GUIDANCE NOTES

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CHINA CLASSIFICATION SOCIETY

GUIDELINES FOR INSPECTION OF HULL WELDS

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CONTENTS

CHAPTER 1 GENERAL

Section 1 GENERAL

1.1.1 Objectives

1.1.1.1 Welding is an essential link in the chain of construction and repair for modern ships and offshore installations. The Guidelines have been developed to ensure an appropriate control of technological factors involved throughout the process of ship and offshore installation welding.

1.1.1.2 The requirements in the Guidelines are recommendatory, except those which are the same as the requirements in CCS Rules for Materials and Welding, etc. Where the parties concerned have better solutions according to their actual experience or required contractually, they may perform relevant welding design, assessment and inspection accordingly.

1.1.2 Application

1.1.2.1 The Guidelines apply to use of welding consumables, qualification tests of welders, design and approval of welding procedures, hull assembly and welding, non-destructive testing of welds and materials as well as other inspections in respect to construction and repair for ships and offshore installations.

1.1.2.2 The Guidelines apply mainly to welding of relevant metallic materials covered by CCS Rules for Materials and Welding.

1.1.2.3 The Guidelines apply to welding processes commonly used in the shipbuilding industry, e.g. shielded metal arc welding, submerged arc welding, gas metal arc welding, gas tungsten arc welding and electro gas welding. At meanwhile, the Guidelines also apply to the special welding processes such as tube braze welding, laser beam welding and friction stir welding, etc.

1.1.2.4 The Guidelines apply to butt welds, tee, corner and cruciform joints with or without full penetration, and fillet welds of hull structures and offshore installation structures.

1.1.2.5 For references in the Guidelines with no date indication, their latest version applies to the Guidelines.

1.1.3 Welders

1.1.3.1 Welders engaged in operations covered by the Guidelines are to be specially trained in relevant knowledge and qualified by CCS through tests in accordance with CCS Rules for Materials and Welding.

1.1.3.2 Welders holding a qualification certificate issued by CCS are to perform welding within the range specified in the certificate.

1.1.4 Laboratory and testing equipment

1.1.4.1 Welding tests related to approval are to be carried out in a laboratory recognized by CCS. The laboratory is to be adequately equipped and competently staffed, with the testing equipment being kept in a good condition as required for service.

1.1.4.2 Laboratories engaged in analysis of chemical composition, mechanical test and other tests in which metrological calibration is needed, are to comply with the requirements for metrological certification of laboratories. The testing equipment to be measured is to be recalibrated regularly by an organization recognized by CCS, and the calibration of testing machines is to be traced to national metrological standards.

1.1.5 Inspectors and test personnel

1.1.5.1 Weld inspectors of shipyards are to be trained in basic expertise and to have rich experience in weld inspection.

1.1.5.2 Test personnel are to have relevant expertise and to be competent for their jobs.

CHAPTER 2 WELDING CONSUMABLES

Section 1 GENERAL PROVISIONS

2.1.1 Application

2.1.1.1 This Chapter applies to inspection and use of welding consumables used in the welding of ships, offshore installations and marine products.

2.1.1.2 Auxiliary materials (e.g. shielding gases) used in the above welding are to comply with the recognized standards, of which the purity of CO_2 is not to be less than 99.8%.

2.1.2 Requirements for manufacturers of welding consumables

2.1.2.1 Manufacturers of welding consumables are to establish an effective quality control system and ensure quality control of the following links:
(1) bought-in materials;
(2) manufacturing control;
(3) identification and marking;
(4) final inspection, packing and storage;
(5) test welding and testing of mechanical properties;
(6) rejected materials and products.

2.1.2.2 Prior to delivery, welding consumables are to be inspected in batches according to recognized standards and a quality certificate is to be provided to users.

2.1.3 Requirements for packaging, storage and use of welding consumables

2.1.3.1 Electrodes, wires and fluxes are to be sealed in damp-proof packages according to the specified weight or pieces (for electrodes only), ensuring that they will not be deteriorated if stored in a dry warehouse. The storage mode and environmental conditions are to meet the relevant requirements of welding consumables manufacturer.

2.1.3.2 The following are normally marked on the external side of packages of welding consumables: grade, type, brand, batch number, production date and manufacturer. In addition, the type or brand of electrodes is to be printed on their covering near the grip end.

2.1.3.3 The storage of welding consumables is to meet the following conditions:
(1) welding consumables are to be stored in dry and well ventilated rooms in which no harmful gas or corrosive medium is allowed;
(2) the storage rooms are to be fitted with thermometers and hygrometers, with recommended ambient temperature being least 5℃ and relative humidity not exceeding 60%;
(3) welding consumables are preferably not to be placed directly on the ground. They are to be put on shelves or pallets kept at a certain distance from the ground or wall to maintain air circulation;
(4) the stored welding consumables are to be classified according to their types, brands, batch nos., specifications and receiving dates, and clearly identified accordingly;
(5) they are to be handled with care, not damaging their packaging.

2.1.3.4 Prior to use, welding consumables (electrodes, fluxes etc.) are to be baked to the bake temperature and holding time recommended by the manufacturer, and then kept in thermal containers having a temperature of 100℃ to 150℃ for ready use.

2.1.3.5 Attention is to be given to the following when using welding consumables:
(1) Where in use on site, the dried welding consumables are to be placed in the electrode dryer or thermal container at the specified temperature. The unused welding consumables collected on the same day are to be returned to the warehouse;
(2) electrodes or fluxes are not to be kept in baking ovens having a temperature of 100℃ to 150℃ for more than 7 days or the baked electrodes or fluxes are not to be placed under the ambient temperature over the period of time determined by the user, otherwise they are to be re-baked. Low-hydrogen electrodes are preferably not to be re-baked more than twice;
(3) electrodes and fluxes in vacuum packages may be directly used after firstly unpackaged, without baking. Otherwise, they are to be baked according to the requirements recommended by the manufacturer;

(4) when unpackaged, the flux cored wires for gas shielded arc welding are to be used up in 2 days. Appropriate measures are to be taken according to the storage environment to reduce the contact with moisture in the air when the wires are not recycled and need to be left in a wire feeder.

Section 2 TESTING OF WELDING CONSUMABLES

2.2.1 General requirements

2.2.1.1 General marine welding consumables are to comply with test and acceptance requirements in Chapter 2, PART THREE of CCS Rules for Materials and Welding.

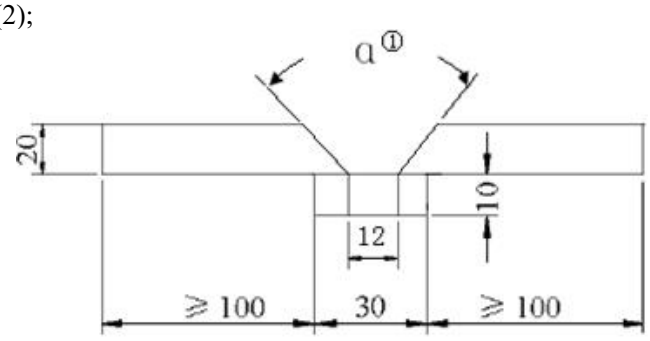
2.2.1.2 Unless contractually specified, the testing and acceptance requirements for welding consumables used for copper and copper alloys, welding consumables used for titanium and titanium alloys, temporary backing materials for one-side welding and braze welding consumables are to be consistent with this Section. Relevant approval requirements are to be in accordance with Section 1, Chapter 2, PART THREE of CCS Rules for Materials and Welding.

2.2.1.3 In respect to welding consumables other than those specified in 2.2.1.1 and 2.2.1.2, relevant technical information is to be submitted to CCS. Such welding consumables may be used only after they are verified by testing accordingly.

2.2.2 Testing of welding consumables for welding of copper and copper alloys

2.2.2.1 The welding consumables for the welding of copper and copper alloys covered by this Section include mainly Cu-Ni-Fe alloy electrodes and copper alloy welding consumables used for repair welding of copper alloy propellers. Marine copper and copper alloy electrodes and wires are to be subjected to deposited metal test and butt weld test.

