5 The continuity of welding is to be kept. If the welding is interrupted, the succeeding weld is to be overlapped on the previous one for 10 mm to 20 mm. Where the multi-run welding technique is employed, care is to be taken to the cleanliness between two runs and the interpass temperature, craters are to be filled and the restart point is to be fused and fully penetrated.
5.5.4.6 During argon-shielded tungsten arc welding, contact of the tungsten electrode with weld metal is to be avoided, otherwise the contaminated layer is to be removed and if necessary, the tip of the tungsten electrode is to be repaired by grinding before further welding.
5.5.4.7 During argon-shielded welding, the purity of argon is not to be less than 99.99%, and reliable argon shield is to be provided to both front and back of the weld during root run welding.
5.5.4.8 Root runs are to be gouged by carbon arc-air gouging by AC. Penetrant testing is to be increased after root cleaning so as to effectively eliminate and prevent the diffusion of cracks at craters.
5.5.4.9 Each run is to be cleaned by stainless steel wire brushes to prevent slag inclusions. Cracks or shrinkage cavities found at craters are to be ground off.

5.5.5 Treatment after welding

5.5.5.1 After welding, slag, overlap, spatter and other dirt on the surface of the weldment are to be removed. Local rectification is to be carried out to welds when necessary by grinding.
5.5.5.2 To prevent cold cracking, thick walls or important components are to be subject to postweld stress relief heat treatment.

5.5.6 Inspection and repairing of welds

5.5.6.1 Final welds are to be subjected to visual examination and non-destructive testing. The methods of testing and acceptance criteria are to be agreed by CCS.
5.5.6.2 The internal quality of welds is to be examined by non-destructive testing (radiographic examination or ultrasonic testing). The extent and number of non-destructive testing and the procedures and standards used are to be in compliance with the standards acceptable to CCS.
5.5.6.3 The welds are to have a uniform and sound profile, with a smooth transition to the parent metal, and are to be free from cracks, incomplete penetration, overlap as well as overshoot undercuts, pores, slag inclusions and craters.
5.5.6.4 No cracks, shrinkage holes, copper inclusions, lack of fusion and incomplete penetration are allowed inside nickel alloy steel welds.
5.5.6.5 Nickel alloy steel weld repairs are to be carried out using the same welding consumables and procedures as those adopted for the original welds. The weld repairs for the same position are generally not to be performed more than twice unless approved by CCS. The surface of the repaired welds is to be subjected to dye penetrant testing and radiographic examination or ultrasonic testing again.
5.5.6.6 Where tools and jigs are used for temporarily fixing connection welds, the surface of weld marks left after their removal is also to be subjected to dye penetrant testing.

CHAPTER 6 WELDING OF OFFSHORE STRUCTURES

Section 1 GENERAL PROVISIONS

6.1.1 Application

6.1.1.1 This Chapter applies to the welding and inspection of mobile and fixed offshore steel structures.

6.1.2 Welding consumables

6.1.2.1 Welding consumables used for offshore structures are to comply with the relevant requirements of Chapter 2 of this PART.

6.1.2.2 For the joining of pipes with wall thickness exceeding 50 mm, the welding consumables are to be selected on the basis of Charpy V-notch impact tests and fracture toughness tests, and are to be agreed by CCS.

6.1.2.3 For welding consumables used for special structural members, welding tests are to be carried out by the builder on newly delivered welding consumables so as to re-inspect the mechanical properties and the impact toughness of weld joints and deposited metal.

6.1.2.4 Welding consumables are to be sealed and stored in a dry place where the relative humidity is not greater than 45% and the temperature not less than 15℃. Re-tests are to be carried out on welding consumables prior to construction, and the use of welding consumables which are moistened, rusted, contaminated or overdue is prohibited.

6.1.3 Approval tests for welding procedures

6.1.3.1 Welding procedure approval tests for offshore structures are to be carried out in accordance with the relevant provisions of Chapter 3 of this PART.

6.1.3.2 If a CCS-approved welding procedure has not been adopted for the construction of similar structures within six years from the date of approval, tests are to be carried out once again before the welding procedure is re-adopted.

Section 2 WELDING OF STRUCTURES

6.2.1 General requirements

6.2.1.1 Before the commencement of construction of offshore structures, the builder is to submit for approval the relevant structural plans which indicate the position and size of each weld as well as the welding method and site.

6.2.1.2 The welding of offshore structures is to be carried out strictly in accordance with the approved welding procedure specification.

6.2.1.3 In order to ensure the quality of the deposited metal, low hydrogen electrodes are generally to be used for manual welding.

6.2.2 Welding conditions

6.2.2.1 Welding is to be carried out in a sheltered place free from wind, rain and snow. The ambient temperature is not to be lower than the minimum temperature specified for the welding procedure approval test. Where welding is carried out in cold weather, adequate measures are to be taken. During welding, both sides of the groove are to be heated to remove moisture at a temperature of not less than 5℃.

6.2.2.2 When the manual welding is being used, the arc is not to be struck outside the weld area. For submerged-arc welding, run-on and run-off tabs are to be fitted on both ends of the weldment.

6.2.3 Preparations before welding

6.2.3.1 Before welding, the groove and its both sides are to be cleaned to remove moisture, grease, paint, rust or other oxides, etc. Where primers are applied over areas which will subsequently be welded, tests agreed by CCS are to be carried out in accordance with the relevant requirements.

6.2.3.2 Before welding, welding consumables are to be baked in accordance with the manufacturer’s instructions and then stored in drier barrels at the welding site for ready use. The fluxes for submerged-arc welding are to be kept dry and if moistened, they are to be baked again.

6.2.3.3 Tack welding is to be carried out by qualified welders. The electrodes used are to be the same as those for finished welds. Tack welding is to be kept to a minimum. The thickness of tack welds is not to be less than that of the root run, and their length is not to be less than 4 times the thickness of the thicker piece or 50 mm, whichever is the lesser. The quality requirements for tack welds are to be the same as those for finished welds. Where any unallowable defect is found in tack welds, the final welding is not to be carried out until the defect is eliminated.

6.2.3.4 Except that full penetration is ensured, the back sealing run at weld joints for which full penetration is required is to be applied after cutting out the root run to clean metal. Where carbon arc-air gouging is used, carbonization or overheating of the base metal as well as the weld seam is to be avoided. If there exists carbonization or overheating, grinding is to be employed. The shape of the ground groove is to comply with the requirements of the welding procedure.

6.2.4 Preheating and interpass temperatures

6.2.4.1 Preheating and interpass temperatures are to be determined according to the characteristics of steel structures, welding conditions, welding processes, steel grades including chemical composition and welding properties, and the results of welding procedure approval tests.

6.2.4.2 The use of steels with a carbon equivalent exceeding 0.45% is to be avoided where possible. Where the carbon equivalent is greater than 0.45%, the builder is to obtain the agreement of CCS for tests of preheating and interpass temperatures.

6.2.5 Welding

6.2.5.1 Butt welds of offshore structures are generally to be fully penetrated. The profile of the weld reinforcement is to be as required and with a smooth transition to the base metal.

6.2.5.2 Usually fillet welds are used for connecting plates and stiffeners or fixing brackets, etc.

Where there is a permitted gap between two pieces, the throat thickness of the weld is to be increased accordingly for the gap.

6.2.5.3 Important fillet welds and those of highly stressed structural members which may suffer fatigue damage are to be fully penetrated, and technological measures such as alternate symmetrical runs and prepared edge surfaces being built up with preliminary runs may be taken in welding.

6.2.5.4 Reasonable assembling processes and welding sequences are to be employed to minimize the welding deformation, to avoid excessive residual stresses and to prevent cracking.

6.2.6 Welding of very thick members (t > 50 mm) and for joining of pipes

6.2.6.1 The welding of very thick members and pipes is to be carried out using low hydrogen electrodes and proper welding procedures and full penetration is to be ensured.

6.2.6.2 Preheating is to be performed prior to welding, and post-weld heat treatment is to be performed in accordance with the requirements of 6.2.7 of this Section.

6.2.6.3 In the welding for joining of pipes, care is to be taken to prevent burning-through and the profile of welds is to be continuous and uniform. The connection of two pipes is to have s smooth transition. In order to improve the fatigue resistance of the joints, it is recommended that electrodes with a small diameter be used for capping runs. For the welds required to be ground in the design, the curvature radius of the ground weld surface is to comply with the relevant requirements of the design and construction.

6.2.7 Post-weld heat treatment

6.2.7.1 Post-weld heat treatment for stress relieving is generally required for weld joints with thickness greater than 50 mm and pipe joints subjected to complicate loading, unless adequate fracture toughness of the weld joints is documented.

6.2.7.2 Where steels specified in Chapter 3 of PART ONE are adopted for offshore structures, post-weld heat treatment is to be carried out at a temperature in the range of 550℃ to 620℃, holding that temperature for one hour per 25 mm of maximum thickness of the weldment. Heating rate is to be controlled adequately so as to prevent distortion and cracking. The temperature variation in the heating furnace is to be controlled within 15℃, and the temperature difference between the inside and outside surfaces of the weldment is not to exceed 30℃. When the heating temperature is above 300℃, the temperature difference along lines or planes of symmetry is not to exceed 30℃.

6.2.7.3 Local post-weld heat treatment for stress relieving may be employed for individual positions of large members. During the heat treatment, the specified temperature is to be kept in a region extending at least 3 times the material's thickness from either side of the weld. The temperature at the external border of

the insulated area is not to exceed 300℃.

6.2.8 Repairs

6.2.8.1 Where the welding defects of special and primary structural members are to be repaired, a detailed welding procedure specification for repairs is to be prepared by the builder.

6.2.8.2 Prior to repairs, all weld defects are to be thoroughly removed and where necessary, magnetic particle or dye penetrant inspection is to be carried out.

6.2.8.3 The preheating and interpass temperatures when making shallow and local repairs are to be 25℃ higher than the temperature used for ordinary welding, and at least 100℃.

6.2.8.4 In order to ensure the quality of repairs for important welds, the length of each single repaired weld is not to be less than 100 mm.

6.2.8.5 In general, a defect in the same position of a special structural member is permitted to be repaired twice only.

6.2.8.6 Long welds may be repaired in sections to prevent excessive internal stresses and cracks.

6.2.8.7 After the repair of a weld joint which has been subjected to post-weld heat treatment, a new heat treatment is to be carried out.

6.2.8.8 Where weld defects are found repeatedly or the range of defects is great, the welding procedure and the qualification of welders are to be re-examined.

6.2.8.9 The repaired welds are to have a smooth transition to the adjacent area and to be subjected to visual and internal quality inspections in accordance with the requirements in Section 3 of this Chapter.

6.2.8.10 Positions and sizes of defects repaired, repair processes and quality inspections after repairs are to be recorded by the builder for reference.

Section 3 INSPECTION OF WELDS

6.3.1 General requirements

6.3.1.1 For welding of offshore structures, self- and mutual inspections are to be carried out. Special personnel are to be appointed by the builder for strict supervision and inspection of welding processes and quality before, during and after the welding. Prior to the acceptance, the reports of inspections are to be submitted to CCS Surveyor. All the reports are to be kept for reference.

6.3.1.2 A detailed inspection schedule is to be prepared and submitted to CCS by the builder for approval. The schedule is to cover the sequence of construction, inspection positions and acceptance criteria for all main construction stages.

6.3.1.3 The welds, which have been inspected by the builder, are to be subjected to acceptance by CCS Surveyor before being painted. In case of any doubt about the weld quality, the Surveyor may require re-inspection or extension of the inspection range.

6.3.1.4 The procedures and criteria of non-destructive testing used by the builder are to be agreed by CCS.

6.3.1.5 The builder is to submit calibration certificates for non-destructive testing equipment to CCS and to keep the equipment in good working condition.

6.3.1.6 The non-destructive testing operators are to be trained in theoretical knowledge and practical operation, and undertake the testing only after having passed examinations and obtained the Qualification Certificate of Non-Destructive Testing Operator. The inspectors and non-destructive testing operators are to have the knowledge concerning welding techniques, inspection procedures and non-destructive test equipment and are to be capable of determining the location, size and nature of defects, analyzing the cause of defects and proposing the range of repairs.

6.3.1.7 Visual inspection is to be carried out on all finished weld surfaces (including the use of a magnifying glass with up to 10 × magnification). All finished welds are to be uniform, with a smooth transition to the base metal. The profile of welds is to comply with design drawings and the requirements of 6.3.2.1.

6.3.1.8 In the visual inspection of weld surfaces, no cracks, slag inclusions, lack of fusion as well as unacceptable pores, overlaps, craters and undercuts are allowed.

6.3.1.9 Radiographic, ultrasonic, magnetic particle or dye penetrant testing is to be used for non-destructive testing according to different positions. The use of any other method is subject to agreement of CCS.

6.3.1.10 For high strength quenched and tempered steels with yield strength not less than 420 N/mm^2,

non-destructive testing is to be carried out no earlier than 48 h after the completion of the welds in question. When the weldment is to undergo heat treatment, non-destructive testing is to be carried out after the completion of the heat treatment.

6.3.1.11 Where defects cannot be exactly evaluated by one non-destructive testing method, another non-destructive testing method is to be used for a comprehensive evaluation.

6.3.1.12 Where any unacceptable weld is revealed by non-destructive testing, an increased extent of examination is required from both ends of the defective weld.

6.3.1.13 The non-destructive test is to be carried out for welds repaired, and reports of inspections before and after repairs are to be submitted to CCS for reference.

6.3.1.14 Weld defects exceeding the limits of acceptance criteria, which are proved harmless to the safety of the structure by results of fracture toughness tests or comprehensive information related, may be exempted from repairs, subject to agreement of CCS.

6.3.2 Supplementary requirements for fixed offshore structures

6.3.2.1 Visual inspection

(1) Profiles of welds are to comply with design drawings and the following requirements:

① the reinforcement of butt welds is to comply with the relevant criteria and not to exceed 3 mm;

② for fillet welds, the length difference between two legs is not to exceed 2 mm and buildup is not to exceed the value calculated by the following formula:

$$R = 0.1K + 0.76 \quad \text{mm}$$

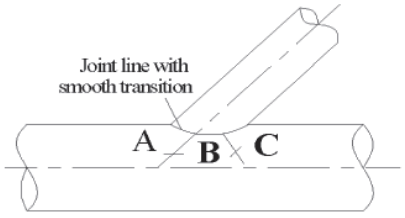
where: K – leg length of fillet welds;

③ weld dimensions of pipe joints are to be as shown in Figure 6.3.2.1(1)①, ② and Table 6.3.2.1(1). The profile after grinding is to comply with the relevant requirements of the design and construction;

④ all laps of tight welds are to be of continuous fillet welds, of which the leg length is usually not to exceed 5 mm, unless stated otherwise.