2.2.2.2 The requirements for deposited metal test are as follows:
(1) a test assembly is to be welded with electrodes or wires of the largest diameter for which the manufacturer requests approval;
(2) the base metal used is to be compatible with the weld metal in respect of chemical composition. The test plate is to be 20 mm in thickness and not less than 200 mm in length, with edge preparation and size as shown in Figure 2.2.2.2(2);



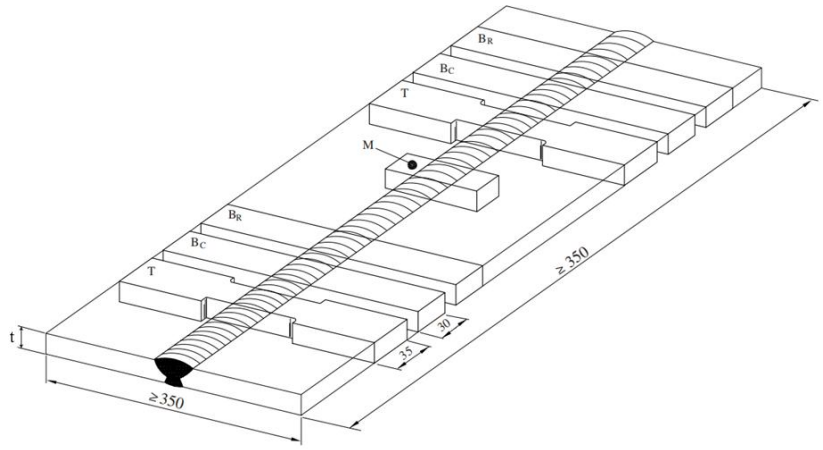
Note: ① 60° for Cu-Ni-Fe alloy, 60° ~ 90° for other copper alloys

Figure 2.2.2.2(2) Edge preparation and size of deposited metal test assembly

(3) the welding is to be performed with the plate in the flat position according to the welding conditions recommended by the manufacturer, using the multi-run method;
(4) one longitudinal tensile specimen and specimens for chemical analysis of deposited metal are to be taken from each test assembly.

2.2.2.3 The requirements for butt weld test are as follows:
(1) one test assembly of 10 to 12 mm in thickness is to be prepared for each welding position recommended by the manufacturer. Where welding at the down-hand and vertical positions is satisfactorily tested, the test at the horizontal position may be omitted, subject to agreement by CCS;
(2) the base metal for the butt weld test assembly is to be selected for similar chemical composition and mechanical properties. The materials usually used are given in Table 2.2.2.4(2);
(3) the required diameters of electrodes and wires for each welding position are given in Chapter 2, PART THREE of CCS Rules for Materials and Welding;

(4) the welding is to be performed according to the welding conditions recommended by the manufacturer. The root run is to be cut out to clean metal for all test assemblies;
(5) two flat tensile test specimens (only tensile strength is tested), four bend test specimens (two face bend test specimens and two root bend test specimens) and one macrographic section are to be taken from each test assembly. The positions for taking specimens are referred to Figure 2.2.2.3(5).



T – Flat tensile test specimen B_C – Face bend test specimen B_R – Root bend test specimen
M – Macrographic section $t = 10 \sim 12$ 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 test assembly; 3) In the case of double V test assembly, both sides are to be welded at the same welding position.

Figure 2.2.2.3(5) Butt weld test assembly for positional welding

2.2.2.4 The acceptance criteria for welding consumables for the welding of copper and copper alloys are as follows:
(1) The contents of all significant elements are to be included in the report of chemical composition of deposited metal. The test results are not to exceed the recognized standards or values specified by the manufacturer;
(2) The mechanical properties of deposited metal and welded joints are to comply with Table 2.2.2.4(2). The tensile test of those materials not listed in the Table is to comply with the requirements for corresponding base metals;
(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,without any slag inclusion or porosity beyond those allowed by recognized standards.

Mechanical properties of deposited metal and welded joints for welding consumables for copper and copper alloys **Table 2.2.2.4(2)**

Grade of welding consumables①		CuNi-A	CuNi-B	SCu1	SCu2	SCu3	SCu4
Brand of base metal used for test		90/10 Cu-Ni-Fe	70/30 Cu-Ni-Fe	Cu1	Cu2	Cu3	Cu4
Tensile test	Tensile strength R_m not less than (N/mm^2)	270	360	370	410	500	550
	Yield strength R_{eH} not less than (N/mm^2)	100	120	175	175	245	275
	Elongation A_5 not less than %	30	30	20	20	16	18
Bend test	Diameter of former *d* not greater than (mm)	4t②				③	③
	Angle of bend α	180°					
	Test requirement	Tested specimen is not to reveal any crack or other imperfection having a length greater than 3 mm in any direction.					

Notes: ① CuNi-A and CuNi-B represent welding consumables containing 10% and 30% Ni respectively; SCu1 ~ SCu4 represent welding consumables applicable to repair welding of Cu1 ~ Cu4 respectively.
② t is plate thickness.
③ Value obtained by the formula $d = \frac{(100 \times t)}{A_5} - t$.

2.2.3 Testing of temporary backing for one-sided welding

2.2.3.1 The temporary backing materials for the one-sided welding are to be tested for their properties, the performance of aluminum foil tapes, and the welding test related to applicable welding processes.

2.2.3.2 Ceramic backings which are different in their chemical composition are to be tested for their properties, including moisture absorption rate and water absorption rate, volume density, fire resistance, free fall strength and sulfur and phosphorus content. Test method and specific acceptance criteria are given in CB/T 3715.

2.2.3.3 Performance tests of aluminum foil tapes include peeling strength test and holding power test. Test method and specific acceptance criteria are given in CB/T 3715.

2.2.3.4 The requirements for the test of welding are generally as follows:

(1) the welding test of backings applicable to different welding processes are to be carried out with the maximum heat input suitable for the related welding process;
(2) in respect to backings used for different types of joints (i.e. backings with different shapes), butt-welded backings may be representative of the welding of test plates;
(3) electrodes or wires (wire-gas, wire-flux) are to be selected according to appropriate grades, regardless of their diameters;
(4) an appropriate base metal grade is to be selected according to the grade of welding consumables used, see Section 1, Chapter 2, PART THREE of CCS Rules for Materials and Welding (a toughness grade lower than that required in the Table may also be selected);
(5) a one-sided butt weld test assembly is to be prepared according to the edge beveling and welding conditions recommended by the manufacturer, using plates of 20 mm to 25 mm in thickness. The length of the test assembly is to be appropriate to the number and size of test specimens for the prescribed tests;
(6) in general, welding is to be performed at the down-hand position, except the electro gas welding;
(7) stable arc are to be guaranteed during welding, without significantly increased spatters.

2.2.3.5 Welded test plates are to be subjected to the following tests:
(1) visual examination of welds;
(2) radiographic examination of welds;
(3) mechanical test: 1 longitudinal tensile, 2 transverse tensile, 2 bend specimens and 2 sets of Charpy V-notch impact test specimens (notched at the centre of the weld). The axis of the tensile specimen is to coincide with the centre of the weld and the mid-thickness of the test plate as far as possible. Sampling positions of impact specimens are shown in Figure 2.2.3.5(3).

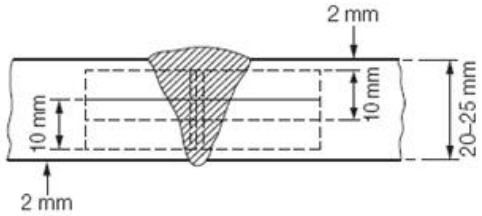


Figure 2.2.3.5(3) Sampling of impact specimens

2.2.3.6 The required test results of welding are as follows:
(1) back runs are smooth, free of imperfections such as slag inclusions, cracks, pores and undercuts etc., with finished external sizes being as required;
(2) radiographic examination results comply with recognized standards;
(3) mechanical test results comply with the requirements for the testing of welding consumables, see Section 2, Chapter 2, PART THREE of CCS Rules for Materials and Welding.