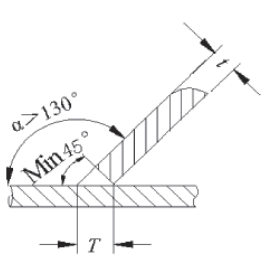
α and T for Typical Connection **Table 6.3.2.1(1)**

α	T
$\leq 35°$	1.75t
$35° < \alpha \leq 50°$	1.50t
$50° < \alpha \leq 135°$	1.25t
$> 135°$	See section A



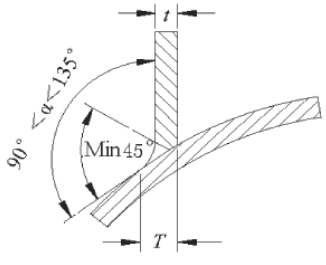
Typical connection

Angle α is the angle formed by the external surfaces of the brace and chord at any point on their joint line

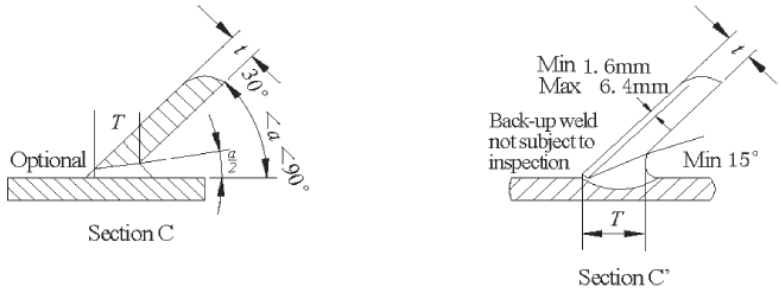


Section A

T is not to exceed 1.75t and full penetration is to be ensured



Section B



The thickness "*T*" does not include the concave due to the smooth transition from the weld to the base metal

Figure 6.3.2.1(1)①

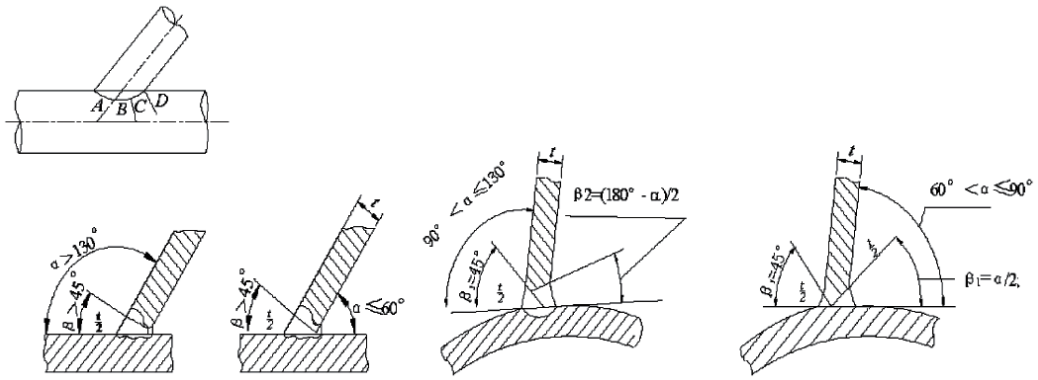


Figure 6.3.2.1(1)②

(2) The undercut depth is not to exceed 0.25 mm for primary members and 0.6 mm for secondary members.

(3) All surface defects are to be completely repaired prior to non-destructive and tightness tests. Repairing procedures are to comply with the relevant requirements in 6.2.8 of this Chapter.

6.3.2.2 Non-destructive testing of welds

(1) The non-destructive testing for butt welds is specified as follows:

① for the welds of special members or the welds connecting special and primary members, 100% ultrasonic inspection is to be performed. Additionally according to service conditions and plate thicknesses etc., 10% ~ 20% radiographic inspection and 20% ~ 100% magnetic particle inspection are to be carried out. The extent for radiographic and magnetic particle inspections of welds is to be agreed by CCS;

② for the welds of primary members or the welds connecting primary and secondary members, 10% ~ 20% ultrasonic inspection and 10% ~ 20% magnetic particle inspection are to be performed. The extent for such inspections is to be agreed by CCS. Where there is any doubt about the results of ultrasonic inspection of welds, additional radiographic inspection is to be made;

③ for the welds of secondary members, 0% ~ 5% ultrasonic inspection and 0% ~ 5%magnetic particle inspection are to be performed. The extent for such inspections is to be agreed by CCS;

④ for (T-shaped or cruciform) intersections of primary butt welds, radiographic inspection is to be performed.

(2) Non-destructive testing for full-penetration fillet welds is specified as follows:

① for the welds of special members and the welds connecting primary and secondary members, 100% ultrasonic inspection and 100% magnetic particle inspection are to be performed. A certain extent of radiographic inspection may be required by CCS according to actual conditions;

② for the welds of primary members and the welds connecting primary and secondary members, 20% ultrasonic inspection and 20% ~ 100% magnetic particle inspection are to be performed. The extent of magnetic particle inspection is to be agreed by CCS;

③ for the welds of secondary members, 0% ~ 5% ultrasonic inspection and 0% ~ 5% magnetic particle inspection are to be performed. The extent for such inspections is to be agreed by CCS.

(3) For the welds of pipe joints, 100% ultrasonic inspection and 100% magnetic particle inspection are to be carried out. A certain extent for radiographic inspection may be required by CCS.

(4) Radiographic inspection:

① Positions of such inspection and radiographs required may be proposed by the builder according to the categories, types, service conditions of structural members and the requirements of 6.3.2.2, subject to agreement of CCS.

② The radiographic sensitivity is to comply with the following requirements:

(a) in the radiograph, image quality indicators (IQI) of the wire type are to be placed on the side of the radioactive source. In case the source side is inaccessible, they may also be placed on the film side after determining the effects on the penetrating sensitivity provided that compliance of the actual sensitivity with the specified requirements is ensured by contrast tests. If one exposure technique is used to cover the whole pipe girth weld, at least 3 equally spaced image quality indicators are to be placed around the girth;

(b) the penetrating sensitivity (S) of the IQI placed on the source side is to be determined by the following formula:

$$S = \frac{d \times 100}{t}\%$$

where: d – diameter of the thinnest visible wire, in mm;

t – thickness of the weld, in mm.

The sensitivity obtained by the above formula is to comply with the requirements in Figure 6.3.2.2(4)②.

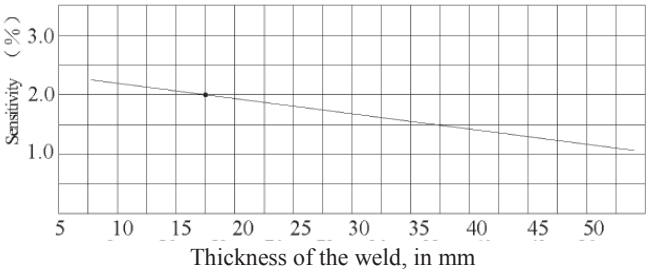


Figure 6.3.2.2(4)②

③ Items such as name of inspector, no. of the weld, date of radiographing, penetrating sensitivity, weld length radiographed, shape/size/nature of defects are to be indicated in the inspection report. The weld quality is to be evaluated according to the requirements in 6.3.2.2(6), and positions to be repaired are to be proposed. All the films of radiographic inspection together with the report are to be kept on file for reference.

(5) Ultrasonic inspection:

① For full-penetration fillet welds and pipe joints due to which structural members are subjected to tensional stresses in the through thickness direction, ultrasonic inspection is to be carried out within an area of 100 mm in width along the weld to examine whether there is lamellar tearing.

② The builder is to prepare inspection procedures for specific structures beforehand, calibrate the ultrasonoscope and determine the initial sensitivity. If abnormal test results are obtained or the ulstrasonoscope is damaged during inspection, re-calibration and re-test are to be carried out.

③ Calibration of the ultrasonoscope is to be performed on test pieces having simulated defects or contrast blocks with a drilled hole. The simulated test pieces or contrast blocks are usually to be made of the same material as the structural members. Where the sizes of defects are evaluated by calibrating amplitudes, the effects of sound beam attenuation, surface roughness and curvature, etc. are to be taken into consideration.

④ For unqualified and nearly unqualified welds, the following data are to be listed and shown schematically in the ultrasonic inspection report:

(a) positions and length of defects along the center line of welds;

(b) positions and size (width) of defects in the cross section of welds;

(c) estimated defect types.

Welding quality is to be evaluated and the extent of repairs proposed according to the requirements in

6.3.2.2(6).

(6) Acceptance criteria for internal quality of welds:

① The internal quality of welds of fixed offshore structures is to comply with the requirements shown in Table 6.3.2.2(6)①. Where other criteria are to be used, they are to be agreed by CCS.

② Weld defects exceeding the limits of acceptance criteria, which are proved harmless to the safety of the structure by results of fracture toughness tests or comprehensive information related, may be exempted from repairs, subject to agreement of CCS.

Criteria for Internal Quality of Welds **Table 6.3.2.2(6)①**

Type of defects \ Category of members		Special and primary members	Secondary members
Cracks		Not allowed	Not allowed
Lack of fusion		Not allowed	Not allowed
Incomplete penetration		Not allowed	Not allowed
Slag inclusion	Bar slag (length)	$\leq t/2$	$\leq 2t/3$
	Spot slag (size of each point)	$\leq t/4$	$\leq t/3$
Pore	Tubular pore (length)	$\leq t/2$	$\leq 2t/3$
	Scattered spot pores (size of each point)	$\leq t/4$	$\leq t/3$
	Sum of diameters of clustered pores	$\leq t/2$	$\leq 2t/3$
Sum of lengths of all defects within the range of any weld of $6t$ in length		$\leq 3t/4$	$\leq t$
The minimum space between defects greater than 2.4 mm		$\geq 2.2t$	$\geq 2t$

Notes: ① Bar slag inclusions or tubular pores refer to the defects of which the aspect ratio exceeds 3. Those defects of which the aspect ratio does not exceed 3 refer to spot slag inclusions or scattered spot pores.

② t is the effective throat thickness for fillet welds and the plate thickness for butt welds, in mm.

③ The maximum size of spot slag inclusions or scattered spot pores is 4 mm for $t \leq 51$ mm and 6 mm for $t > 51$ mm.

CHAPTER 7 WELDING OF PRESSURE SHELLS

Section 1 GENERAL PROVISIONS

7.1.1 Application

7.1.1.1 This Chapter applies to the welding and survey of pressure shells of enclosed structures which are subjected to internal pressure or external pressure, such as boilers and pressure vessels, diving systems and submersibles. The welding and survey of type C independent tanks and process pressure vessels of ships carrying liquefied gases in bulk are to comply with Chapters 4 and 6 of CCS Rules for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk.

7.1.1.2 This Chapter applies to welded joints of carbon steel, low alloy steel, austenitic and duplex stainless steel pressure vessels made by a manual, semi-automatic or automatic arc welding process. Where it is proposed to use other welding processes, details are to be submitted to CCS for approval.

7.1.1.3 Where materials other than those specified in 7.1.1.2 are used, the testing, manufacturing and survey are to meet the requirements of recognized standards.

7.1.2 Consumables

7.1.2.1 Welding consumables used for pressure shells of welded construction are to be appropriate to the parent metal and approved by CCS.

7.1.3 Approval

7.1.3.1 Unless provided otherwise in the Appendix to Chapter 3, PART ONE of CCS Rules for Classification of Sea-going Steel Ships, manufacturers of pressure shells are to apply to CCS for works approval.

7.1.3.2 When a product is to be manufactured for the first time or when a new welding procedure is to be adopted, the manufacturer is required to submit the welding procedure for the appropriate structural type to CCS for approval in accordance with the requirements of Chapter 3 of this PART. In the approval tests, the diameter of the bend former used for specimens of boilers and pressure vessels is to comply with the requirements given in Table 7.2.3.4 of this Chapter.

7.1.3.3 For the welding procedure approval test of Class III pressure vessels, only face and root bend, butt weld tensile and nick bend tests are required.

7.1.3.4 The nick bend test specimen is to be as shown in Figure 7.1.3.4. The specimen is to have a slot cut into each side along the centerline of the weld and perpendicular to the plate surface. During testing, the specimen is to be bent along the weld centerline until fracture occurs, or to be fractured by a drop hammer, and the fracture faces are to be examined visually or using a magnifying glass of not more than 10-fold magnification. The fracture is to reveal a sound weld, substantially free from slag inclusions, porosity, and coarse crystallinity.

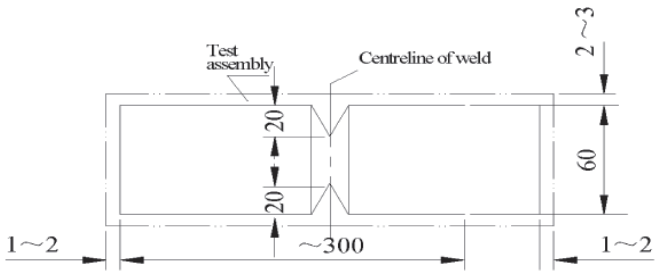


Figure 7.1.3.4

7.1.4 Plans and standards

7.1.4.1 The welding, fabrication and inspection of pressure shells are to be carried out in accordance with the plans, procedures approved by and the standards acceptable to CCS.

Section 2 PRODUCTION WELDING TESTS OF PRESSURE SHELLS

7.2.1 General requirements

7.2.1.1 During production of any class of welded pressure shells (except for pressure vessels of Class III),

production welding tests are to be carried out according to the requirements of this Section.

7.2.1.2 Boilers and pressure vessels are to be classified in accordance with the relevant requirements of Chapter 6 of PART THREE of CCS Rules for Classification of Sea-going Steel Ships. The pressure shells of diving systems and submersibles are deemed to be Class I pressure shells, unless specially approved by CCS.

7.2.2 Test assemblies

7.2.2.1 Two test assemblies are generally to be prepared for each pressure shell. One test assembly is to be prepared as a minimum for each 20 m of the pressure shell of large diving systems and submersibles. Where it is impracticable to prepare two test assemblies for boilers and common pressure vessels, subject to agreement of the Surveyor, one test assembly may be prepared provided that its length is sufficient for providing one complete set of specimens required by Table 7.2.3.1 of this Section and for cutting out additional re-test pieces.

7.2.2.2 If a batch of Class II boilers or pressure vessels is made by the same manufacturer using the same welding process and the variation of plate thickness is not more than 5 mm, one test assembly may be welded for each 35 m of length, with the thickness being equal to the thickness of the thickest shell plate, and at least one test assembly is to be welded for each batch.

7.2.2.3 The test plates for production welding tests are to be of the same thickness and the same steel grade as used in the construction of the shell. The test plates are not to be less than 150 mm in width and of a length sufficient to provide one complete set of specimens required by Table 7.2.3.1 of this Section. The edges of test plates are to be beveled in the same way as for the welds of shell plates. Test plates are to be tack welded to the shell plate in such a manner that the edges to be welded are a continuation and simulation of the corresponding edges of the longitudinal joint.

7.2.2.4 Generally, test assemblies need not be prepared for the circumferential seams of boilers and pressure vessels, except where the shell has circumferential seams only or where the welding procedure for the circumferential joints is significantly different from that used for the longitudinal joints, one test assembly is to be prepared. This test assembly is to provide one complete set of specimens required by Table 7.2.3.1 of this Section and specimens for re-test purposes. For the manufacture of pressure shells of the same type, one test assembly may be welded for each 30 m of circumferential seams.

7.2.2.5 The process, procedure and heat treatment for welding test assemblies are to be the same as those for the shell. The test assemblies are to be heat treated together with the shell.

7.2.2.6 Proper measures are to be taken to minimize the warping resulted from welding. The test assemblies are to be straightened before being subjected to heat treatment.

7.2.2.7 Before being cut out, the test assemblies are to be stamped with CCS stamp and marked by CCS Surveyor or his deputy.

7.2.3 Specimens and testing

7.2.3.1 The test specimens for various classes of pressure shells are to be taken as required by Figure 7.2.3.1 and Table 7.2.3.1.

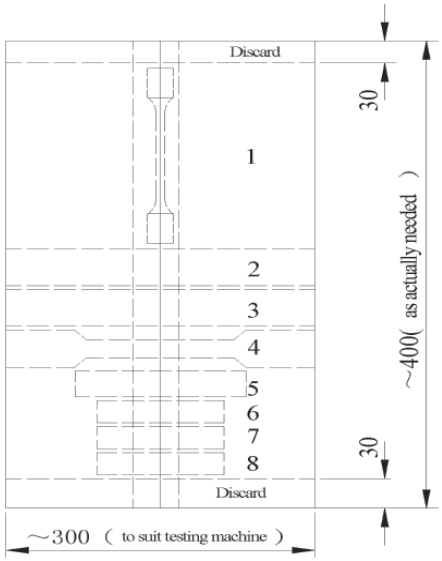


Figure 7.2.3.1

Specimens for Classes of Pressure Shells **Table 7.2.3.1**

No.	Specimen	Pressure shell	
		Class I	Class II
1	Deposited metal longitudinal tensile	Required	Required
2	Face bend①	Required	Required
3	Root bend①	Required	Required
4	Butt weld transverse tensile	Required	Required
5	Macro examination	Required	Required
6, 7, 8	Impact test for center of the weld②	Required	

Notes: ① Where a test plate is greater than 20 mm in thickness, a side bend test specimen may be substituted for the face or root bend specimen.