2.2.4 Testing of braze welding consumables

2.2.4.1 Braze welding consumables mainly include solders and brazing fluxes, generally required as follows:
(1) solders are to have a suitable melting point, good wettability and filling power. In addition, they are to have certain mechanical and physicochemical properties required for the serviceability of joints;
(2) brazing fluxes are to be capable of removing oxides from the surface of solders and base metals, preventing weldments and liquid solders from oxidation during brazing and improving the wetting of weldments by liquid solders.

2.2.4.2 In general, solders are to be tested according to recognized standards, as follows:

(1) the chemical composition of all solders is to be analyzed;
(2) powered solders are to be sieved to guarantee the required particle size.

2.2.4.3 In general, brazing fluxes are to be tested according to recognized standards, as follows:
(1) all brazing fluxes are to be tested for water content, adhesion, fluidity at high temperature and active life;
(2) they are to be tested in combination with appropriate solders for fluxing action and filler metal fluidity;
(3) in addition, liquid and paste brazing fluxes are to be tested for graininess.

2.2.5 Testing of welding consumables for welding of titanium and titanium alloys

2.2.5.1 Titanium and titanium alloy wires are to be subjected to deposited metal test and butt weld test. When a wire is used in composition with grouped shielding gases, they are to be subjected to an approval test respectively.

2.2.5.2 The requirements for deposited metal test are as follows:

(1) a test assembly is to be welded respectively with wires of the largest diameter and wires of the smallest diameter for which the manufacturer requests approval; If wires of only one type of diameter is manufactured by the manufacturer, a test assembly is to be welded with wires of such diameter.

(2) the base metal used is to be compatible with the weld metal in respect of chemical composition. The test plate is to be 20 mm in thickness and not less than 300 mm in length, with edge preparation and size recommended as shown in Figure 2.2.5.2;

(3) the welding is to be performed with the plate in the flat position according to the welding conditions recommended by the manufacturer, using the multi-run method;

(4) 30 mm is cut off from both ends of the test assembly after welding. One chemical analysis test specimen, one longitudinal tensile test specimen and a set of three impact test specimens (if required) are to be taken from each test assembly.

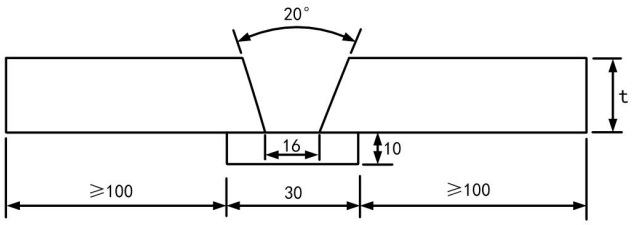


Figure 2.2.5.2 Edge preparation and size of deposited metal test assembly

2.2.5.3 The requirements for butt weld test are as follows:

(1) one test assembly is to be prepared for each welding position recommended by the manufacturer.

(2) the base metal for the butt weld test assembly is to be selected for similar chemical composition and mechanical properties. The materials usually used are given in Table 2.2.5.3;

(3) the required diameters of wires for each welding position are given in Section 5, Chapter 2, PART THREE of CCS Rules for Materials and Welding;

(4) the test assembly is generally 15 to 20 mm in thickness, and of sufficient length to allow the cutting out of test specimens of the prescribed number and size. The welding is to be performed according to the welding conditions recommended by the manufacturer;

(5) 30 mm is cut off from both ends of the test assembly after welding. One flat tensile test specimen (only tensile strength is tested), two bend test specimens (one face bend test specimen and one root bend test specimen) and a set of three impact test specimens (if required) are to be taken from each test assembly.

Base metal used for test **Table 2.2.5.3**

Grade of welding consumable	Brand of base metal used for test
STA1	TA1
STA2	TA2
STA3	TA3
STA9	TA9
STA9-1	TA9-1
STA10	TA10
STA31	TA31
STA18	TA18
STC4	TC4
STC4 ELI	TC4 ELI

2.2.5.4 The acceptance criteria for welding consumables for the welding of titanium and titanium alloys are as follows:

(1) The contents of all significant elements (including major alloying elements and Fe、C、N、H、O) are to be included in the report of chemical composition of deposited metal. The test results are not to exceed the values specified by recognized standards or the manufacturer;

(2) Unless otherwise agreed in the contract, the mechanical properties of deposited metal and welded joints are to comply with Table 2.2.5.4. The tensile test of those materials not listed in the Table is to comply with the requirements for corresponding base metals.

Mechanical properties of deposited metal and welded joints for welding consumables for titanium and titanium alloys

Table 2.2.5.4

Grade of welding consumables		STA2	STA3	STA7	STA9	STA9-1	STA10	STA18	STA31	STC4	STC4ELI
Tensile test③	Tensile strength R_m not less than② (N/mm^2)	345	500	735	400	240	460	590	880	895	860
Bend test	Diameter of former d not greater than (mm)	10t	10t	14t	8t	8t	10t	10t	14t	20t	20t
	Angle of bend a	180°	180°	90°	180°	180°	180°	180°	90°	90°	90°
	Test requirement	Tested specimen is not to reveal any crack or other imperfection having a length greater than 3 mm in any direction.									

Notes: ① t is thickness of test specimen.

② The tensile strength of deposited metal is not to be less than 90% of the values in the Table.

③ The elongation record report of tensile test of deposited metal.

Section 3 PRINCIPLES FOR SELECTION OF WELDING CONSUMABLES

2.3.1 General requirements

2.3.1.1 General principles are specified in this Section for selection of welding consumables for the welding of stainless steels, aluminum alloys and copper alloys. The selection of welding consumables of hull structure steel refers to Section 1, Chapter 5, PART THREE of CCS Rules for Materials and Welding. The selection of welding consumables of titanium alloys refers to Section 3, Chapter 11 of PART THREE of CCS Rules for Materials and Welding.

2.3.1.2 Examples of selection of welding consumables for typical dissimilar materials are given in Appendix 2A.

2.3.2 Austenitic and duplex stainless steels

2.3.2.1 Welding consumables for austenitic and duplex stainless steels are to be selected according to the texture and working conditions (including working temperature and media to be contacted) of base metals, ensuring that the corrosion resistance and mechanical properties of the weld metal are basically equivalent to those of base metals and that the required cracking resistance is achieved. Special consideration is to be taken for the selection of lean duplex stainless steel welding consumables and agreed by CCS.

2.3.2.2 Welding consumables having the same or similar alloy contents as the base metal are usually selected for the welding of austenitic stainless steels, generally requiring that the carbon content of the deposited metal does not exceed that of the base metal.

2.3.2.3 Welding consumables of the same type as the base metal are usually selected for the welding of duplex stainless steels, having the same Cr and Mo contents as the base metal and a Ni content usually 2 to 4 % higher than the base metal.

2.3.2.4 Welding consumables having contents of Cr, Ni etc. higher than the base stainless steel are to be selected for the welding of stainless steels to marine dissimilar structural steels, and welded joints are to have the same mechanical properties as the base metal of the lower grade.

2.3.2.5 Except in cases where the structural rigidity is high, acid covering electrodes are usually selected for the welding of stainless steels.

2.3.3 Aluminum alloys

2.3.3.1 The selection of welding consumables for aluminum alloys is to be considered in a comprehensive way, mainly according to the type of base metals, cracking resistance, mechanical properties and corrosion of welded joints.

2.3.3.2 Welding consumables, the chemical composition of which is similar to that of the base metal and the strength of which complies with CCS grades A, B and C respectively (see Section 9, Chapter 2, PART THREE of CCS Rules for Materials and Welding), are usually selected for aluminum-magnesium alloys (5000 series).

2.3.3.3 In general, welding consumables the chemical composition of which is different from the base metal are selected for aluminum-silicon-magnesium alloys (6000 series), and the strength of welded joints is to be CCS grade D (see Section 9, Chapter 2, PART THREE of CCS Rules for Materials and Welding).

2.3.4 Copper alloys

2.3.4.1 The selection of welding consumables for copper alloys refers to 11.5.2 of Section 5, Chapter 11 of PART THREE of CCS Rules for Materials and Welding.

2.3.4.2 The selection of welding consumables for the repair welding of copper propellers may refer to Table 8.4.7.3 of Section 4, Chapter 8, PART THREE of CCS Rules for Materials and Welding.

Appendix 2A Examples of Selection of Welding Consumables for Typical Dissimilar Materials

Example of selection of welding consumables for common dissimilar stainless steels Table 2A-1

Example grade of welding consumables①		base metal 2②										
		S30403 S30408	S30453	S31603 S31608	S31653	S31703 S31708	S31753	S34778	S22053 S22253	S25554	S25073	Low carbon or low alloy steels
Base metal 1②	S30403 S30408	308L	308L	308L	308L	308L	308L	308L	308L	308L	308L	309
	S30453		308L	308L	308L	308L	308L	308L	308L	308L	308L	309
	S31603 S31608			316L	316L	316L	316L	316L	316L	316L	316L	309
	S31653				317L	317L	317L	316L	316L	316L	316L	309
	S31703 S31708					317L	317L	316L	317L	317L	317L	309
	S31753						317L	316L	2209	317L	317L	309
	S34778							347	308L	308L	308L	309
	S22053 S22253								2209	2209	2209	309 2209
	S25554									2553	2553	309
	S25073										2594	309

① Listed consumables are recommended as low-cost and easy-to-weld ones on the basis of achieving required strength, corrosion resistance and cracking resistance of welded joints, they are not exclusive options.

② Base metals are listed according to the uniform number code of national standard and their corresponding grades are given in Chapter 3, PART ONE of CCS Rules for Materials and Welding.

Example of selection of welding consumables for common dissimilar aluminum alloys Table 2A-2

Example grade of welding consumables		Base metal 2		
		5754, 5454, 5086	5059,5083, 5383, 5456	6061, 6005A, 6082
Base metal 1	5754, 5454, 5086	5356, 5556, 5183	5356, 5556, 5183	5356, 5556, 5183
	5059,5083, 5383, 5456		5183①	5356, 5556, 5183
	6061, 6005A, 6082			5356, 5556, 5183

① If the permissible stress is reduced, other fillers such as 5356 and 5556 may also be used.

CHAPTER 3 QUALIFICATION TESTS OF WELDERS AND WELDING OPERATORS

Section 1 GENERAL PROVISIONS

3.1.1 Application

3.1.1.1 This Chapter applies to the qualification tests of welders for shielded metal arc welding, semi-automatic gas metal arc welding,gas tungsten arc welding and flame brazing of steels, aluminium alloys, stainless steel, copper alloys and titanium alloys for structures, machinery installations, boilers, pressure vessels and piping system, etc. of ships and offshore installations.

3.1.1.2 The qualification tests for fully mechanized welding and automatic welding operators may be carried out according to Section 3 of this Chapter.

3.1.2 General requirements

3.1.2.1 Welders engaged in both construction of new ships and ship repairs are to pass qualification tests and obtain a certificate issued or accepted by CCS.

3.1.2.2 Welders, who have been engaged in the welding of test plates for an approved welding procedure, may be qualified to the corresponding welding conditions (welding processes, positions and consumables), subject to prior agreement by CCS Surveyor.

3.1.3 Qualification tests and evaluation of welders

3.1.3.1 Qualification categories, test items, evaluation methods and retests are to comply with the requirements in Chapter 4, PART THREE of CCS Rules for Materials and Welding.

3.1.3.2 There are no mandatory requirements for the types of welded joints (welding by both sides, one-side welding, with or without backing, if gouged or not), edge preparation and size (groove angle, root face, root gap) of test plates, they may be determined according to the actual condition of production.

3.1.3.3 The test of a combination of two welding processes (e.g. a one-side joint with the root to be welded by gas tungsten arc welding and to be filled by shielded metal arc welding) may be either of the following:

(1) the test is carried out directly by combining the two processes; or
(2) the test is carried out by using the two processes (one-side gas tungsten arc welding and shielded metal arc welding from both sides) separately.

3.1.3.4 Attention is to be given to the following for qualification tests of welders:
(1) before being welded, a stamp is to be affixed to the test assembly and kept at all test stages;
(2) the assembly of the test plates, adjustment of welding parameters and groove cleaning etc. are to be performed by the welder himself;
(3) the test assembly is to have at least one stop/restart in the top capping run from which the bend test specimen is to be taken. For the one-side welding without backing and with back formation, there is also to be a stop/restart in the root run;
(4) for any material or procedure requiring preheating, post-weld heating or heat input, the conditions for tests are to be the same as those for production;
(5) minor imperfections are to be allowed to be removed, except on the surface layer, by grinding or any other repair method, subject to agreement by the Surveyor.

3.1.3.5 The Surveyor is to witness tests, measurements of test specimens and evaluation.

3.1.4 Scope of application of welder’s qualification

3.1.4.1 The scope of application of welder’s qualification for steel and aluminum alloy is to satisfy the requirements of Section 3, Chapter 4, PART THREE of CCS Rules for Materials and Welding. The scope of application of welder’s qualification for titanium and copper alloy are respectively given in Sections 2 and 4 of this Chapter.

3.1.4.2 Attention is to be given to the following points for austenitic or duplex stainless steels within the scope of application of welder’s qualification:

(1) The welders with qualification for austenitic or duplex stainless steels can cover each other;
(2) The welders with qualification for austenitic or duplex stainless steels cannot be qualified for welding the base metals of carbon steels and low alloy structural steels and vice versa;
(3) The welders with qualification for austenitic or duplex stainless steels can be qualified for the following items, provided that austenitic or duplex stainless steel filler materials are used:
The welding of dissimilar steels between austenitic stainless steels/duplex stainless steels and carbon steels/low alloy structural steels; The welding of dissimilar steels between austenitic stainless steels and duplex stainless steels;
(4) For lean duplex stainless steel, the application of welder qualification is to be in accordance with that of duplex stainless steel.

3.1.5 Qualification Certificate of Welder

3.1.5.1 Upon a satisfactory qualification test carried out by CCS, a Qualification Certificate of Welder is to be issued by CCS. The period of validity and renewal of the certificate and the extension of its period of validity are to comply with the requirements in Chapter 4, PART THREE of CCS Rules for Materials and Welding.

3.1.5.2 Shipyards/manufacturers are to control the period of validity and the application of the Qualification Certificate of Welder.

3.1.5.3 For the format of Welder's Qualification Certificate, see Appendix 3A of this Chapter. The actual certificate issued by CCS is to prevail.

3.1.5.4 Attention is to be given to the following cases for the completion of the Qualification Certificate of Welder and its applicability:

(1) The qualification for the one-side welding with ceramic backing and back formation falls into the category of "welding with backing" and is the same as the qualification for one-side welding with steel backing, not covering the qualification for the welding without backing and with back formation.
(2) Upon successful completion of the combined tests referred to in 3.1.3.3, both welding processes and associated plate thicknesses are to be stated in the certificate. Such certificate applies respectively to the one-side welding with root run and the welding by both sides with top capping run, with applicable throat thicknesses being appropriate to those of respective test assemblies.

Section 2 SPECIAL REQUIREMENTS FOR QUALIFICATION TESTS OF WELDERS FOR WELDING COPPER ALLOYS

3.2.1 Application

3.2.1.1 This Section applies to the qualification tests for shielded metal arc welding, gas metal arc welding, gas tungsten arc welding, plasma arc welding and electro gas welding of copper alloys.