② An additional set of 3 impact specimens with the notch located on the fusion line is to be tested in the following conditions:

a. pressure shells of diving systems and submersibles;

b. all pressure shells with design temperature at 0℃ and below;

c. pressure shells made of alloy steels (excluding austenitic stainless steel).

7.2.3.2 In addition to the requirements of 7.2.3.3 and 7.2.3.4 of this Section, preparation and testing of test specimens are to comply with the relevant requirements of Section 2, Chapter 1 of this PART.

7.2.3.3 Where the test plate is greater than 70 mm in thickness, two deposited metal tensile test specimens are to be taken as shown in Figure 7.2.3.3. If a specimen of 10 mm diameter cannot be taken, the largest practicable diameter is to be used, and the gauge length of the test specimen is to be 5 times the diameter. For steel plates of less than 16 mm in thickness, the deposited metal tensile test may be waived.

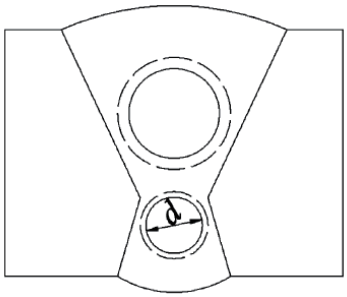


Figure 7.2.3.3

7.2.3.4 For bend tests, the diameter of the former and the clear space between the supports are to comply with the requirements given in Table 7.2.3.4.

Former Diameter and Space between Supports **Table 7.2.3.4**

Min. specified elongation of parent metal A_5 (%)	Diameter of former(mm)	Clear space between supports(mm)
$A_5 \geq 20$	$4t$①	$6t+3$①
$A_5 < 20$	d②	$d+2t+3$①②

Notes: ① t being the plate thickness, in mm.

② $d = \dfrac{(100 \times t)}{A_5} - t$, in mm.

7.2.4 Acceptance and re-tests

7.2.4.1 The results of various tests are to comply with the requirements given in Table 7.2.4.1.

Requirements for Production Welding Tests **Table 7.2.4.1**

Test	Pressure shells	
	Class I	C1ass II
Deposited metal tensile	(1) Tensile strength: not less than the minimum specified tensile strength of the parent metal or comply with the technical requirements specified by the design document. (2) Elongation not less than the following two values, whichever is less: 20%; 4820/R_m +10 (R_m is the minimum specified tensile strength of the parent metal)	
Bend	The diameter of the former and the clear space between supports are to be in accordance with Table 7.2.3.4. A former with its axis perpendicular to the specimen is to bend the specimen by pushing it through the clear space between the supports. After bending, there is to be no crack or other defects exceeding 3 mm in dimension on the outer surface of the bent portion	
Butt weld transverse tensile	Butt weld tensile strength is not to be less than the minimum specified tensile strength of the parent metal, or comply with the technical requirements specified by the design document	
Macro examination	No cracks, incomplete penetration, lack of fusion and significant slag inclusions or other defects are allowed	
Impact	The average energy obtained is not to be less than the value required for the parent metal①	Not required

Note: ①Impact specimens for pressure shells are to be tested at temperatures required according to their parent metals, except that those for boilers and common pressure vessels are to be tested at ambient temperature. For the temperature for impact tests for stainless steel pressure vessels, refer to 3.2.7, Chapter 3 of this PART.

7.2.4.2 If any of the tests fail, the reason for the failure is to be investigated and additional specimens are to be prepared from the original specimen for re-tests. The number of specimens is to comply with the requirements of 1.2.5.2 and 1.2.5.3, Chapter 1 of this PART.

7.2.4.3 Where two test assemblies have been prepared, the re-test specimens are to be cut from the second test assembly.

7.2.4.4 If it can be shown that the failure of the initial test resulted from a local or accidental defect and the re-test results are satisfactory, the re-test results may be accepted.

Section 3 MANUFACTURE AND WORKMANSHIP OF PRESSURE SHELLS

7.3.1 General requirements

7.3.1.1 Unless otherwise specified, all major seams in the pressure shells are to be butt welded.

7.3.2 Edge preparation

7.3.2.1 Where plate edges of pressure shells are to be joined by welding, they are to be well beveled. Edges may be prepared by flame cutting, plasma cutting, machining, chipping or grinding. Where flame cutting is employed, any remaining slag and scale are to be removed by machining or grinding from the beveled edges. For austenitic and duplex stainless steels, flame cutting is to be avoided.

7.3.3 Alignment of butt welds

7.3.3.1 For cylindrical pressure shells, the surfaces of two butt welded plates are not to be out of alignment with each other at any point by more than 10% of the plate thickness. But in no case is the misalignment to exceed 3 mm for longitudinal seams or 4 mm for circumferential seams.

7.3.3.2 For end joints of spherical pressure shells and cylindrical shells, the surfaces of the two butt welded plates are not to be out of alignment with each other at any point by more than 10% of the plate thickness or 3 mm.

7.3.3.3 Where a shell is constructed of plates of different thicknesses (tube plate and wrapper plate), the plates are to be so arranged that their centerlines form a continuous circle, and the following requirements are to be complied with:

(1) For the longitudinal seam, the thicker plate is to be equally chamfered inside and outside by machining over a circumferential distance not less than twice the difference in the thickness, so that the two plates are of equal thickness at the longitudinal weld seam. For the circumferential seam, the thicker plate is to be similarly prepared over the same distance longitudinally.

(2) For the circumferential seam, where the difference in the thickness is the same throughout the circumference, the thicker plate is to be reduced in thickness by machining to a taper for a distance not less than 4 times the offset, so that the two plates are of equal thickness at the weld point.

(3) If the weld is wide enough to form a taper connection on the surface of the weld as described in above

(1) and (2), the thicker plate may not be chamfered.
7.3.3.4 No beveling is needed for fillet welds that are not required to be of full penetration. The assembled components are to be tight fitted and gaps between components which cannot be tight fitted to each other locally are not to exceed:
(1) 2 mm for plate thicknesses not greater than 10 mm;
(2) 3 mm for plate thicknesses greater than 10 mm;
(3) 2 mm for overhead welding.

7.3.4 Welding

7.3.4.1 Before welding, all surfaces of the pieces to be welded are to be thoroughly cleaned of scale, moisture, grease or other dirt which would be detrimental to the quality of welding for a distance of at least 25 mm from the weld. All tack welds and edge imperfections which would be detrimental to the quality of welding are to be removed prior to welding.
7.3.4.2 Welding is to be carried out in a sheltered place free from wind, rain and snow. Reliable preheating or dehumidifying means are to be available when welding is to be carried out at low ambient temperatures or under high humidity conditions.
7.3.4.3 Unless otherwise approved, low hydrogen or ultra-low hydrogen welding consumables are to be used for the welding of pressure shells. The consumables are to be dried before application in strict accordance with the specifications.
7.3.4.4 In general, butt welding is to be carried out from both sides and stressed fillet welds are to be of full penetration for pressure shells. The back sealing run is to be applied after cutting out the root run to clean metal. Where it is impracticable to apply the back sealing run for special structures, one-side welding (including argon-arc root run, temporary backing and steel backing welding) may be allowed. If steel backing strips are used, they are to be of the same nominal composition as the plates to be welded.
7.3.4.5 Where a butt joint is welded from one side of the plate only, suitable measures are to be taken to ensure that the root is properly fused and that distortion due to the contraction of the weld metal is minimized.
7.3.4.6 Welding is to be carried out in the downhand position as far as practicable. In the case of circumferential seams, means are to be adopted to ensure compliance with this requirement.
7.3.4.7 Preheating and maintenance of minimum interpass temperature are to be employed where necessitated by the joint restraint, thickness of the plate or composition of the material to be welded.
7.3.4.8 Where the multi-run welding technique is employed, care is to be taken to the cleaning between two runs. Where for any reason the welding is interrupted, care is to be taken in restarting to ensure that the previously deposited weld metal is thoroughly cleaned of slag and debris, and that there is proper penetration into the plate and the previously deposited weld metal.
7.3.4.9 Spool pieces, flanges and pads are in general to be attached to the pressure shell by double continuous fillet welding, and all welds are to be completed prior to heat treatment.
7.3.4.10 The outer surface of the weld may be flush with the surfaces of the plates joined, but no objection will be raised if the total thickness at the center of the weld is greater than the thickness of the plates, provided that the change of the reinforced cross section is gradual.
7.3.4.11 All lugs, brackets, branches, manhole frames, reinforcements around openings and other fittings are to have a close fit to the surface of the shell plate to which they are attached, and all welds are to be completed prior to heat treatment. If such fittings have to be welded after heat treatment for structural reasons, prior approval of CCS is to be obtained.
7.3.4.12 The procedure for the welding of the above-mentioned fittings, together with other attachments used for supporting internal and external components, to the pressure shell is to be the same as that required for the shell, and the material used is to be of compatible composition.
7.3.4.13 Where austenitic or duplex stainless steels are used in pressure vessels, relevant requirements of Section 4, Chapter 5 of this PART are to be complied with in addition to the requirements above.

Section 4 HEAT TREATMENT

7.4.1 General requirements

7.4.1.1 Pressure shells and their test assemblies for production welding tests are to be heat treated on completion of the welding and prior to the hydraulic test.
7.4.1.2 Post-weld heat treatment may be exempted for the following pressure shells:

(1) boilers made of carbon or carbon-manganese steel and having a plate thickness less than 20 mm for their welded components;
(2) Class I and II general pressure vessels made of carbon or carbon-manganese steel, having a plate thickness not exceeding 30 mm for their welded components(When steels with specified Charpy V-notch impact properties at low-temperature are used, such thickness may be increased subject to the agreement of CCS);
(3) all Class III pressure vessels.
7.4.1.3 Post-weld heat treatment is to be carried out for diving systems and submersibles with plate thickness over 20 mm, which may be exempted with prior agreement of the Surveyor, provided the weld joints are proved to be of fine fracture toughness.
7.4.1.4 Unless otherwise specified by the design document, welding joints of austenitic and duplex stainless steels may not be heat treated.

7.4.2 Furnaces for heat treatment
7.4.2.1 The furnaces used for heat treatment are to be provided with:
(1) adequate means of temperature control;
(2) pyrometers capable of measuring and recording temperature changes within the furnace.

7.4.3 Heat treatment
7.4.3.1 The pressure shells are generally to be subjected to heat treatment as a whole. Where it is impracticable to do so, the shells may be heated in sections, provided that sufficient overlap is allowed to ensure the heat treatment of the entire length of the longitudinal seam.
7.4.3.2 The heat treatment is to heat the pressure shell slowly and uniformly to a suitable stress relieving temperature, soak it at this temperature for a suitable time, then cool it slowly and uniformly in the furnace to a temperature not exceeding 400℃ and subsequently cool it in a still atmosphere.
7.4.3.3 The heat treatment temperatures, soaking times, heating and cooling rates are to be so selected as to relieve residual stress and improve the properties of the material, without undue deterioration of its properties.
7.4.3.4 For carbon and carbon-manganese steels, it is recommended that the stress relieving temperatures and soaking times be in accordance with the requirements given in Table 7.4.3.4. The heat treatment of alloy steels is to be based on the material used and agreed by CCS.

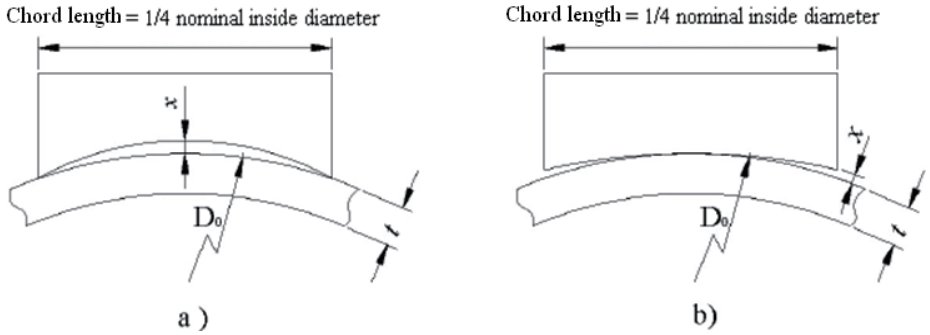
Stress Relieving Temperature and Soaking Time **Table 7.4.3.4**

Grade of steel	Temperature (℃)	Soaking time (h)
360, 410, 460, 490	580 ~ 620	1 h per 25 mm of thickness, but at least 1 h

Section 5 INSPECTIONS AND REPAIRING

7.5.1 General requirements
7.5.1.1 The inspection of pressure shells is to include measuring the amount of out-of-roundness, visual examination and non-destructive testing of welds, and hydraulic testing.
7.5.1.2 The hydraulic tests of pressure shells are to be carried out according to the requirements for specific products.

7.5.2 Measuring of amount of out-of-roundness
7.5.2.1 The out-of-roundness and overall dimensions of pressure shells are to be examined after completion of manufacture, before and after the final heat treatment. The out-of-roundness is defined as the difference between the maximum and minimum internal diameters measured at one cross-section.
7.5.2.2 The cylindrical shell is to be measured for the amount of out-of-roundness either when laid flat on side or when set up on end. When the shell is lying on side, the diameter is to be measured twice for each 90° and the mean value of the two measurements taken while turning the shell around its longitudinal axis, thereby obtaining the out-of-roundness value of the shell.
7.5.2.3 The deviation of the profile (local out-of-roundness) of the shell from the designed form is the difference between the actual profile and the theoretical profile measured by a gauge of the designed form of the shell. Measurements are to be carried out on the inside (Figure 7.5.2.3(a)) or outside (Figure 7.5.2.3(b)) of the shell, for determining the deviation X from the actual profile.



D_0 – nominal outside diameter; t– shell thickness; x – maximum deviation from designed form

Figure 7.5.2.3

7.5.2.4 For boilers and common pressure vessels, the gauge of the designed form is to have a chord length equal to 1/4 of the nominal inside diameter of the shell. The deviation X and the overall out-of-roundness $\Delta\varphi$ are to comply with the requirements of Table 7.5.2.4.

Out-of-Roundness Deviation of Boilers and Common Pressure Vessels Table 7.5.2.4

Nominal inside diameter of pressure shell D_i (mm)	Allowable out-of-roundness $\Delta\varphi$ (mm)	Maximum deviation from designed form X (mm)
$D_i \le 300$	$\le 0.1D_i$	1.2
$300 < D_i \le 460$		1.6
$460 < D_i \le 600$		2.4
$600 < D_i \le 900$		3.2
$900 < D_i \le 1220$		4.0
$1220 < D_i \le 1520$		4.8
$1520 < D_i \le 1900$		5.6
$1900 < D_i \le 2300$	≤ 19	6.4
$2300 < D_i \le 2670$		7.2
$2670 < D_i \le 3950$		8.0
$3950 < D_i \le 4650$	≤ 19	$0.002D_i$
$D_i > 4650$	$\le 0.004D_i$	$0.002D_i$

7.5.2.5 The external circumference of the completed shell of boilers and pressure vessels is not to deviate from the calculated circumference (based upon the nominal inside diameter and actual plate thickness of the shell) by more than the values given in Table 7.5.2.5.

Deviation of External Circumference Table 7.5.2.5

Outside diameter (nominal inside diameter plus twice plate thickness) (mm)	Circumferential tolerance (mm)
300 ~ 600	$\le \pm 5$
> 600	$\le \pm 0.25\%$ circumference

7.5.2.6 For pressure shells bearing external loads such as those of diving systems and submersibles, the overall out-of-roundness $\Delta\varphi$ is not to exceed 0.5% of the nominal diameter.

7.5.2.7 For pressure shells bearing external loads such as those of diving systems and submersibles, the "gauge of the design form" is to have a chord length as obtained from the following formulae according to specific structural configurations:

(1) spherical shells: $L_a = 4\sqrt{R_0 t}$, in mm;

(2) cylindrical shells: $L_a = \sqrt{l\sqrt{R_0 t}}$ or $L_a = 0.5\pi R_0$, in mm, whichever is smaller

where: L_a — arc length of sample template, in mm;
R_0 — nominal inside radius of the shell, in mm;
t — actual thickness of the shell plate, in mm;
l — spacing between ring frames, in mm.