3.2.2 Test items and requirements

3.2.2.1 The items for qualification tests of welding copper alloys are to be referred to those required for welding steels and aluminium alloys in Chapter 4, PART THREE of CCS Rules for Materials and Welding, of which the diameter of former for bend tests is to satisfy the requirements of 4.3.2.3(2) in Section 3, Chapter 4 of the Guidelines.

3.2.3 Coverage of materials

3.2.3.1 In order to minimize unnecessary multiplication of technically identical tests, copper alloys are divided into groups according to similar metallurgical and welding characteristics, as shown in Table 3.2.3.1.

Groups of copper alloys **Table 3.2.3.1**

Material group	Type of copper alloy	Typical examples in CCS rules
W31	Pure copper	-
W32	Copper zinc alloy	Aluminum brass
W33	Copper tin alloy	90/10 Cu-Sn phosphor bronze, 88/10/2 gunmetal etc.
W34	Copper nickel alloy	90/10 Cu-Ni-Fe, 70/30 Cu-Ni-Fe
W35	Copper aluminum alloy	Cu3, Cu4
W36	Copper nickel zinc alloy	Cu1, Cu2

3.2.3.2 Welding consumables used in the test are to be appropriate to the chemical composition of base metals.

3.2.3.3 The qualification for any material in one group covers all other materials in the same group.

3.2.3.4 The coverage of welder qualification for different groups of copper alloys is given in Table 3.2.3.4.

Application of welder qualification for copper alloys **Table 3.2.3.4**

Material group of test assembly	Range of approval					
	W31	W32	W33	W34	W35	W36
W31	*	–	×	×	×	–
W32	–	*	–	–	–	×
W33	–	–	*	–	–	–
W34	–	–	–	*	×	–
W35	–	–	–	×	*	–
W36	–	×	–	–	—	*

Notes: * represents the material group for which the welder is approved from the approval test
× represents the material group for which the welder is also approved
– represents the material group for which the welder is not approved

3.2.3.5 A special test is to be carried out for welding together copper alloys of different groups.

3.2.4 Application of test assembly specifications

3.2.4.1 The application of test assembly thicknesses for butt welding of plates, fillet welding of plates or butt welding of pipes is given in Table 3.2.4.1.

Application of copper alloy test assembly thickness **Table 3.2.4.1**

Test assembly thickness (mm)	Range of approval①②
t	(0.5 ~ 1.5) t

Note: ① In the case of oxy-acetylene welding, separate tests are to be carried out for maximum and minimum production thicknesses.

② In the case of repair welding, *t* is depth of repair welding.

3.2.4.2 The application of test pipe diameters for butt welding of pipes is given in Table 3.2.4.2.

Application of copper alloy test Pipe diameter **Table 3.2.4.2**

Test pipe diameter (mm)	Range of approval
D ≤ 25	D ~ 2D
D > 25	≥ 0.5D (minimum 25 mm)

3.2.5 Others

3.2.5.1 The coverage of other essential variables (e.g. welding processes, joint types and welding positions) of qualification tests of welding copper alloys are to be referred to that of welding steels and aluminum alloys, except for 3.2.3 and 3.2.4.

Section 3 QUALIFICATION TEST REQUIREMENTS OF WELDING OPERATORS

3.3.1 Application

3.3.1.1 The requirements of this Section are applicable to welding operators who are responsible for parameter setting and/or adjustment of fully mechanized and automated welding equipment or system (whether or not in actual operation).

3.3.1.2 The test requirements and coverage specified in this Section are applicable to common marine welding processes of steels (including austenitic stainless steel, duplex stainless steel and lean duplex stainless steel), aluminum alloy and titanium alloy. If the base metal or welding process is different from that specified in this Section, it may be used for reference.

3.3.1.3 For the welding operator who solely operates the equipment without responsibility for setting up

and/or adjustment (for example, only operating the start button on the automatic welding line), if his/her relevant welding work experience and the product welds meet the quality requirements, he/she is unnecessary to take the examination.

3.3.2 Terms and definitions

3.3.2.1 The terms and definitions applicable to this Section are as followings:

(1) Automatic welding: means a welding process automatically implemented without the intervention of the welding operator (i.e.: the welding parameters in the welding operation does not need manual adjustment by the operator);
(2) Fully mechanized welding: means a welding process which the required welding conditions are provided by mechanical or electronic means, but can be changed manually in the welding operation;
(3) Welding equipment: means separate equipment for welding, such as welding power supply, wire feeder, etc.;
(4) Welding system: means all equipment used for welding, including auxiliary devices such as clamp, fixture, robot control arm and rotating device.

3.3.3 General requirements

3.3.3.1 Application requirements for welding operators are to be in accordance with 4.1.3 of Chapter 4, PART THREE of CCS Rules for Materials and Welding.

3.3.3.2 The skill test of welding operators is generally to be carried out by the means specified in this Section, but if the welding operator successfully completes the welding procedure qualification test, he/she can also be regarded as passing the relevant welding condition test.

3.3.3.3 The welding of the test assembly and the test of the specimen are to be witnessed by the surveyor.

3.3.3.4 In case of failure in the first examination, the requirements for re-examination and re-test are the same as those in 4.1.5, Chapter 4, Chapter 3 of CCS Rules for Materials and Welding.

3.3.4 Type and size of test assemblies

3.3.4.1 The type of test assemblies for skill examination includes plate butt welding, pipe butt welding and plate fillet welding, see Figure 4.2.2.1, Chapter 4, PART THREE of CCS Rules for Materials and Welding, but the length of test assemblies for plate butt welding and fillet welding is not to be less than 500mm.

3.3.4.2 The specific thickness, joint type (double side welding, single side welding, with or without backing) and groove size (groove angle, blunt edge, gap) of the test assemblies may be determined by the shipyard / manufacturer according to the requirements of actual production or the welding system.

3.3.4.3 Run-on and run-off tabs with the similar material and thickness to the base metal may be installed at both ends of the test assembly.

3.3.5 Making of test assembly

3.3.5.1 The base metal of test assembly is to comply with the relevant requirements of PART One in CCS Rules for Materials and Welding. The welding consumables used are to match the properties of the base metal.

3.3.5.2 Welding is to be carried out according to WPS (or PWPS) to simulate production conditions as far as possible.

3.3.5.3 The assembly of specimen, adjustment of welding parameters and cleaning of groove are to be handled by the examinee himself/herself.

3.3.5.4 Each weld bead is to be continuously welded, and dedicated joint is unnecessary to provide in the middle.

3.3.5.5 After welding, the weld surface is not to be polished or repaired.

3.3.6 Test or inspection

3.3.6.1 Different types of test assembly are to be inspected and tested according to the items specified in Table 3.3.6.1.

Inspection and test items **Table 3.3.6.1**

Type of test assembly	Test or inspection item	Number
Butt welding	1. Visual inspection 2. Bend test①②	Visual inspection: the whole length Bending: 2 for face bend, 2 for root bend (if the thickness <12mm) or 4 for side bend (if the thickness ≥12mm)
Fillet welding	1. Visual inspection 2. Macro section③	Visual inspection: the whole length Macro section: 2

Notes: ① Except for steel solid cored wire or metal powder cored wire GMAW and aluminum alloy welding, the radiographic inspection or fracture test of the whole weld length may replace the bending test.
② For the welder of marine boiler and pressure vessel, radiographic testing and bending test are adopted.
③ For fillet welding, the fracture test may be used to replace the 2 macro section inspections.

3.3.6.2 For the sampling position, test method and qualification standard of various test or inspection items, please see the relevant requirements in 4.2.4, Chapter 4, PART THREE of CCS Rules for Materials and Welding.

3.3.7 Certificate and term of validity

3.3.7.1 When the welding operator passes the qualification examination, CCS is to issue the qualification certificate. Each shipyard/manufacturer is to be responsible for the term of validity and scope of application for the certificate.