7.5.2.8 For shells subjected to external pressure, the local out-of-roundness X of the shell is not to exceed the value obtained from the following formula when it is measured with the sample template as specified in 7.5.2.7 of this Section:

$$X = \frac{0.01L_a}{1+\frac{L_a}{R_0}} \quad \text{mm}$$

where: L_a — arc length of sample template, in mm;
R_0 — nominal inside radius of the shell, in mm.

7.5.2.9 For cylindrical shells subjected to external pressure, the local out-of-straightness of the generating line of the shell is to be checked instead of measuring the amount of local out-of-roundness where $l/R_0 < 2.25\sqrt{t/R}$. The local out-of-straightness is defined as the maximum radial difference between the shell plate among frames and the generating line of the shell, which is not to exceed the X value specified in 7.5.2.8.

7.5.2.10 For shells subjected to external pressure, the local tolerance of ring frames is to be checked. The local tolerance of ring frames after installation is to comply with the following (as shown in Figure 7.5.2.9):
(1) vertical deviation δ_1 of the web is not to exceed 3% of the web height, or 10 mm when the web height is more than 300 mm;
(2) horizontal deviation δ_2 of the wing is not to exceed 5% of the wing width.

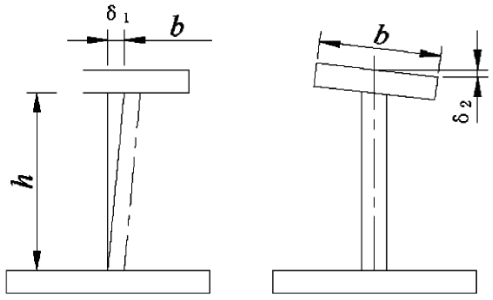


Figure 7.5.2.9

7.5.3 Visual examination

7.5.3.1 All finished welds in the pressure shell are to be uniform and sound, and free from cracks, overlaps, pores, slag inclusions, undercuts, craters and unfilled cavities. In case of occurrence of the above defects, they are to be completely removed prior to the non-destructive testing.

7.5.3.2 Shell surfaces are to be free from mechanical damages. Tacking lugs on the shell are to be removed by chipping, or to be flame cut at 3 mm to 5 mm from the surface of the shell, then to be ground smooth.

7.5.4 Non-destructive testing of welds

7.5.4.1 The welds in pressure shells are to be subjected to non-destructive testing. The method, number and location of the examination are to comply with the requirements of Table 7.5.4.1. The procedures of the non-destructive testing are to be agreed by CCS.

Testing Requirements for Pressure Vessels **Table 7.5.4.1**

Method	Boilers and general pressure vessels②		Diving systems and submersibles
	Class I	Class II	
Radiographic testing	Examination 100% for all longitudinal and circumferential butt welds① in shells, drums, headers and pipes and tubes together with test plates	100% for test plates and at least 10% for butt welds	100% for butt welds of the shell
	Butt welds in furnaces, combustion chambers and similar pressure components are to be subjected to spot radiographic examination		
Ultrasonic testing	Where the plate thickness exceeds 50 mm, ultrasonic testing may be accepted as an alternative to radiographic examination, subject to agreement of CCS. If necessary, examination by radiography is to be required at selected locations. 100% for full penetration fillet welds on pressure shells		100% for full penetration fillet welds of the shell
Magnetic particle or dye penetrant testing③	The welds on standpipes, compensating plates, stubs and branches which have not been radiographically tested are to be subjected to magnetic particle or dye penetrant examination for 10% of such welds. The number and locations for testing may be increased by the Surveyor if necessary		Random testing on 10% of aggregated weld length; 100% for strengthened welds at openings and piping connections

Notes: ① For tubular parts of 170 mm or less in outside diameter, 25% of circumferential butt welds in headers and 10% of circumferential butt welds in other pipes are to be subject to radiographic testing.
② The non-destructive testing of Class III pressure vessels may be required by the Surveyor at his discretion according to their specific purposes.
③ For low-temperature pressure vessels, 100% of full penetration fillet welds between connection pipes with external diameter ≤57 mm and pressure shells are to be subject to magnetic particle or dye penetrant testing.

7.5.4.2 Pressure vessels bearing external load are to be visually examined after pressure test. Magnetic particle or dye penetrant testing is to be additionally carried out on their essential areas. The number and location of tests are to be agreed by the Surveyor.

7.5.4.3 Where the accuracy of non-destructive testing may be influenced by the surface roughness of welds and adjacent areas, the surfaces of such portions are to be ground to the required surface smoothness.

7.5.4.4 The non-destructive testing is to take the effects of delayed cracking into account. For higher strength steels having a yield strength over 395 N/mm^2, the non-destructive testing is to be carried out not earlier than 48 h after the completion of the welds in question.

7.5.4.5 The technical grade of radiographic and ultrasonic testing is to comply with the requirements of applicable grade of recognized standards. The sensitivity, optical density and geometric un-sharpness for radiographic examination are to comply with the following:

(1) For the use of image quality indicators of the step/hole type, the radiographical sensitivity requirements are given in Table 7.5.4.5(1).

(2) For the use of image quality indicators of the wire type, the radiographical sensitivity requirements are given in Table 7.5.4.5(2).

(3) Unless specified otherwise, the optical density of the film is generally to be between 2.0~4.5.

(4) Geometric un-sharpness $f \geq 10d \cdot b^{2/3}$

where: f—distance from the radiation source to the work piece surface;
d—effective focus size;
b—distance from the work piece to the film.

Radiographical Sensitivity Requirements for Image Quality Indicators of Step/Hole Type

Table 7.5.4.5(1)

Nominal thickness of workpiece (mm)	Hole no. visible in the radiograph (hole diameter, in mm)
$3.5 < t \leq 6$	H5 (0.320)
$6 < t \leq 10$	H6 (0.400)
$10 < t \leq 15$	H7 (0.500)
$15 < t \leq 24$	H8 (0.630)
$24 < t \leq 30$	H9 (0.800)
$30 < t \leq 40$	H10 (1.000)
$40 < t \leq 60$	H11 (1.250)
$60 < t \leq 100$	H12 (1.600)
$100 < t \leq 150$	H13 (2.000)

Radiographical Sensitivity Requirements for Image Quality Indicators of Wire Type

Table 7.5.4.5(2)

Nominal thickness of workpiece (mm)	Wire no. visible in the radiograph (wire diameter, in mm)
$3.5 < t \leq 5$	W15 (0.125)
$5 < t \leq 7$	W14 (0.16)
$7 < t \leq 10$	W13 (0.20)
$10 < t \leq 15$	W12 (0.25)
$15 < t \leq 25$	W11 (0.32)
$25 < t \leq 32$	W10 (0.40)
$32 < t \leq 40$	W9 (0.50)
$40 < t \leq 55$	W8 (0.63)
$55 < t \leq 85$	W7 (0.80)
$85 < t \leq 150$	W6 (1.00)

7.5.4.6 Image quality indicators are to be placed at both ends of each radiograph and are to be put at the weld surface facing the radioactive source as far as practicable.
7.5.4.7 The sensitivity for magnetic particle testing is to be selected based on the specific location of testing and agreed by the Surveyor.
7.5.4.8 The quality of welds subjected to non-destructive testing is to be evaluated according to the criteria acceptable to CCS.
7.5.4.9 When unacceptable defects which are difficult to repair are found in the pressure shells of diving systems and submersibles, the acceptance criteria for weld defects based on fracture mechanics may be applied subject to agreement of CCS.

7.5.5 Repairs of defects
7.5.5.1 Where non-destructive tests show unacceptable defects in the welds, the extent of the defects is to be determined. Unacceptable defects are to be removed. If necessary, magnetic particle or dye penetrant testing may be applied. Repairs by welding are to be carried out after the complete removal of the defects has been confirmed.
7.5.5.2 When unacceptable defects are revealed in a spot examination of welds, two further randomly selected spots are to be examined in the weld length represented by the first spot examination. If these reveal no further unacceptable defects, the defects revealed by the first spot examination are to be removed and repair welding is to be carried out. If the further spot examinations reveal unacceptable defects, then either:
(1) the whole weld length represented is to be cut out and re-welded, then subjected to spot examination as if it were a new weld, and the original test plates associated with the weld are to be similarly treated; or
(2) the whole weld length represented is to be examined. Unacceptable defects are to be repaired and the repaired portions are to be subjected to re-examination.
7.5.5.3 The repairing procedures for pressure shells are to be agreed by CCS Surveyor.
7.5.5.4 The welding repairs for one defective area are generally not to be more than twice.
7.5.5.5 The removing of defects and rewelding are to be completed prior to post-weld heat treatment.
7.5.5.6 The results of the re-examination after repairing are to be to the satisfaction of CCS Surveyor.

CHAPTER 8 WELDING OF IMPORTANT MACHINERY COMPONENTS

Section 1 GENERAL PROVISIONS

8.1.1 Application

8.1.1.1 This Chapter applies to the welding of important components and bedplates of diesel engines, turbines, reduction gear boxes, exhaust gas turbochargers, etc.

8.1.2 Consumables

8.1.2.1 The welding consumables employed are to be approved according to the relevant requirements specified in Chapter 2 of this PART.

8.1.3 Approval of welding procedures

8.1.3.1 Prior to the commencement of welding of important components, the intended welding procedure specification is to be submitted to CCS for approval as specified in Section 1, Chapter 3 of this PART.

8.1.3.2 If welding approval procedure tests are required, manufacturers are to carry out the tests in accordance with the relevant requirements of Sections 2 and 3 of this Chapter and for this purpose, representative welds are to be made by simulating the actual welding conditions.

8.1.4 Construction

8.1.4.1 Major components which will be subjected to alternating or impact loads are usually to be butt welded with edge preparation to ensure full penetration.

8.1.4.2 Where two plates of different thicknesses are butt welded, the edge of the thicker plate is to be tapered so as to ensure an uniform transition if the difference between thicknesses is equal to or greater than 4 mm. The width of taper is not to be less than 4 times the difference between thicknesses.

8.1.4.3 Where a combination of casting and welding is used for components of complex design, care is to be taken to avoid the intersection of welded seams at a acute angle and any abrupt change in cross sections.

8.1.5 Preheating

8.1.5.1 Suitable preheating is to be considered in the following cases:

(1) where heavy components, complex components, and important components specially indicated on plans are welded;

(2) where either the carbon content of the weldment or workpiece is greater than 0.23% or the carbon equivalent C_{eq} obtained by $C_{eq} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$ is greater than 0.41%;

(3) where welding is carried out at an ambient temperature below 0℃ and/or high ambient humidity.

Section 2 WELDING OF ROTOR SHAFTS

8.2.1 General requirements

8.2.1.1 This Section applies to the welding of rotor shafts of turbines and exhaust gas turbochargers.

8.2.1.2 Before the commencement of welding, rotor shafts are to be uniformly preheated and the temperature is to be strictly maintained during welding. The preheating temperature may be dependent on the materials used.

8.2.2 Welding procedure approval test

8.2.2.1 Prior to the commencement of welding, test assemblies are to be prepared in accordance with the welding procedure specification approved by CCS, and deposited metal tensile test, transverse tensile test, face bend and root bend tests, and macro examination are to be carried out.

8.2.3 Post-weld heat treatment

8.2.3.1 Rotor shafts are to be properly heat treated on completion of welding. The requirements for heat treatment are to be dependent on the materials and welding processes used, subject to agreement of CCS.

8.2.3.2 All superficial and internal defects in the welds are to be completely removed and repaired prior to the post-weld heat treatment.

8.2.4 Non-destructive testing

8.2.4.1 Prior to finish machining, welded rotors are to be subjected to surface inspection by magnetic particle testing or other effective means. Any cracks and other defects thus revealed are to be thoroughly cut out and repaired by welding and then the components are to be heat treated for stress relieving.

Section 3
WELDING OF BEDPLATES, ENGINE FRAMES, CYLINDERS AND CASINGS

8.3.1 General requirements

8.3.1.1 This Section applies to the welding of the machinery components such as the bedplates, engine frames, crankcases and cylinder bodies of diesel engines, and the foundations, cylinders, diaphragms, condensers of turbines, as well as the casings of exhaust gas turbochargers and reduction gearboxes.

8.3.2 Welding procedure approval test

8.3.2.1 For the bedplates and engine frames of diesel engines and the foundations of turbines, test specimens representative of the welded joints are to be prepared for tensile, bend, impact tests and macro examination, and the results are to comply with the following requirements:
(1) Tensile test: not less than the specified minimum tensile strength of the parent metal.
(2) Impact test: not less than the specified minimum average energy of the parent metal.
(3) Bend test: same as required by Table 7.2.4.1 in Chapter 7 of this PART.
(4) Macro examination: no cracks, incomplete penetration and lack of fusion, and no unacceptable undercuts, slag inclusions etc.
8.3.2.2 For turbine cylinders, the tests of butt joints are to include tensile, bend tests and macro examination and the results are to comply with the relevant requirements of Table 7.2.4.1 in Chapter 7 of this PART.
8.3.2.3 For diaphragms, nozzle plates of turbines, representative samples are to be sectioned and etched for macro examination.

8.3.3 Preparations before welding

8.3.3.1 The beveling of plate edges is to be performed by gas cutting or machining to the required shape and surface roughness.
8.3.3.2 The component parts to be welded are to be accurately assembled and aligned, and the form of edge preparation and the root gap are to comply with the relevant requirements.
8.3.3.3 Prior to welding, the plate edges to be welded are to be cleaned and free from scale, slag and grease which may affect the welding quality.
8.3.3.4 The welding is to be carried out in the downhand position wherever possible, and the effects of adverse ambient conditions are to be avoided.

8.3.4 Post-weld heat treatment

8.3.4.1 For bedplates and turbine cylinders made of carbon steel or carbon-manganese steel, the post-weld heat treatment is to be carried out in accordance with the requirements for temperature and soaking time as specified in Table 7.4.3.4 in Chapter 7 of this PART.
8.3.4.2 Details for the heat treatment of alloy steels are to be submitted to CCS for approval.

8.3.5 Non-destructive testing

8.3.5.1 Examinations of welds by non-destructive methods are to be made on completion of heat treatment as follows:
(1) Cylinders of turbines: major stressed joints in pressure shells are to be radiographed.
(2) Other joints of turbines: joints of nozzle plates, branch pipe connections and diaphragms are to be examined by non-destructive methods agreed by CCS.
(3) Welds in combined beams of diesel engines are to be examined by non-destructive methods agreed by CCS.
(4) Joints of other important machinery components, if deemed necessary by CCS Surveyor, are also to be subjected to non-destructive testing.

Section 4 NON-DESTRUCTIVE INSPECTION AND WELD REPAIRS OF PROPELLERS

8.4.1 General requirements

8.4.1.1 This Section applies to the inspections, repairs and weld repairs of propellers, blades and bosses specified in the Rules.

8.4.1.2 This Section also applies to the repairs and inspections for damaged propellers of ships in service.

8.4.1.3 In addition to complying with this Section, the weld repairs of propellers are to be in accordance with the relevant requirements in Chapter 1 of this PART.

8.4.2 Skew angle of a propeller and division of its severity zones

8.4.2.1 The skew of a propeller is described by the skew angle of the propeller blade. 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 centerline and a second line through the shaft centerline which acts as a tangent to the locus of the midpoints of the helical blade sections (see Figure 8.4.2.1). High skew propellers have a skew angle greater than 25°, low skew propellers a skew angle of up to 25°.

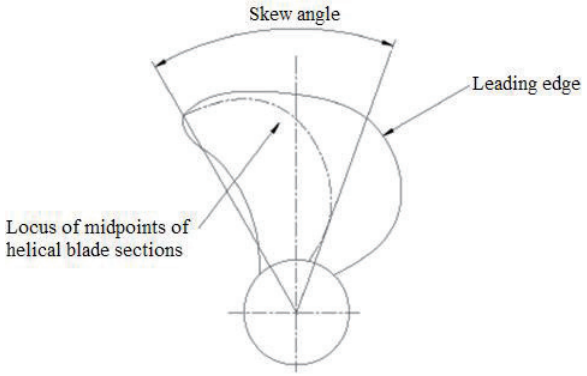


Figure 8.4.2.1 Definition of Skew Angle

8.4.2.2 In order to relate the degree of inspection to the criticality of defects in the propeller blade and to help reduce the risk of failure by fatigue cracking after repair, the propeller blade is divided into the three zones designated A , B and C:

(1) 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.

(2) Zone B is a region where the operation stresses may be high.

(3) Zone C is a region in which the operation stresses are low and where the blade thicknesses are relatively small.

8.4.2.3 Division of severity zones of low-skew propellers is to be as follows:

(1) 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 C_r from the leading edge and 0.2 times C_r from the trailing edge, respectively (see Figure 8.4.2.3(1)a). Where the hub radius (R_b) exceeds 0.27R (R being the radius of the propeller), the other boundary of zone A is to be increased to 1.5R_b.

Zone A also includes the parts of the separate cast propeller hub which lie in the area of the windows as described in Figure 8.4.2.3(1)b and the flange and fillet area of controllable pitch and built-up propeller blades as described in Figure 8.4.2.3(1)c.

(2) Zone B is on the pressure side the remaining area up to 0.7R and on the suction side the area from the fillet to 0.7R (see Figure 8.4.2.3(1)a).

(3) Zone C is the area outside 0.7R on both sides of the blade. It also includes the surface of the hub of a monobloc propeller and all the surfaces of the hub of a controllable pitch propeller other than those of the designated zone A above.

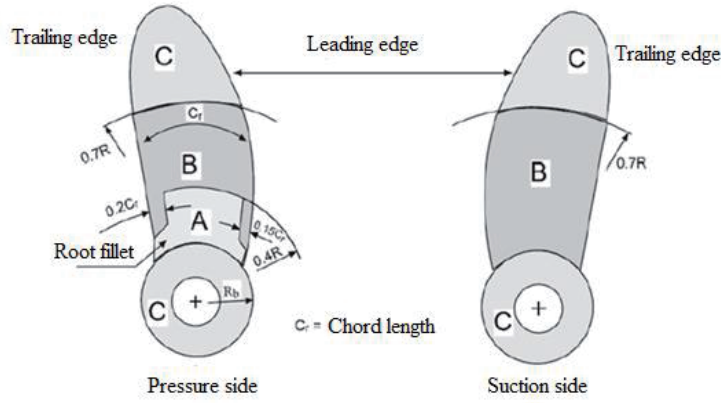


Figure 8.4.2.3(1)(a) Severity Zones for Monobloc Low Skew Propeller

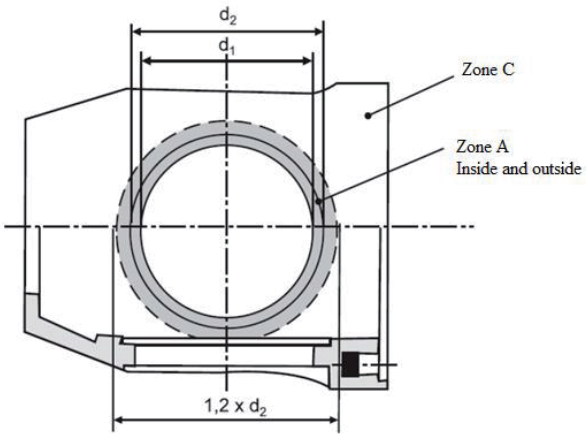


Figure 8.4.2.3(1)(b) Severity Zones for Separate Cast Propeller Boss

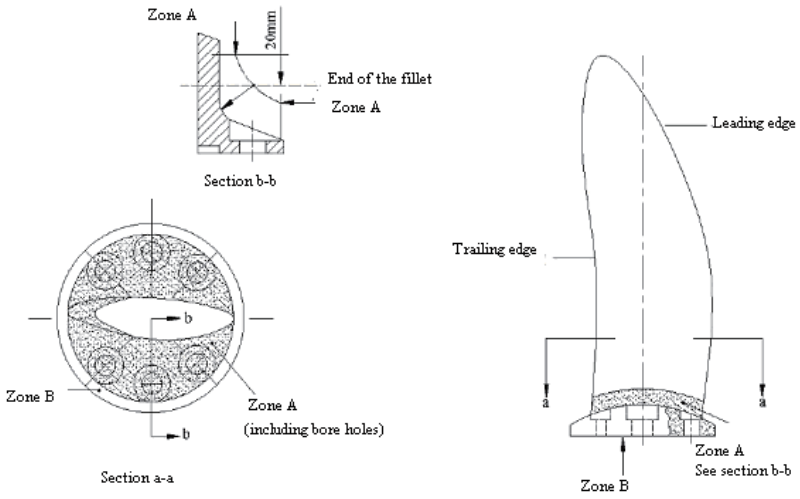


Figure 8.4.2.3(1)(c) Severity Zones for Controllable Pitch Propeller Blade Flange and Root Fillet

Note: The remaining surface of the propeller blades are to be divided into the severity zones as given for solid cast propellers (see Figure 8.4.2.3(1)a and Figure 8.4.2.4(1)).

8.4.2.4 Division of severity zones of high-skew propellers is to be as follows:

(1) Zone A is the area on the pressure face contained within the blade root-fillet and a line running from the junction of the leading edge with the root fillet to the trailing edge at 0.9*R* and at passing through the midpoint of the blade chord (0.5C_r) at 0.7*R* and a point situated at 0.3C_r of the chord length from the leading edge at 0.4*R*. The remaining area inside 0.4*R* also belongs to zone A. It also includes an area along the trailing edge on the suction side of the blade from the root to 0.9*R* and with its inner boundary at 0.15C_r of the chord lengths from the trailing edge (see Figure 8.4.2.4(1)).
(2) Zone B constitutes the whole of the remaining blade surfaces other than zone A (see Figure 8.4.2.4(1)).

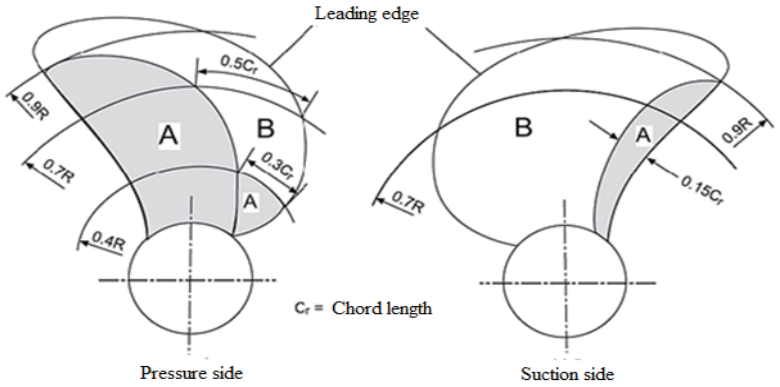


Figure 8.4.2.4(1) Severity Zones for High Skew Propeller

8.4.3 Non-destructive inspections

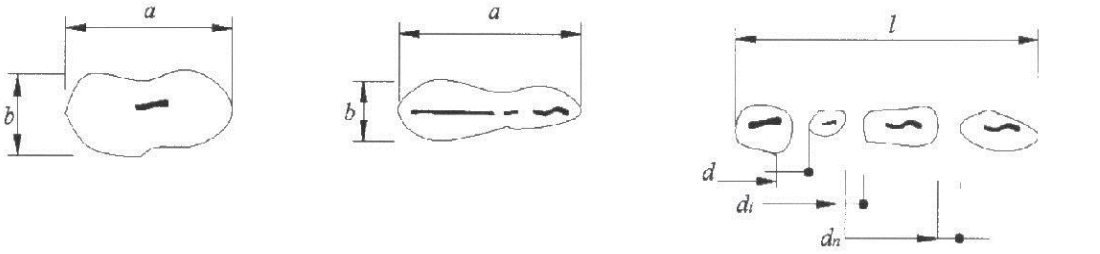
8.4.3.1 Surfaces of all finished propeller castings are subject to non-destructive inspections in accordance with the three zones specified in 8.4.2.3 and 8.4.2.4. The inspections of zone A are generally to be carried out in the presence of the Surveyor, while the inspections of zones B and C may be witnessed by the Surveyor upon his request.

8.4.3.2 Surface inspections of propellers are generally to be carried out as dye penetrant inspections. The dye penetrant inspection is to be carried out in accordance with a standard or specification approved by CCS. Magnetic particle examination is not applicable to copper and austenitic stainless steel propellers.

8.4.3.3 In the dye penetrant inspection, an indication is the presence of detectable bleed-out of the penetrant liquid from the material discontinuities appearing at a time as recommended by the dye liquid manufacturer or at least 10 minutes after the developer has been applied.

8.4.3.4 For the judgment, the surface to be inspected is to be divided into square or rectangular (with the major dimension not exceeding 250 mm) reference areas of 100 cm^2. The area is to be taken in the most unfavourable location relative to the indication being evaluated.

8.4.3.5 A distinction is made between circular, linear and aligned dye penetrant indications, as shown in Figure 8.4.3.5. The indications detected are, with respect to their size and number, not to exceed the values given in Table 8.4.3.5.



a/b<3
Circular

a/b≥3
Linear

number of indications≥3 and 0<d_i≤2 mm
Aligned

Figure 8.4.3.5 Shape of Indications

Allowable Number and Size of Indications in a Reference Area Table 8.4.3.5

Severity zone	Max. total number of indications	Indication type	Max. number for each type	Max. size of indication (mm)
A	7	Circular	5	4
		Linear	2	3
		Aligned	2	3
B	14	Circular	10	6
		Linear	4	6
		Aligned	4	6
C	20	Circular	14	8
		Linear	6	6
		Aligned	6	6

Notes: ① Single circular indications less than 2 mm in zone A and less than 3 mm in other zones may be disregarded.
② The total number of circular indications may be increased to the maximum total number, or part thereof, represented by the absence of linear or aligned indications.

8.4.3.6 Where serious doubt exists that the castings are not free from internal defects, radiographic and/or ultrasonic tests may be carried out upon request of the Surveyor. The acceptance criteria are then to be agreed between the manufacturer and CCS. For this purpose, the following are to be observed:
(1) due to the limited thicknesses that can be radiographed as well as for other practical reasons readiography is generally not a realistic method for checking of the thickest parts of large propellers;
(2) as a general rule, ultrasonic testing of stainless steel, 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.
8.4.3.7 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.
8.4.3.8 The foundry is to maintain records of inspections traceable to each casting. These records are to be confirmed by the Surveyor.

8.4.4 General requirements for repairs

8.4.4.1 The rectification of small defects which do not themselves adversely affect the strength of the casting is generally not required. Where local pores are present in the surface of the end face or bore of a propeller boss, they may be filled with a suitable plastic filler after the appropriate preparation of the defective area.
8.4.4.2 Indications exceeding the acceptance criteria of Table 8.4.3.5 (e.g. cracks, shrinkage cavities, sand, slag and other non-metallic inclusions, blowholes and other defects which may impair the safe service of the propeller) are to be rectified or repaired by welding as necessary.
8.4.4.3 In general, the repairs are to be carried out by mechanical means, e.g. by grinding, chipping or milling, and preferably not by welding. Weld repairs are to be undertaken only when they are considered to be necessary and detailed repair information (including sketches or photographs showing the location and major dimensions of the grooves prepared for welding) and inspection procedure are to be submitted to and approved by CCS in advance.
8.4.4.4 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.
8.4.4.5 The maximum total area of repairs and the maximum area of any single repair in any one zone or region may be referred to the relevant standards acceptable to CCS, but welding of areas less than 5 cm^2 is to be avoided.
8.4.4.6 Weld repairs of defects in zone A are to be as follows:
(1) In zone A, repair welding is generally not allowed unless specially approved by CCS. Where such weld repair is applied, all welds are to be stress relieved by heat treatment, and the heat treatment procedure is to be agreed by CCS Surveyor.
(2) Grinding is to be carried out to an extent which maintains the blade thickness of the approved drawing.
(3) The possible repair of defects which are deeper than those referred to in (2) above is to be specially considered by CCS.
8.4.4.7 Weld repairs of defects in zone B are to be as follows:
(1) With the prior approval by CCS, repair welding is generally allowed in zone B, but avoidance of such repairs is preferred. Detailed and complete information of defects/damages and the intended weld repair

procedure is to be submitted for each approval.
(2) Defects that are not deeper than t/40 mm (t being the minimum local thickness according to the approved drawing) or 2 mm (whichever is greater) are to be removed by grinding.
(3) Those defects which are deeper than those referred to in (2) above may be repaired by welding.
8.4.4.8 In zone C, repair welds are generally permitted in accordance with the approved procedures.
8.4.4.9 The foundry is to maintain a report of repairing and welding, subsequent heat treatment and final inspection results traceable to each casting repaired, and such report is to be confirmed by the Surveyor.

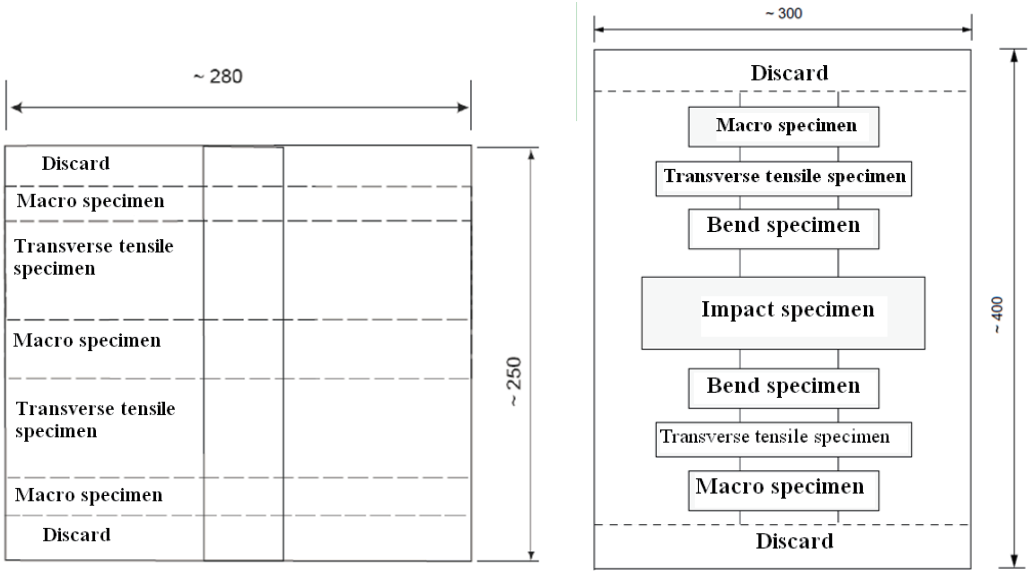
8.4.5 Weld repairs

8.4.5.1 Companies wishing to carry out welding work on propellers are to demonstrate to the Surveyor that they have at their disposal the necessary workshops, lifting gear, welding equipment, preheating and testing devices as well as certified welders and expert welding supervisors.
8.4.5.2 Before welding is started, a detailed welding procedure specification is to be prepared and submitted by the company concerned, covering the weld preparation, welding procedure, filler metals, preheating, post-weld heat treatment and inspection procedures.
8.4.5.3 The use of any welding procedure without prior approval is subject to a satisfactory approval test witnessed by the Surveyor (detailed test requirements are given in Table 8.4.5.3). The test is to be carried out with the same base metal, welding process, filler metal, preheating and stress-relieving treatment as those intended applied by the actual repair work. All weld repairs are to be made by certified welders strictly in accordance with approved procedures.