3.3.7.2 The qualification certificate of welding operator is to include the following contents:
(1) Coverage of base metal, welding process, welding equipment or system, welding joint type, welding position and other main parameters;
(2) Expiration date of validity;
(3) Name, date of birth, ID number and photo of welding operator;
(4) Name of shipyard/manufacturer.

3.3.7.3 If the welding operator takes the examination at the first time, his/her qualification validity period usually starts from the date of issuing certificate after all tests have passed.

3.3.7.4 The certificate is to be signed by the person in charge of welding quality of the shipyard/ manufacturer every 6 months to prove that the welding operator is engaged in welding work within the scope of application marked in the certificate, and the interruption time is not to exceed 6 months.

3.3.7.5 Under the requirements of 3.3.7.4, in order to continue the validity of the certificate, the welding operator's skills are to be periodically verified by one of the following methods:

(1) The skill examination is to be carried out every 6 years, with the specific method as the same as 3.3.4-3.3.6, but if bending test is used, the number of samples will be reduced by half;
(2) Verification conducted every 3 years: radiographic inspection, ultrasonic inspection or destructive test is to be carried out on 2 welds welded by the welding operator within the last 6 months of the 3-year validity period and recorded. The welds are to reproduce the initial test conditions (except plate thickness). After passing these tests, the qualification of welding operator may be extended for 3 years;
(3) Re-verification is to be carried out not exceeding 3 years and the method is to be in accordance with 4.1.7.4 (3), Section 1, Chapter 4, PART THREE of the CCS Rules for Materials and Welding.

3.3.7.6 Upon verifying that the above conditions are met, CCS is to sign the qualification certificate of welder operator to confirm the continuation of his/her qualification.

3.3.8 Coverage of welder operator qualification

3.3.8.1 The category and code of welding processes commonly used in ship construction for fully mechanized and automatic welding are shown in Table 3.3.8.1. Reexamination is to be carried out if the code of welding process is changed.

Category of welding processes for welding operator examination **Table 3.3.8.1**

Code	Mechanized and automatic welding processes in actual working	Digital code in ISO 4063
SAW	Submerged arc welding	12
GMAW	Gas metal arc welding (including MIG、MAG、FCAW)	13
GTAW	Gas tungsten arc welding	141

GFW	Gravity welding	112
EGW	Electro-gas welding	73
LBW	Laser beam welding	52

3.3.8.2 After the welding operator passes the examination, the coverage of base metal quality is the same as that stipulated for welder examination (see 4.3.4, Chapter 4, PART THREE of CCS Rules for Materials and Welding for details), but the thickness and pipe diameter are not limited.

3.3.8.3 The coverage of welding positions is the same as that stipulated for welder examination (see 4.3.7.1, Chapter 4, PART THREE of CCS Rules for Materials and Welding for details).

3.3.8.4 The coverage of joint type and process are as follows:
(1) Fillet welding can be covered after the butt welding examination is qualified, but not vice versa;
(2) Single side welding without backing can cover single side welding with backing (double side welding can be regarded as backing), but not vice versa;
(3) Multi-bead welding can cover single-bead welding, but not vice versa;
(4) Double-wire welding can cover single-wire welding, but not vice versa.

3.3.8.5 For mechanized welding, reexamination is to be carried out if the following factors are changed:

(1) Change from visual observation to remote control, and vice versa;
(2) Delete the automatic arc length control system;
(3) Delete the automatic connector tracking;
(4) Remove the fusibility moulding.

3.3.8.6 For automatic welding, reexamination is also to be carried out if the following factors are changed:

(1) With or without arc and/or connector sensors;
(2) Change of type of welding system (including change of robot control system).

3.3.8.7 For the same welding process, when the automatic welding is changed to mechanized welding, the welding operator is to take the reexamination.

3.3.8.8 When the above-mentioned welding variables are the same, the qualification of weld operators engaged in boiler and pressure vessel welding can cover that of weld operators engaged in welding work for ships and offshore installations.

Section 4 SPECIAL REQUIREMENTS FOR QUALIFICATION TESTS OF WELDERS FOR WELDING TITANIUM ALLOYS

3.4.1 Application

3.4.1.1 This Section applies to the qualification tests of welders for tungsten inert gas (TIG) welding, metal-arc inert gas welding (MIG) and plasma welding of titanium alloys. The qualification tests of welders for other welding processes are subject to individual consideration.

3.4.2 Type and dimensions of test assemblies

3.4.2.1 Test assemblies of butt welding of plates are composed of two test plates, each plate not less than 250 mm in length and 125 mm in width; the specific plate thickness, groove angle and gap may be determined by the welding procedure specification developed by the manufacturer.

3.4.2.2 Dimensions for test assemblies of fillet welding of plates, butt welding of pipes and fillet welding of pipes are not to be less than those specified in 4.2.2.1, Section 2, Chapter 4, PART THREE of CCS Rules for Materials and Welding; the specific plate thickness, groove angle and gap may be determined by the welding procedure specification developed by the manufacturer.

3.4.2.3 Both ends of the test plate are to be fitted with run-on and run-off tabs which are of the same thickness as that of the test plate.

3.4.3 Inspection and test items

3.4.3.1 After completion of welding, the surface of welds is to be inspected visually.

3.4.3.2 Butt welds are to be subject to radiographic testing.

3.4.3.3 Test items and required specimens for different types of test assemblies are shown in Table 3.4.3.3.

Test Items and Required Specimens Table 3.4.3.3

Type of assembly	Test items	Required specimens
Butt welding of plates	Bend test	one for face bend test and one for root bend test①
Butt welding of pipes	Bend test	one for face bend test and one for root bend test①at 1G and 2G two for face bend test and two for root bend test①at 5G,6G and 6GR
Fillet welding of plates	Fracture test or macro examination	Fracture: examination length of weld② Macro: two③
Pipe-to-plate fillet welds	Macro examination	Macro: two③

Notes: ① If the thickness of the test assembly is not less than 12 mm, side bends may be used instead.
② The examination length of weld is the length deducted by 25 mm from both ends of the test assembly respectively.
③ One of them is to be taken at the stop/restart point.

3.4.3.4 For bend tests, the angle of bend and the diameter of former is to be in compliance with those specified in Table 3.4.3.4.

Bending angle and diameter of former for bend test Table 3.4.3.4

Grade of material or designation code	TA9, TA9-1	TA2, TA3, TA10, TA18	TA7, TA31	TC4, TC4ELI
Diameter of former (mm)	8*t*	10*t*	14*t*	20*t*
Bending angle	180°	180°	90°	90°

Note: *t* is thickness of the specimen.

3.4.4 Evaluation of test assemblies

3.4.4.1 Visual inspection of the surface of welds is to satisfy the requirements for steel welds in 4.2.4, Section 2, Chapter 4, PART THREE of CCS Rules for Materials and Welding, and the color of welds and adjacent zones is to be silver white or yellow.

3.4.4.2 The results of the radiographic test of welds are to comply with recognized standards.

3.4.4.3 The results of the bend test, fracture test or macro examination are to satisfy the relevant requirements in 4.2.4, Chapter 4, PART THREE of CCS Rules for Materials and Welding.

3.4.5 Coverage of welder qualification

3.4.5.1 Where the same welding specification is used, successful completion of the qualification test for any titanium and titanium alloys may cover titanium and titanium alloys in the same group. The specific material groups are shown in Table 3.4.5.1:

Application for qualification test of welders for welding titanium alloys Table 3.4.5.1

Group	Type of titanium and titanium alloys	Typical examples in CCS Rules for Materials and Welding
51	Pure titanium	TA2, TA3
52	α type titanium alloys (or similar to α type)	TA7, TA9,TA9-1, TA10, TA18,TA31
53	α - β type titanium alloys	TA4 TC4ELI

3.4.5.2 Except for 3.4.5.1, the coverage of other variables (e.g. thicknesses of base metals, pipe diameters, welding processes, joint types, welding positions, etc.) of qualification tests of welding titanium alloys satisfy the relevant requirements for qualification tests of welding steels in Section 3, Chapter 4, PART THREE of CCS Rules for Materials and Welding.