Test requirements for approval of repair welding techniques for propeller① Table 8.4.5.3

Material of propeller	Min. thickness of assembly② (mm)	Test item③	Requirements for test results
Cast copper alloy propeller	30	Visual inspection and surface liquid penetrant testing: weld length	No surface cracking
		Radiographic testing: weld length	In compliance with recognized standards
		Transverse tensile: 2	Cu1: R_m≥370 N/mm^2 Cu2: R_m≥410 N/mm^2 Cu3: R_m≥500 N/mm^2 Cu4: R_m≥550 N/mm^2
		Macro: 3	No cracking or pores over 3 mm in diameter
Cast steel propeller	30	Visual inspection and surface liquid penetrant testing: weld length	Satisfying requirements for Zone A in Table 8.4.3.5
		Radiographic testing: weld length	In compliance with recognized standards
		Transverse tensile: 2	R_m satisfies the minimum requirements specified for base metal
		Side bends: 2	Diameter of former: austenitic stainless steel 3t, other materials 4t; after the specimens are bent, they are not to exhibit cracking over 2 mm in length on the surface
		Macro: 2	No cracking or defects similar to cracking, no slag inclusions or pores over 3 mm in diameter
		Impact: where there are impact requirements for base metal, one set for the center weld and the fusion line respectively	The impact temperature and impact energy satisfy the requirements for base metal

Notes: ① For the repair of cast copper alloy propellers, the test items and requirements specified in the Table are also applicable to the welder's qualification test.
② Back sealing runs are allowed in single V weld assemblies. The specimen is in general to be welded in down-hand (flat) position.
③ The dimensions and specific locations of test specimens are shown in Figure 8.4.5.3.



(1) Cast copper alloy propeller (2) Cast steel propeller

Figure 8.4.5.3 Test specimen locations for approval of repair welding techniques for propeller

8.4.5.4 Defects to be repaired by welding are to be ground to sound material. To ensure complete removal of the defects the ground areas are to be examined by dye penetrant methods in the presence of the Surveyor.

8.4.5.5 The welding grooves are to be prepared in such a manner which will allow a good fusion of the groove bottom and leave it clean and dry.

8.4.5.6 Welding consumables are to match parent metals. The welding consumables for copper alloy propellers may be selected as recommended in Table 8.4.7.3. Flux-coated electrodes are to be dried and stored before welding according to the manufacturer's instructions.

8.4.5.7 All welding work is to be carried out preferably in the shop free from draughts and influence of the weather.

8.4.5.8 Based on the experience of the manufacturer, arc welding with coated electrodes or gas-shielded metal arc process may be applied for all types of repair on propellers. Argon-shielded tungsten welding is to be used with care.

Metal arc welding is recommended for all types of repair on bronze propellers.

Gas welding may be applied for repair of defects on Cu1 and Cu2 copper alloy propellers, provided that the application is limited to a distance of 1/3 radius of the propeller from its outside edge and material thickness less than 30 mm.

8.4.5.9 Adequate preheating is to be carried out by natural gas or liquefied petroleum gas soft-flame torches or by electric wire heating devices with care to avoid concentrated flames and local overheating.

8.4.5.10 Propellers are generally to be welded in downhand (flat) position. Where this cannot be done, gas-shielded metal arc welding is to be carried out.

8.4.5.11 To minimize the risk of distortion and cracking, interpass temperatures are to be kept low. This is especially the case with Cu3 alloys.

8.4.5.12 Slag, undercuts and other defects are to be removed before depositing the next run.

8.4.6 Straightening

8.4.6.1 Minor distortions of propellers may be straightened with or without heating. Cold straightening is to be used for minor repairs of tips and edges only. For hot and cold straightening purposes, only static loading is to be used.

8.4.6.2 Straightening of a bent propeller blade or a pitch modification is to 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 8.4.7.3.

8.4.6.3 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 to 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.

8.4.6.4 After straightening, the propeller is generally to be packed by a blanket or other means for cooling slowly to room temperature.

8.4.7 Heat treatment

8.4.7.1 Unless demonstrated by the manufacturer as not necessary, all cold straightening or weld repairs of Cu1, Cu2 and Cu4 copper alloy propellers are to be stress relief heat treated. Stress relief heat treatment of alloy Cu3 propeller castings may be required after repairs in zone B (and specially approved welding in zone A) or if a welding consumable susceptible to stress corrosion cracking is used.

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

8.4.7.3 The recommended stress relief heat treatment temperatures for copper alloy propellers are listed in Table 8.4.7.3. Soaking times are to be in accordance with Table 9.1.4.4 in Chapter 9 of PART ONE of the Rules.

Recommended Filler Metals, Preheating and Heat Treatment Temperatures Table 8.4.7.3

Alloy type	Filler metal	Min preheating temperature ℃	Max. interpass temperature ℃	Stress relief temperature ℃	Hot straightening temperature ℃
Cu1	Al-bronze① Mn-bronze	150	300	350 ~ 500	500 ~ 800
Cu2	Al-bronze Ni-Mn-bronze	150	300	350 ~ 550	500 ~ 800
Cu3	Al-bronze Ni-Al-bronze② Mn-Al-bronze	100	250	450 ~ 500	700 ~ 900
Cu4	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.

8.4.7.4 Throughout the process of heat treatment, workpieces are to be sufficiently supported so as to minimize distortion.

8.4.7.5 The heating and cooling is to be carried out slowly under controlled conditions. The heating rate is normally not to exceed 100℃/h, and the cooling rate after any stress relieving heat treatment is not to exceed 50℃/h until the temperature of 200℃ is reached.

8.4.8 Inspections of repairs

8.4.8.1 On completion of weld repair and heat treatment (if adopted), the weld repairs and adjacent material are to be ground smooth and are to be subject to re-inspection in accordance with the relevant requirements in 8.4.3 of this Section.

CHAPTER 9 WELDING OF PRESSURE PIPES

Section 1 GENERAL PROVISIONS

9.1.1 Application

9.1.1.1 This Chapter applies to manual, automatic, semi-automatic arc welding or other processes approved by CCS, for butt joints in pipes and for joints in the attachment of branch pieces and flanges.

9.1.1.2 Oxy-acetylene welding is to be used only for butt joints in pipes not exceeding 100 mm in diameter or 9.5 mm in wall thickness.

9.1.2 Material

9.1.2.1 The following requirements apply to the types of steels used in the fabrication of Class I and II piping systems operating at ambient or elevated temperatures:

(1) carbon and carbon-manganese steels having minimum tensile strength (R_m) of 320, 360, 410, 460 or 490 N/mm^2;

(2) low alloy steels having chemical compositions of 0.3Mo, 1Cr0.5Mo, 2.25CrMo or 0.5Cr0.5Mo0.25V.

9.1.2.2 The above materials may also be used in the fabrication of Class III piping systems and repair welding of pipelines.

9.1.2.3 Piping systems operating at temperatures lower than -40℃ will be given special consideration by CCS.

9.1.3 Approval of welding procedures

9.1.3.1 Where any of the following joints is to be welded for the first time or when a new welding procedure is proposed to the following joints, details of the welding procedure specification are to be submitted to CCS for approval, in accordance with the relevant requirements in Chapter 3 of this PART:

(1) attachment of flanges to pipes;

(2) attachment of valve chests to pipes;

(3) attachment of fittings to pipes;

(4) butt joints of pipes to pipes;

(5) fabrication of branch pieces.

9.1.3.2 The manufacturer is to prepare test specimens with representative joints by simulating the actual welding conditions, for carrying out the welding procedure approval test.

9.1.3.3 Test welds are to be examined for defects in accordance with the requirements given in Section 3 of this Chapter, and then to be sectioned at positions selected by the Surveyor, with one surface of each section being prepared, etched and examined for defects in the weld and heat affected zones.

9.1.3.4 For joints of pipes and branches made of alloy steels, destructive tests and as specified in Section 2, Chapter 1 of this PART, mechanical tests are also required. And for joints of pipes and branches made of carbon and carbon-manganese steels, where deemed necessary by CCS Surveyor, the mechanical tests may also be required to demonstrate that the joints are of adequate strength.

Section 2 WELDING OF PIPE JOINTS

9.2.1 General requirements

9.2.1.1 All welds are to be away from the bends and expansion compensation portions of pipes and so arranged that the effects of bending moments or alternating loads are minimized.

9.2.1.2 Pipes are to be welded in workshops as far as practicable. Where welding on board is intended, consideration is to be given to an ample space necessary for preheating, welding, heat treatment and inspection.

9.2.1.3 The preparation of the edges is preferably to be carried out by mechanical means. When flame cutting is used, care is to be taken to remove the oxide scales and any notch due to irregular cutting by matching grinding or chipping back to sound metal.

9.2.1.4 Welding is to be done according to applicable requirements. The weld preparation and the welded joint are to be inspected as may be necessary in the course of fabrication and after completion of the post-weld heat treatment.

9.2.2 Welding

9.2.2.1 During assembling, the axes of pipes are to be properly aligned so as to minimize the offset as far as practicable. The tolerances on the alignment for Class I and II piping systems are not to be greater than those required as follows:

(1) For pipes welded with fixed backing rings: 0.5 mm.

(2) For pipes welded without fixed backing rings:

① 1 mm or *t*/4, whichever is the lesser, for internal diameters less than 150 mm and thicknesses up to 6 mm;

② 1.5 mm or *t*/4, whichever is the lesser, for internal diameters less than 300 mm and thicknesses up to 9.5 mm;

③ 2.0 mm or *t*/4, whichever is the lesser, for internal diameters of 300 mm or over, or thicknesses over 9.5 mm.

t being the wall thickness of pipes.

9.2.2.2 Prior to welding, the surfaces to be welded are to be free from scale, moisture, grease and dirt. The edge preparation and root gap are to comply with the requirements of the welding procedure specification.

9.2.2.3 The preheating temperature of pipe joints is to be determined according to the chemical composition of the pipe material and the wall thickness of pipes. The temperature is, in general, to comply with the requirements in Table 9.2.2.3.

Preheating Temperature of Pipe Joints Table 9.2.2.3

Type of steel	Thickness of thicker part (mm)	Minimum temperature (℃)
Carbon and carbon-manganese steels (C + Mn/6 ≤ 0.4)	≥ 20②	50
Carbon and carbon-manganese steels (C + Mn/6 > 0.4)	≥ 20②	100
0.3 Mo	> 13②	100
1Cr0.5Mo	< 13	100
	≥ 13	150
2.25CrMo and 0.5Cr0.5Mo0.25V①	< 13	150
	≥ 13	200

Notes: ① For these materials, preheating may be omitted for thicknesses up to 6 mm if hardness tests results for welding procedure approval are accepted by CCS.

② For welding at ambient temperatures below 0℃, preheating is to be carried out at the minimum preheating temperature regardless of the thickness. Special consideration will be given by CCS to special cases.

③ The values in the Table are based on using low hydrogen processes. When low hydrogen processes are not used, higher preheating temperatures are to be considered.

9.2.2.4 Tack welds are to be made using electrodes suitable for the base metal and an approved welding process. When the base metal requires preheating, the same preheating temperature is to be applied for tack welding.

9.2.2.5 The surface of butt welds is to be uniform with a smooth transition to the base metal.

Section 3 INSPECTION OF WELDING QUALITY

9.3.1 General requirements

9.3.1.1 Visual inspection, non-destructive testing and hydraulic pressure test are to be carried out after the welding of pipes.

9.3.1.2 The hydraulic tests are to be carried out in accordance with the requirements of Section 5, Chapter 2 of PART THREE of CCS Rules for Classification of Sea-going Steel Ships.

9.3.2 Visual inspection

9.3.2.1 The surface of welds is to be free from cracks, overlaps, pores, undercuts, unfilled cavities and

depressions. In case of the above defects, repairs by welding are to be performed.

9.3.3 Non-destructive testing

9.3.3.1 All butt joints of Class I pipes having an external diameter greater than 75 mm are to be subjected to radiographic or gammagraphic examination.

9.3.3.2 10% of butt joints of Class II pipes having an external diameter greater than 100 mm and Class I pipes having an external diameter equal to or less than 75 mm are to be subjected to radiographic or gammagraphic examination.

9.3.3.3 An approved ultrasonic testing procedure may be accepted in lieu of radiographic testing where the conditions are such that a comparable level of welding quality is assured.

9.3.3.4 Fillet welds on flange pipe connections of Class I pipes are to be examined by the magnetic particle method or by other appropriate non-destructive methods. For pipes of other classes, magnetic particle examination or equivalent non-destructive testing may be required for fillet welds depending upon the material, wall thickness and outside diameter of pipes and the nature of the medium being carried.

9.3.3.5 Ultrasonic examination in addition to the above non-destructive testing may be required in special cases.

9.3.3.6 Radiographic, gammagraphic and ultrasonic examinations are to be performed by Grade II operators certified by CCS, using an appropriate procedure. If necessary, complete details of the radiographic, gammagraphic and ultrasonic procedures are to be submitted for examination.

9.3.3.7 Magnetic particle examination is to be performed with suitable equipment and procedures, using a magnetic flux output sufficient for defect detection. If necessary, the equipment is to be checked against standard samples.

9.3.3.8 The welds are to meet an acceptable standard. Unacceptable defects are to be removed and repaired as required.

Section 4 HEAT TREATMENT

9.4.1 General requirements

9.4.1.1 According to different materials and processing conditions of pressure pipes, heat treatment after forming and welding may be required as necessary, in compliance with the requirements of this Section.

9.4.1.2 The heat treatment is not to impair the specified properties of the materials. Verifications may be required to this effect as necessary.

9.4.1.3 The heat treatment is in general to be carried out in a furnace provided with temperature recording equipment. However, localized heat treatment of a sufficient length with an approved procedure can be accepted for welded joints.

9.4.2 Stress relieving heat treatment

9.4.2.1 Steel pipes and fabricated branch pieces are to be subjected to stress relieving heat treatment in the following cases according to the requirements of Table 9.4.2.1:

(1) Cr-Mo and Cr-Mo-V pipes where hot forming is carried out in the temperature range of 850 ~ 1,000℃;

(2) cold bent pipes of all Classes, except for carbon and carbon-manganese pipes with tensile strength not greater than 410 N/mm^2;

(3) pipes are joined by arc welding.

Requirements of Stress Relieving Heat Treatment **Table 9.4.2.1**

Type of steel	Thickness of thicker part (mm)	Stress relief heat treatment temperature (℃)
C and C-Mn	≥ 15①③	550 ~ 620
0.3Mo	≥ 15①	580 ~ 640
1Cr0.5Mo	> 8	620 ~ 680
2.25CrMo and 0.5Cr0.5Mo0.25V	Any②	650 ~ 720

Notes: ① When steels with specified Charpy V notch impact properties at low temperatures are used, the thickness above which postweld heat treatment is to be applied may be increased by special agreement with CCS.

② Heat treatment may be omitted for pipes having thickness ≤ 8 mm, diameter ≤ 100 mm and minimum service temperature 450℃.

③ For C and C-Mn steels, heat treatment may be omitted up to 30 mm thickness by special agreement with CCS.

9.4.2.2 The stress relieving heat treatment is to heat and cool pipes slowly and uniformly, with the soaking time taken as one hour per 25 mm of thickness (at least 0.5 h). They are to be cooled in the furnace to a temperature not exceeding 400℃ and subsequently cooling in a still atmosphere.

9.4.2.3 In any case, the heat treatment temperature is not to be greater than t_T-20℃ where t_T is the temperature of the final tempering treatment of the material.

9.4.3 Other heat treatments

9.4.3.1 Steel pipes and fabricated branch pieces of all Classes are to be subjected to a heat treatment of normalizing or normalizing and tempering in the following cases according to the requirements of Table 9.4.3.1:

(1) the hot forming is carried beyond the temperature range specified in 9.4.2.1(1);

(2) pipes are cold bent to a radius of less than 4 times the external pipe diameter;

(3) the oxy-acetylene welding procedure is employed.

Requirements of Heat Treatment for Different Types of Steel Table 9.4.3.1

Type of steel	Heat treatment and temperature (℃)
C and C-Mn	Normalizing 880 ~ 940
0.3Mo	Normalizing 900 ~ 940
1Cr0.5Mo	Normalizing 900 ~ 960 Tempering 640 ~ 720
2.25CrMo	Normalizing 900 ~ 960 Tempering 650 ~ 780
0.5Cr0.5Mo0.25V	Normalizing 930 ~ 980 Tempering 670 ~ 720

9.4.3.2 Copper and copper alloy pipes which have been hardened by cold bending are to be suitably heat treated on completion of fabrication and prior to hydraulic testing. Copper pipes are to be annealed and copper alloy pipes are to be either annealed or stress relief heat treated. Detailed requirements are to be determined in accordance with the chemical composition.