Section 5 SPECIAL REQUIREMENTS FOR QUALIFICATION TESTS OF WELDERS FOR BRAZING

3.5.1 Application

3.5.1.1 This Section applies to the qualification tests of welders for flame brazing of copper alloy pipe.

3.5.2 Type and dimensions of test assemblies

3.5.2.1 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. The length of the butt and lap test assembly is not to be less than 250 mm. When the outside diameter of the pipe is greater than 76 mm, samples are to be taken from the two symmetrical positions respectively. When the outside diameter of the pipe is less than or equal to 76 mm, two test assemblies are to be welded and one sample is to be taken from each test assembly.

3.5.2.2 For lap joint, a flange may be made at the end of test pipe of lap welding and the lapped length is to be at least 4 times the thickness of the thinner pipe wall or to be in compliance with the design requirements.

3.5.3 Inspection and test items

3.5.3.1 All test assemblies are to be visually examined. The examination result is to meet B level of ISO 18279 or other equivalent standards.

3.5.3.2 For butt joints, two test specimens are taken for macro examination, which is to reveal that no crack in the joint. Imperfection such as pores, lack of fusion or slag inclusions are to meet B level of ISO 18279 or other equivalent standards.

3.5.3.3 For lap joints, two peel test specimens are taken. Width of the peel test specimens is 38 mm. The lapped area was shown to be fully brazed after peeling. Imperfections on the lapped surface such as pores, lack of fusion or slag inclusions are to meet B level of ISO 18279 or other equivalent standards. Macro examination tests may be substituted for the peel test when the peel test cannot be performed (e.g., when the strength of the brazing filler metal is equal to or greater than the strength of the base metals).

3.5.4 Application of welder qualification

3.5.4.1 Brazing process is only applicable to method of qualification test.

3.5.4.2 Any type of copper alloy base metal and filler metal can cover other copper alloy base metals and filler metals. The applicable scope of base metals is shown in Table 3.5.4.2. When the thicknesses of base metals are different, the applicable thickness ranges are to be determined separately. The applicable scope of the outer diameter of pipe is less than or equal to that of the qualification test.

Applicable scope of base metal thickness **Table 3.5.4.2**

Thickness of test assembly t(mm)	Applicable thickness (mm)
$t<3$	$(0.5\sim2)t$
$3\leq t\leq10$	$1.5\sim2t$
$t>10$	$5\sim2t$

3.5.4.3 Welding joint type is only applicable to joint type of qualification test. For lap joints, the applicable scope of lap length is less than or equal to the lap length of the qualification test.

3.5.4.4 The coverage of welding position (flow direction of filler metal) is given in Table 3.5.4.4.

Coverage of welding position **Table 3.5.4.4**

Welding position	Coverage
Horizontal flow	Horizontal flow, Vertical downflow
Vertical downflow	Vertical downflow
Vertical upflow	Horizontal flow , Vertical downflow, Vertical upflow

Appendix 3A Example of Welder's Qualification Certificate

CCS WELDER'S QUALIFICATION CERTIFICATE
中国船级社焊工能力认证证书

<table>
<tr><td>Type
证书类别</td><td colspan="2">Welding operator
焊接操作者 □</td><td>Welder
焊工 □</td></tr>
<tr><td>Welder's name
焊工姓名</td><td colspan="2">Date of birth
出生日期</td><td rowspan="5">Photograph
照片</td></tr>
<tr><td>Cert. No.
证书号</td><td colspan="2">Sex
性别</td></tr>
<tr><td colspan="3">Identification No.
身份证号</td></tr>
<tr><td colspan="3">WPS/pWPS No.
WPS/pWPS编号</td></tr>
<tr><td colspan="4">Employer's name and address
工厂名称和地址</td></tr>
<tr><td colspan="2">Date of initial approval
初次发证日期</td><td colspan="2">Product type
产品类型</td></tr>
<tr><td colspan="4">This is to certify that the welder has passed the qualification test (/and re-validation record audit) according to the rules of CCS, and is qualified to undertake welding operation specified in range of qualification of this certificate.
此证书证明焊工根据本社规范通过了资格考试（/和重新生效记录审核），具有从事此证书规定范围内焊接工作的资格。</td></tr>
<tr><td>Items
项目</td><td>Test piece
试件</td><td colspan="2">Range of qualification
适用范围</td></tr>
<tr><td>Welding process
焊接方法</td><td></td><td colspan="2"></td></tr>
<tr><td>Base metal
母材</td><td></td><td colspan="2"></td></tr>
<tr><td>Filler metal type
填充金属类型</td><td></td><td colspan="2"></td></tr>
<tr><td>Plate /pipe wall thickness
板/管壁厚度</td><td></td><td colspan="2"></td></tr>
<tr><td>Pipe outside diameter
管子外径</td><td></td><td colspan="2"></td></tr>
<tr><td>Type of welded joint
焊接接头形式</td><td></td><td colspan="2"></td></tr>
<tr><td>Welding position
焊接位置</td><td></td><td colspan="2"></td></tr>
<tr><td>Revalidation method
周期性验证方式</td><td colspan="3">In accordance with 4.1.7.4, Chapter 4, Part THREE of CCS Rules for Materials and Welding(welder)
选用CCS《材料与焊接规范》第3篇第4章第4.1.7.4条（焊工）
1)□ 2)□ 3)□
In accordance with 3.3.7.5, Chapter 3 of CCS Guidelines for Inspection of Hull Welds(welding operator)
选用CCS《船舶焊接检验指南》第3章第3.3.7.5条（焊接操作者）
1)□ 2)□ 3)□</td></tr>
<tr><td>Other details
其他细节</td><td></td><td colspan="2"></td></tr>
</table>

This certificate is issued at [place] , and valid until [DD/MM/YYYY] .
发证地点： ， 有效期至：
Signature/seal of surveyor: Issued on [DD/MM/YYYY] .
验船师签名/盖章： ， 签发日期：

RECORDS OF SUPERVISION BY EMPLOYER EVERY SIX MONTHS

工厂每6个月考察记录

	Report No. to be reviewed 审核的报告号	Date of report 报告日期	Signature of Employer 工厂审核人签字	Date of signature 签字日期
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				

TEST RECORD

试验记录

Type of test 试验形式	Performed and accepted 完成并通过	Not required 不要求
Visual examination 目视检验		
Radiographic examination 射线检验		
Surface examination 表面检验		
Macro examination 宏观检验		
Fracture test 破断试验		
Bend test 弯曲试验		
Additional tests 附加试验		

注： 表格“试验记录”可作为证书的背页或作为分开文件。

Note: The form of “Test Record” may be used as the back page of the certificate or as a separate document.

CHAPTER 4 APPROVAL OF WELDING PROCEDURES

Section 1 GENERAL PROVISIONS

4.1.1 Application

4.1.1.1 This Chapter constitutes a supplement to Chapter 3, PART THREE of CCS Rules for Materials and Welding. This Chapter also applies to the approval of welding procedures for certain special materials and special welding processes.

4.1.1.2 The welding of special materials covered by this Chapter refers mainly to welding of stainless steels, stainless steel-clad plates, copper alloys, titanium alloys, steel-aluminium transition joints, and repair welding of steel castings and copper propellers.

4.1.1.3 The special welding processes covered by this Chapter are mainly pipe brazing, laser beam welding, friction stir welding, etc.