CHAPTER 10 WELDING OF SUBMARINE PIPING

Section 1 GENERAL PROVISIONS

10.1.1 Application

10.1.1.1 This Chapter applies to welding for on-site assembling of submarine piping and for manufacturing of welded pipes.

10.1.1.2 This Chapter applies to manual welding, semi-automatic welding, automatic welding, flash butt welding and other welding processes approved by CCS.

10.1.2 Material

10.1.2.1 Seamless pipes or pipes manufactured by welding rolled steel plates may be used for submarine piping.

10.1.2.2 Steels used for submarine piping are to have a yield strength not greater than 500 MPa and to be approved by CCS.

10.1.3 Welding procedures

10.1.3.1 Welding procedures for submarine piping are to be subject to approval tests as required in Chapter 3 of this PART.

10.1.3.2 Underwater welding procedures for installation at sea are to be approved by CCS.

10.1.4 Welders

10.1.4.1 Welders engaged in welding for on-site assembling are to hold a qualification certificate suitable for the work and to be subject to training and tests appropriate for the working conditions of installation at sea.

10.1.4.2 Welders engaged in underwater welding are to hold a Qualification Certificate of Underwater Welder issued or approved by CCS as well as an appropriate diver's certificate.

Section 2 WELDING IN PIPING ASSEMBLING

10.2.1 General requirements

10.2.1.1 Welding in piping assembling may be divided into welding for preassembling and welding for on-site assembling. Preassembling may be carried out either on land or at sea.

10.2.1.2 The assembling site is to be provided with suitable and reliable welding equipment and ambient conditions to ensure that welding is carried out safely and successfully.

10.2.1.3 Visual inspections and dimension checks are to be carried out at the assembling site on pipes that are brought to the site. Defects caused during transportation are to be removed before pipes are put into service.

10.2.1.4 Welding in assembling is generally to be performed before corrosion protection coating is applied. However, butt welding may be carried out after coating operations according to the requirements for pipe laying.

10.2.2 Welding procedures

10.2.2.1 Before assembling it is appropriate to paint a serial number on the pipe's external surface to facilitate recognition, measurement and record making. The dimension is to be re-measured and marked when the pipe is cut short.

10.2.2.2 The beveled area is to be free from moisture, grease, scale which may impair welding quality.

10.2.2.3 Welding is to be carried out strictly according to the approved procedures. Low hydrogen consumables and precautions are to be adopted in welding of higher strength steel pipes.

10.2.2.4 Both internal and external alignment devices are generally not to be removed before the first two runs are completed. Where tack welding is necessary for alignment, it is to be carried out according to the approved procedure specification and within the grooves only. Faulty tack welds are to be removed.

10.2.2.5 The welding is not to be interrupted until an adequate strength of the joint is reached so as to avoid plastic deformation or cracking during transportation or movement.

10.2.2.6 Before the next run is started after an interruption of welding, slag is to be removed. If preheating is required in the welding procedure, the joint is to be preheated to the minimum temperature required.
10.2.2.7 Permanent bracing members, fittings and suspension lugs for risers and pipes are generally to be welded on stiffening rings. Temporary stiffening rings are to be fastened by jigs.
10.2.2.8 Permanent stiffening rings are generally to be of an integral type, and the material of which is to comply with the requirements for pressure members. Backing strips are to be applied in welding of longitudinal seams of the rings in order not to burn through the pipes. Circumferential seams are to be continuous and so welded as to minimize the risk of root cracking and lamellar tearing.

10.2.3 Underwater welding procedures
10.2.3.1 Underwater welding is to be carried out in drained chambers with low hydrogen consumables and procedures. Other methods adopted are to be approved by CCS.
10.2.3.2 The sealed arrangement for welding is to comply with the requirements of design and manufacture. The sealed sweeper is in general to be subject to pressure test before being fitted into pipes unless it is proved to be reliable by application.
10.2.3.3 A detailed welding procedure specification is to be prepared to cover the relevant requirements in Chapter 3 of this PART as well as the following:
(1) depth of water;
(2) pressure in the sealed welding chamber;
(3) gas composition in the chamber;
(4) humidity in the chamber;
(5) temperature in the chamber.
10.2.3.4 The basic parameters of the welding procedure may vary within the range specified in Chapter 3 of this PART and are to comply with the following requirements:
(1) No pressure increase is to occur in the chamber;
(2) No change in gas composition is to occur in the chamber;
(3) The humidity in the chamber is not to exceed the required range.
10.2.3.5 The beveled area is to be preheated to an appropriate temperature to remove moisture and prevent diffusion of hydrogen in the weld.
10.2.3.6 The underwater welding site is to be well illuminated and ventilated to ensure the operation is carried out smoothly.
10.2.3.7 Joining welds completed in underwater operations are to be subject to non-detective testing for the full length and to be accepted according to the specified standard.

10.2.4 Inspection of finished welds
10.2.4.1 All welds completed for assembling are to be subjected to 100% visual inspection and 100% radiographic testing. The procedure of non-destructive testing is to be approved by CCS.
10.2.4.2 Each weld subjected to visual inspection or radiographic testing is to be recorded for easy locating of suspicious welds and non-destructive re-examination.
10.2.4.3 Welds completed are to comply with the requirements in Table 10.2.4.3.

10.2.5 Weld repairs
10.2.5.1 If unacceptable defects are detected, they may be removed by repairing or the defective pipe lengths cut off.
10.2.5.2 Shallow defects may be removed by grinding, and the remaining wall thickness of pipes after grinding is not to be less than the minimum thickness required. Grinding is to be performed by skilled personnel and the surface is to be ground smooth.
10.2.5.3 A repair welding procedure specification is to be prepared for pipes and welds before welding. Approval tests may be required for the procedure if necessary. The procedure may not be applied without agreement by CCS.
10.2.5.4 The repair welding procedure specification is to cover the requirements in Chapter 3 of this PART as well as the following:
(1) method for defect removal, cleaning of areas to be welded and non-destructive testing procedures after welding;
(2) the maximum and minimum depths and lengths of repairing.

Acceptance Criteria for Welds in Submarine Piping **Table 10.2.4.3**

Defects		Requirements
Inner defects	Pore	Scattered pores: not to exceed 3% of the projected area of the weld and not to exceed either t/4 or 4 mm in diameter. Clustered pores: not to exceed an area of 12 mm in diameter within any continuous weld length of 300 mm. Single pore: not to exceed either t/8 or 2 mm in diameter. Linear pore: not to penetrate to the surface of weld and not to exceed either t/8 or 2 mm in diameter
	Slag inclusion①②③	Single slag inclusion: length ≤ t/2, width ≤ t/4 or 4 mm. Linear slag inclusion: length ≤ 2t or 50 mm, width ≤ 2 mm. Aligned discontinuous slag inclusion: width of parallel indication ≤ 1.5 mm
	Lack of fusion or incomplete penetration①②③	Length ≤ 2t or 50 mm
	Crack	Not allowed
External defects	Misalignment at the joint	< 0.15t or 3 mm as a maximum
	Depression	Depth ≤ 6 mm, length ≤ 1/2 outer diameter of pipe
	Shrinkage cavity/groove, crater and arc scratch	Not allowed, but may be removed by grounding
	Weld reinforcement	≤ 3 mm (outside) or 2 mm (inner side) for wall thickness t ≤ 12.5 mm ≤ 4 mm (outside) or 3 mm (inner side) for wall thickness t > 12.5 mm
	Pit	Pits at the outside of the pipe: unallowable; Pits at the inner side of the pipe: allowable, but the darkness of the pit on the radiograph is not to exceed that of the adjacent parent metal
	Undercut①②	Within any continuous circumferential seam length of 300 mm: Length ≤ 50 mm or 0.8 mm for depth ≤ t/10; Length ≤ 100 mm or 0.4 mm for depth ≤ t/20. The length of undercuts with depth ≤ 0.3 mm may not be taken into account if deemed not to impair the weld
	Lack of fusion or incomplete penetration①②	Length ≤ t
	Crack	Not allowed

Notes: ① Aligned slender defects spaced less than the length of the longest defect are to be deemed as a continuous defect.
② Any clustered indication of slag inclusions, lack of penetration, misalignment or undercuts is to be deemed as the most serious defects.
③ Only one defect as described in ① or ② is allowed in a continuous weld of 5 times the defect length.
④ t being the wall thickness of pipe, in mm.

10.2.5.5 Defects are to be removed completely before repair welding. Non-destructive testing may be applied to confirm the removal if necessary.

10.2.5.6 Welds for local repairs are to have a minimum length of 100 mm. Welds having a much longer length may be repaired in sections.

10.2.5.7 For welding repairs, low hydrogen consumables are to be applied and appropriate preheating and interpass temperatures maintained. After welding, the surface of the weld is to be smooth, and grinding may be applied where necessary.

10.2.5.8 Repairs by welding to one area are not to be performed more than twice unless approved by CCS.

10.2.5.9 The range of non-destructive testing for repaired welds is to extend for 50 mm from both ends of the weld.

CHAPTER 11 WELDING AND RIVETING OF NON-FERROUS MATERIALS

Section 1 GENERAL PROVISIONS

11.1.1 Application

11.1.1.1 This Chapter applies to welding of aluminum, titanium and copper alloy as well as riveting of aluminum alloys for hull and offshore installations.

11.1.2 Welding consumables

11.1.2.1 Welding consumables for aluminum alloy structure are to comply with the relevant requirements of Chapter 2 of this PART.

11.1.2.2 The principle for selection of welding consumables for titanium and titanium alloy material is to comply with the relevant requirements of Sections 3 and 5 of this Chapter.

11.1.3 Procedure specification and inspection standards

11.1.3.1 Before commencement of construction, the proposed procedure specification and inspection standards are to be submitted to CCS for approval, and a welding procedure test (where necessary) will be carried out on this account, according to the requirements of Chapter 3 of this PART. Welding construction and inspection are to be carried out in accordance with the plans, procedure specification and inspection standards approved by CCS.

11.1.3.2 Welding procedure test for titanium and titanium alloy may be carried out with reference to relevant requirements of CCS Guidelines for Inspection of Hull Welds.

Section 2 WELDING OF ALUMINUM ALLOYS

11.2.1 General requirements

11.2.1.1 This Section applies to the welding of weldable aluminum alloys complying with the requirements of Chapter 8, PART ONE of the Rules.

11.2.1.2 The welding procedure specification for aluminum alloys is to be submitted to CCS for approval. The procedure specification is to include measures for preventing and rectifying welding deformation.

11.2.1.3 The welding procedure approval tests for aluminum alloys are to be carried out according to the relevant requirements in Chapter 3 of this PART.

11.2.1.4 Welders engaged in the welding of aluminum alloys are to have been trained in the operational skill and certified accordingly upon qualification tests.

11.2.2 Preparations before welding

11.2.2.1 Protective means against moisture, dust, cold and wind are to be provided at the welding site. The wind speed is to be less than 1.5 m/s during the welding operation.

11.2.2.2 Aluminum alloys may be cut by machining or plasma technique. Edge preparation may be performed by machining such as planing or grinding. Any other proposed method is to be agreed by CCS Surveyor.

11.2.2.3 Wires, welding grooves and adjacent areas are to be thoroughly cleaned, by chemical means where necessary, and kept dry. After cleaning, the welding is to be applied as soon as possible. Usually, the cleaned parts are to be welded within 24 h, otherwise they are to be effectively protected or cleaned again.

11.2.2.4 Preheating is to be considered for the areas to be welded in any one of the following cases:

(1) aluminum alloys with thickness over 8 mm;

(2) ambient temperature below 0℃; or

(3) ambient humidity over 80%.

Flame is unacceptable for preheating of aluminum alloys.

The preheating temperature of aluminum-magnesium alloys is generally to be 50℃±10℃.

11.2.2.5 Where inert gas-shielded arc welding is employed, the purity of the shielding gas is to be checked for compliance with the welding procedure specification, prior to welding.

11.2.3 Welding

11.2.3.1 It is recommended that tungsten inert gas arc welding (TIG) or metal inert gas arc welding (MIG) be adopted for aluminum alloy structures. Both ends of important welds are to be provided with temporary run-on and run-off tabs.
11.2.3.2 Main butt welds are to be downhand butt welded with an angle of inclination less than 20° as far as possible.
11.2.3.3 To minimize the deformation, the following are to be complied with while welding:
(1) starting at the center of the seam and welding outward symmetrically or welding with back step sequence for a single long weld;
(2) starting at the center weld and welding outward symmetrically for long and close-spaced welds;
(3) the dimensions of the welds are not to be enlarged as far as possible so long as the design requirements are met.
11.2.3.4 The continuity of welding is to be kept; where for any reason the welding is interrupted, the location of stopping is to be cleaned before striking the arc; and the succeeding weld is to be overlapped on the previous one for an adequate length. Where the multi-run welding technique is employed, care is to be taken to the cleaning and the interpass temperature between two runs.
11.2.3.5 Root runs are to be cut out to clean metal and weld defects removed by machining such as planing or grinding.
11.2.3.6 For full penetration butt welds, back chipping is required to eliminate all defects after the front side is welded.
11.2.3.7 Where multi-run welding is used, the surface of each run of the deposit is to be thoroughly cleaned before the next run is deposited, and the interpass temperature is to be controlled at 60℃or lower as far as possible.
11.2.3.8 If spatters are visibly attached to the nozzle during MIG welding, the nozzle is to be renewed or cleaned. If the tungsten electrode is found oxidized or defective in shape during TIG welding, it is to be renewed or repaired by grinding. If the tungsten electrode touches the molten bath or the wire, the welding is to be stopped immediately, and the welds having tungsten inclusions are to be thoroughly cleaned. The wire and tungsten electrode stained are also to be cleaned.
11.2.3.9 Where steel-aluminum transition joints are welded, heat input is to be strictly controlled in order to prevent harmful effects to the joints.
11.2.3.10 For intersections of major structures at a small angle, beveling and welding are generally to be performed at the back side, and the leg length of the fillet weld is to comply with the design. The deformation of aluminum alloy structures resulted from the welding is preferably not to be rectified by hammering. Heating for rectification, where employed, is to be carried out in accordance with instructions of the aluminum alloy manufacturer.

11.2.4 Inspection and repairing of welds

11.2.4.1 Final welds are to be subjected to visual inspection and non-destructive testing. The methods of examination and acceptance criteria are to be agreed by CCS.
11.2.4.2 The range of non-destructive testing of welds of main hull structures is to be agreed between the shipyard and the Surveyor. It is recommended that at least 5% of butt welds of main hull structures be radiographic tested. Fillet welds of important structures are to be ultrasonically tested. The defects are to be evaluated in accordance with the standards acceptable to CCS.
11.2.4.3 The surface of welds is to be free from defects such as cracks, tungsten inclusions, unfilled cavities, pores, burning damages and overlaps. Undercuts are not permitted for plates of 3 mm or less in thickness. For plates over 3 mm in thickness, the depth of undercuts is not to be greater than 0.5 mm, their total length is not to be greater than 10% of the length of a single weld and not to exceed 100 mm.
11.2.4.4 The weld repairs for aluminum alloys are generally not to be performed more than twice unless approved by CCS.
11.2.4.5 Weld repairs are to be carried out using the same welding consumables and procedures as those adopted for the original welds. After repairing, the welds are to be inspected again.

Section 3 WELDING OF TITANIUM AND TITANIUM ALLOYS

11.3.1 General requirements

11.3.1.1 This Section applies to the welding of weldable titanium alloys complying with the requirements of Chapter 9, PART ONE of the Rules.

11.3.1.2 The titanium alloy components are to be designed to keep their structural continuity and the smooth transition of weld joints to avoid stress concentration.
11.3.1.3 Titanium and titanium alloys are to be welded according to relevant welding procedure specifications.
11.3.1.4 Welders engaged in the welding of titanium and titanium alloys are to have been trained in the operational skill and certified accordingly upon qualification tests.
11.3.1.5 Personnel engaged in quality inspection of welding is to be subject to technical training so as to have a correct command of quality assessment standards.

11.3.2 Welding consumables
11.3.2.1 The argon-shielded arc welding wires used for titanium and titanium alloys are usually to be of a material homogeneous with the base material.
11.3.2.2 In order to improve plasticity of weld joints, wires with an alloying level lower than that of the base material may be used.
11.3.2.3 For welding of titanium materials of different grades, wire materials are to be selected according to the base material with better corrosion resistance and lower strength level or as required by design.

11.3.3 Preparations before welding
11.3.3.1 Form and size of the edge preparation are to be determined according to factors such as joint type, thickness of base material, welding position, welding method, with or without backing and conditions for use, beveled edges with as less filler metal as possible are to be considered.
11.3.3.2 Titanium alloy materials and their beveled edges may be cut by machining, flame, water jet or plasma, among which flame cutting and plasma cutting are to avoid sparks on the surface of titanium alloy material, and cutting edge and beveled edge are still to be processed and removed from polluted layer by mechanical means. Grinding wheels, saw blades and files which have been used for steel cutting cannot be used again to cut titanium alloys. The surface of processed edges is to be smooth and flat, without defects and impurities that will affect quality. The surface of beveled edges is to have silver-white metallic luster.
11.3.3.3 Dirt such as oil, water and dust as well as oxide scale on surfaces of wires and beveled edges and within 20 mm to 50 mm of both sides are to be removed, using degreasing, mechanical cleaning or chemical cleaning according to surface contamination and thickness of scale.
11.3.3.4 Thoroughly cleaned wires and weldments are to be kept clean and dry to avoid recontamination. Oxidized parts at ends are to be cut, and oxidized wire surface is to be cleaned by chemical means. Welding is to be carried out as quickly as possible after cleaning. If welding is not carried out for 4h, cleaning is to be carried out again.
11.3.3.5 Titanium alloys are to be welded under following conditions:
(1) Titanium alloys are generally to be welded in independent locations. If welding is carried out at workshops, it is to be divided from the steel operation area to form an independent and enclosed titanium welding area.
(2) Welding is to be far from air intakes and open doors and windows, and the welding site is to be cushioned with rubber, etc.
(3) The ambient temperature is to be not less than 5℃, and the relative humidity is to be not more than 80%.
(4) During operation, the wind speed is to be less than 1.5 m/s.

11.3.4 Assembly and alignment
11.3.4.1 The jigs used for the alignment of weld joints or for cooling runs in adjacent areas are to be of copper or other nonmagnetic materials.
11.3.4.2 During assembly, tools and jigs used as well as beveled edges are to be kept clean. The procedure for tack welding is to be the same as that for normal welding. Tack welds are to be free of such defects as cracks, pores and slag inclusions, otherwise timely removal of these defects and rewelding are to be carried out. Rewelding is to be carried out at adjacent areas.
11.3.4.3 Oxide layers (only silver-white and yellow ones allowed) are to be removed from the surface of tack welds, and the transition of both sides of welds are to be made smooth to facilitate restarting, otherwise rectification is to be carried out.

11.3.5 Welding
11.3.5.1 The usual welding methods for titanium alloy components include argon-shielded tungsten arc

welding, metal argon-shielded arc welding and plasma welding.

11.3.5.2 Titanium cannot be connected by penetration welding to many metals such as steel. Mixing with steel and other metals is prohibited in penetration welding of titanium.

11.3.5.3 The parameters of the welding procedure is to be selected to ensure adequate penetration depth and good protection to avoid defects, and welding rules requiring small energy input are to be adopted so far as practicable.

11.3.5.4 A reasonable welding sequence, welding method or rigid fixing is to be adopted to reduce welding deformation and stress.

11.3.5.5 During argon-shielded tungsten arc welding, contact of the tungsten electrode with weld metal is to be avoided. If contact occurs, the contaminated layer is to be removed and the tip of the tungsten electrode is to be repaired by grinding before further welding.

11.3.5.6 The continuity of welding is to be kept. If the welding is interrupted, the succeeding weld is to be overlapped on the previous one for 10 mm to 20 mm. Where the multi-run welding technique is employed, care is to be taken to the cleanliness between two runs and the interpass temperature, craters are to be filled and the restart point is to be fused and fully penetrated.

11.3.5.7 During argon-shielded welding, the purity of argon is not to be less than 99.99%, and reliable argon shield is to be provided to both front and back of the weld. Protection by a welding torch and an additional trailing protection are to be adopted for the front side of the weld at the same time. The back of the weld may be protected by introducing shielding gas into the groove of the jig backing plate, providing a gas shield to the back or filling argon into the weldment, depending on shape and size of the weldment.

11.3.5.8 During welding, gas is to fed in advance and cut off with a time delay. The delay for cutting off gas is to be so determined that the weld at the stop point after cooling will be silver white or light yellow.

11.3.5.9 During multi-layer multi-run welding, the metal surface of each weld layer is to be examined and cleaned as required to ensure the quality of each run. Light yellow and light blue scales are to be erased using stainless steel wire brushes and residual impurities are to be removed using clean white silk cloth and acetone (or alcohol). Such defects as tungsten inclusions and cracks created during welding are to be cut away in time using a power-driven hard alloy knife. For butt welding and full penetration fillet welding which are continuous at both sides, a back sealing run is to be applied after the root run is cut out to clean metal. The root run is to be gouged as required by the welding procedure. For titanium alloy welds, root runs are to be cut to clean metal by chipping, planing or grinding rather than carbon arc-air gouging.

11.3.5.10 After welding, slag, overlap, spatter and other dirt on the surface of the weldment are to be removed. Local rectification is to be carried out to welds when necessary.

11.3.5.11 To prevent delayed cracking, hydrogen content in the welding atmosphere is to be controlled strictly during welding. Thick walls or important components are to be subject to stress relieving heat treatment after welding.

11.3.6 Inspection and repairing of welds

11.3.6.1 Final welds are to be subjected to visual inspection and non-destructive testing. The methods of examination and acceptance criteria are to be agreed by CCS.

11.3.6.2 The original surface color of all titanium welds and heat affected zones is to be inspected. The color of welds and adjacent zones is to be silver white or yellow. For other colors, oxidation tint is to be removed or repair is to be carried out.

11.3.6.3 The internal quality of welds is to be examined by non-destructive testing (radiographic examination or ultrasonic testing). The extent and number of non-destructive testing and the procedures and standards used are to be in compliance with the standards acceptable to CCS (such as JB/T4730).

11.3.6.4 The welds are to have a uniform and sound profile, with a smooth transition to the parent metal, and are to be free from cracks, lack of fusion, overshoot undercuts, pores, slag inclusions and craters.

11.3.6.5 No cut with a depth equal to or greater than 0.5 mm is allowed on the surface of titanium alloy welds. Such cuts, if any, are to be removed. After removal of such cuts, the weld surface is not to be lower than the surface of the parent metal.

11.3.6.6 Titanium alloy weld repairs are to be carried out using the same welding consumables and procedures as those adopted for the original welds. The weld repairs for the same position are generally not to be performed more than twice unless approved by CCS. The surface of the repaired welds is to be subjected to dye penetrant testing again.

11.3.6.7 Where tools and jigs are used for temporarily fixing connection welds, the surface of weld marks left after their removal is also to be subjected to dye penetrant testing.

Section 4 RIVETING

11.4.1 General requirements

11.4.1.1 This Section applies to the riveting of aluminum alloy hull structures only.

11.4.1.2 Riveting is to be carried out in accordance with the approved procedure specification.

11.4.1.3 The manufacturer is to prepare a detailed riveting procedure specification and submit it to CCS for approval.

11.4.1.4 The material of rivets used is to be suitable for the structural material and comply with the relevant requirements of Chapter 8, PART ONE of the Rules. The sealing filler used in the riveted seams is to be suitable for the structural material, and is not to cause electro-chemical corrosion or any other chemical reaction.

11.4.2 Preparation of rivet holes

11.4.2.1 Rivet holes are generally to be drilled by electric or pneumatic means only. Care is to be taken for properly drilling cold-work hardened materials.

11.4.2.2 Where countersunk rivets or semi-countersunk rivets are used and the plate is to be reamed, the angle of the reamer cone is to be suitable for the rivet. When the plate thickness is the same as the depth of the hole, the latter may be reduced by 0.5 mm.

11.4.2.3 The rivet holes of structural members, which are to be riveted, are to be aligned with each other and are to have good fit with rivets. The rivet holes are to be smooth and free from burrs or sharp edges.

11.4.2.4 The diameter, out-of-roundness and center deviation of finished rivets are to comply with tolerances in the relevant standards. The vertical deviation of the axis of rivet holes in respect to the surface of the structural member is to be less than one tenth of the thickness of the structural member.

11.4.3 Preparations before riveting

11.4.3.1 Generally, riveting is to be carried out after welding, perforating and rectifying of the area to be riveted and adjacent areas are finished.

11.4.3.2 The riveted surfaces are to be smooth, clean, tight and free from inclusions. The anticorrosive paint or sealing filler is to be applied only after the structure is thoroughly dried. The thickness of the sealing filler is to be approximately the same for the entire length.

11.4.3.3 In order that the riveting work will be done satisfactorily, suitably spaced locating holes are to be drilled to a diameter slightly smaller than that of rivets at riveting positions to temporarily fixing structural members with bolts before riveting.

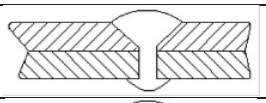
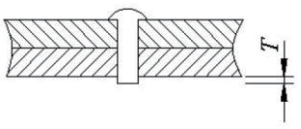
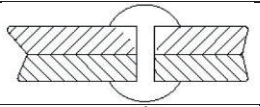
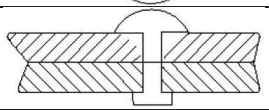
11.4.3.4 Before riveting, the rivets, rivet holes and hole reaming are to be checked for compliance with specified requirements.

11.4.4 Riveting of structures

11.4.4.1 Riveting is to proceed fore and aft symmetrically from the center.

11.4.4.2 The exposed length of the rivet shank is to be as required in Table 11.4.4.2.

Exposed Length of Rivet Shank **Table 11.4.4.2**

Rivet diameter *d* (mm)	Type of closing heads	Shape of closing heads	Extension length *T* (mm)	Remark
3~25	Semi-countersunk head		0.8*d* ~1.2*d*	From the values given for flat closing heads, the larger one is to be taken, and approximately 1 mm is to be added to exposed length of three layers 
3~25	Cup head		1.5*d* ~1.7*d*	
3~13	Flat head		1.3*d* ~1.4*d*	

11.4.4.3 The air hammer and dolly used are to be suitable for the diameter of rivets used.

11.4.4.4 Except that the agreement of the Surveyor is to be obtained in special cases, the flat head of flat head rivets is to be positioned as follows:

(1) The flat head is to be on the section side where a plate and a section are riveted together.

(2) The flat head is to be on the side of the thicker material where the materials to be riveted are different in thickness.
(3) The flat head is to be on the side of the harder material where the materials to be riveted are different in hardness.
11.4.4.5 Where two different metallic materials are to be riveted together, an anticorrosive and insulating material is to be used between them to prevent electro-chemical corrosion.
11.4.4.6 Riveting is to be finished in a single operation as far as practicable and further rectification is not suitable.

11.4.5 Inspection of riveted seams
11.4.5.1 The riveting pitch, row spacing and rivet diameter are to comply with the requirements of plans.
11.4.5.2 After riveting, the surfaces of the structural members around rivets are to be tightly pressed against each other and no obvious indention is to be found at riveting positions.
11.4.5.3 The dimensions of the heads of rivets are to comply with relevant standards. The rivets are to be free from loosening, head eccentricity, cracks, etc.

Section 5 WELDING OF MARINE COPPER AND COPPER ALLOY TUBES

11.5.1 General requirements
11.5.1.1 This Section applies to the welding of copper tubes, brass tubes and copper nickel alloy tubes commonly used in ships with the following welding processes: tungsten inert gas arc welding, metal-arc inert gas welding and plasma arc welding. Where other welding processes, such as manual arc welding and gas welding, are adopted according to the condition of the product, relevant requirements of this Section may be referred to.
11.5.1.2 The welding procedure specification for copper and copper alloy tubes is to be submitted to CCS for approval. The welding procedure approval tests may be carried out with a reference to relevant requirements of CCS Guidelines for Inspection of Hull Welds.
11.5.1.3 Welders engaged in the welding of copper and copper alloy tubes are to have been trained in the operational skill and certified accordingly upon qualification tests. Refer to CCS Guidelines for Inspection of Hull Welds for specific test requirements.

11.5.2 Selection principles for welding consumables
11.5.2.1 Welding consumables are to be compatible with base metals and it is to be ensured that the mechanical properties of welding consumables are higher than or equal to the specified limits of those of base metals. Where corrosion resistance is required, the corrosion resistance of welding consumables are not to be less than that of base metals.
11.5.2.2 Impurities in the welds, such as oxygen, lead, bismuth, sulphur, etc., are to be strictly controlled while sufficient deoxidizing elements are to be guaranteed in welding consumables.
11.5.2.3 For copper and copper nickel alloys, in general, welding consumables added with deoxidizing elements and similar to base metals in composition are to be used. For brass, bronze wires without zinc are to be used in so far as practicable so as to reduce zinc evaporation during welding.

11.5.3 Preparations before welding
11.5.3.1 Protective means against moisture, dust, cold and wind are to be provided at the welding site for copper and copper alloy tubes. The ambient temperature is to be not less than 0℃ and the relative humidity is to be not more than 80%.
11.5.3.2 For butt welding of tubes, edge preparation may be I or V according to the wall thickness of pipes. The specific edge dimensions and assembly precision are to comply with the requirements of the corresponding welding processes.
11.5.3.3 The cutting as well as edge preparation of copper and copper alloy tubes are to be carried out by mechanical means or plasma.
11.5.3.4 Oxide scales, oil and other dirt on surfaces of wires and beveled edges and within 20 mm of both sides at inside and outside surface are to be removed by mechanical or chemical means and the surfaces are to be kept dry. Welding is to be carried out within 24 h after cleaning. Otherwise, cleaning is to be carried out again.

11.5.3.5 The welding consumables, welding processes for tack welding is to be the same as that for normal welding. Tack welds are to be free of such defects as cracks, pores and burn-through, otherwise timely removal of these defects and rewelding are to be carried out.
11.5.3.6 Factors such as type of alloys, welding processes, wall thickness of tubes are to be taken into consideration for the determination of preheating temperature. In general, copper nickel alloy tubes may not be preheated before welding.

11.5.4 Welding
11.5.4.1 Tungsten inert gas arc welding is generally used for root bead and shielding gas are to be filled in the tube to prevent oxidation of back welds. During argon-shielded welding, the purity of argon is not to be less than 99.99%.
11.5.4.2 Parameters of welding processes are to ensure sufficient root penetration and a regular weld profile to avoid defects.
11.5.4.3 During multi-run welding, surface oxides of welds are to be cleaned by stainless steel wire brushes before the subsequent welding is carried out.
11.5.4.4 For copper nickel alloy tubes, the interpass temperature is not to exceed 150℃.

11.5.5 Treatment after welding
11.5.5.1 After welding, overlap, spatter and other dirt on the surface are to be removed.
11.5.5.2 Brass tubes are to be heat treated for stress relieving where necessary so as to prevent cracking due to stress corrosion.

11.5.6 Inspection and repairing of welds
11.5.6.1 Final welds are to be subjected to visual examination and non-destructive testing. The methods of testing and acceptance criteria are to be agreed by CCS.
11.5.6.2 The surface of welds is to be free from defects such as cracks, pores, lack of fusion, tungsten inclusions, etc. The depth of undercuts is not to be greater than 0.5 mm, their total length is not to be greater than 10% of the length of a single weld and not to exceed 100 mm.
11.5.6.3 The internal quality of welds is in general to be subject to non-destructive testing. The defects are to be evaluated in accordance with the standards acceptable to CCS.
11.5.6.4 Welds that fail in visual examination or non-destructive testing are to be repaired. Surface or internal defects are to be ground by mechanical means. Weld repairs are to be carried out with same welding consumables and processes after the defects are completely removed.
11.5.6.5 The weld repairs for the same position are generally not to be performed more than twice unless approved by CCS.
11.5.6.6 For welds requiring heat treatment, heat treatment is to be carried out again after repairing.
11.5.6.7 After repairing, the welds are to be inspected again.