4.1.2 Definitions

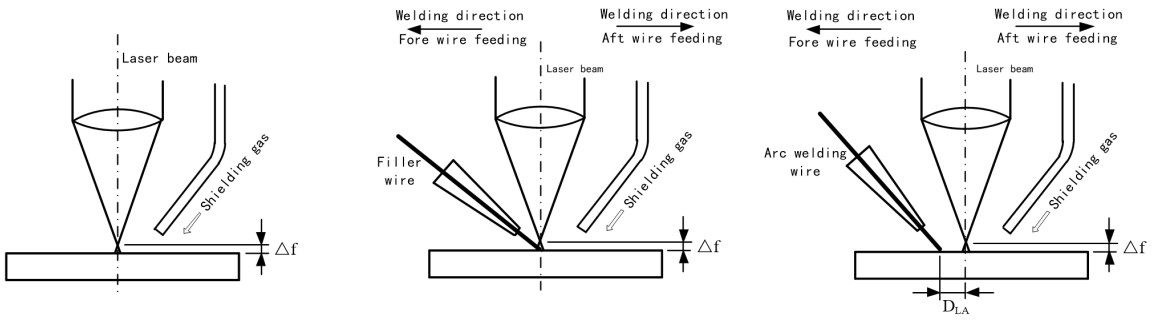
4.1.2.1 *Austenitic stainless steel-clad plate* is a plate consisting of a base metal of carbon or carbon-manganese steel clad on one or both sides, continuously and integrally bonded with a thin layer of austenitic stainless steel (cladding metal).

4.1.2.2 *Steel-aluminum transition joint* is a transition joint used to join a steel structure and an aluminum alloy structure, consisting of three metal layers, the top one of which is aluminum alloy, the intermediate transition one titanium or aluminum and the bottom one a marine structural steel plate.

4.1.2.3 *Pipe brazing* is flame brazing to connect pipes by means of a sleeve.

4.1.2.4 *Friction stir welding* is a solid-phase connection by mechanical force and friction heat. The metal at the connection is plasticized by means of the friction heat between a shaft shoulder, a stir head and the weldment and the plasticized metal is drawn and stirred jointly by the stir head and shaft shoulder to flow backward for filling and forming a solid-phase weld.

4.1.2.5 Laser beam welding: is a welding process by use of laser beam with high-energy density as a heat source for fusion welding. Laser-arc hybrid welding is a kind of welding process which takes laser and arc as welding heat source to form the same molten pool for fusion welding. Common laser beam welding processes are shown in Figure 4.1.2.5.



(1) Laser beam welding (Self-fusion welding) (2) Laser beam welding (Filler wire welding) (3) Laser-arc hybrid welding

△f defocusing amount: means the distance between the focus of laser beam and the welded surface of workpiece. If the focal plane is above the welded surface of workpiece, it is a positive defocusing, otherwise it is a negative defocusing;

D_{LA} the distance between the laser beam and the wire: means the distance from the center of the spot on the welded workpiece surface illuminated by laser beam to the contact point of the end of welding wire with the welded workpiece surface.

Figure 4.1.2.5 Diagram of laser beam welding process

4.1.3 Welding procedure documents

4.1.3.1 The following welding procedure documents are to be submitted: Preliminary Welding Procedure Specification (PWPS), Welding Procedure Qualification Record (WPQR) and Welding Procedure Specification (WPS), as detailed in Section 1, Chapter 3, PART THREE of CCS Rules for Materials and Welding.

4.1.3.2 For recommended formats of the typical Preliminary Welding Procedure Specification (PWPS), Welding Procedure Qualification Record (WPQR) and Welding Procedure Specification (WPS), refer to Appendices 4A, 4B and 4C.

4.1.3.3 Relevant special requirements for special welding processes are to be added in welding procedure documents.

4.1.3.4 In addition to the requirements of 3.1.3.2, Section 1, Chapter 3, PART THREE in the CCS Rules for Materials and Welding, the followings are in general to be added in the laser beam welding procedure document (the related parameters may be described by diagrams):

(1) Laser generator:
- ① type (e.g. CO_2, YAG or fiber laser, etc.);
- ② nominal power;
- ③ continuous wave or pulse;
- ④ mode, divergence, wavelength, polarization and orientation of laser beam.

(2) Laser beam delivery and focusing systems:
- ① method of transmission (fibers or mirrors);
- ② distance from laser generator to focusing system;
- ③ beam diameter on entrance to focusing system;
- ④ beam transmission and focusing systems;
- ⑤ focal length of lens;
- ⑥ diameter of nominal focus and measuring method;
- ⑦ protection system of beam path.

(3) Working gas and shield gas systems.

(4) Wire feeding system (if used).

(5) Method of fixing workpiece.

(6) Back shielding:
- ① type and size of backing plate (if used);
- ② type, group and flow rate of back shield gas.

(7) Welding parameters:
- ① laser beam parameters:
  - — beam power density on workpiece;
  - — nominal focal length/beam diameter (for CO_2 laser);
  - — pulse parameters (including peak power, pulse energy, pulse repetition rate, pulse duration and pulse shape);
  - — details of power change (gradual increase and reduction of laser power at start and end of weld);
  - — details of tack weld;
  - — oscillating model (amplitude, frequency and retention time);
  - — beam orientation, polarization and position in relation to joint and welding direction.
- ② mechanical parameters:
  - — travel speed;
  - — change of travel speed at start and end of weld;
  - — direction, position and angle of wires and rate of wire feeding;
- ③ gas parameters:
  - — gas type and group;
  - — gas flow rate.
- ④ other parameters:
  - — position of focus in relation to workpiece (defocusing amount);
  - — position and orientation of shield gas nozzle in relation to workpiece.

(8) Additional parameters for laser-arc hybrid welding:
- ① arc welding process:

—arc method.

② hybrid:

— relative direction of welding (arc before or after);

—the distance between the laser beam and the wire;

— relative position of electrode axis, laser beam and weld centerline.

4.1.3.5 In addition to the contents in 3.1.3.2, Section 1, Chapter 3, PART THREE of CCS Rules for Materials and Welding, the following are in general to be added in the friction stir welding procedure document:

(1) Welding equipment:

① material, size and shape of stir head;

② pressing force of welding jig.

(2) Welding parameters:

① rotational direction, rotational speed, axial pressure and heel plunge depth of stir head;

② tilt angle, side tilt angle and lateral offset of stir head;

③ dwell time at the start and dwell time at the stop;

④ main control methods (force control, position control).

4.1.3.6 In addition to the contents in 3.1.3.2, Section 1, Chapter 3, PART THREE of CCS Rules for Materials and Welding, the following are in general to be added in the stud welding procedure document:

(1) Surface condition of parent material;

(2) Type of studs and ceramic ferrules (material, size etc.)

(3) Jigs and fixtures;

(4) Welding variables of drawn-arc stud welding:

① polarity;

② welding current;

③ welding time;

④ lift;

⑤ protrusion;

⑥ damper;

⑦ number and position of earth clamps.

(5) Welding variables of capacitor discharge stud welding:

① polarity;

② capacitance;

③ charging voltage;

④ spring force and/or gap length;

⑤ number and position of earth clamps;

⑥ welding cable configuration (if used for current control).

4.1.4 Qualification of personnel

4.1.4.1 The non-destructive testing personnel involved in the approval test of welding procedures are to hold the Qualification Certificate of Non-Destructive Testing Personnel issued or approved by CCS to corresponding grades.

4.1.5 Coverage of approval of welding procedures

4.1.5.1 In addition to the requirements in Section 1, Chapter 3, PART THREE of CCS Rules for Materials and Welding, the coverage of approval for welding procedures is to comply with the requirements of this Chapter.

4.1.5.2 Steel groups are given in Table 4.1.5.2, except for marine structural steels, steel castings and forgings. In principle, the coverage of base metals is as follows:

(1) Where the toughness is the same for the same grade, low carbon and low alloy steels having higher strength cover those having less strength or where the strength level is the same, those having more toughness cover those having less toughness. In addition, where low alloy steel covers low carbon steel, it is to be agreed by CCS; hull structural steel can cover the low carbon steel and low alloy steel with the equivalent strength and toughness, but not vice versa;

(2) For chromium molybdenum steel and duplex stainless steel, the qualified welding process of high group number is suitable for welding of the high group number base metal and low group number base metal;

(3) Ferritic, martensitic and austenitic stainless steels cover only materials in the same group;
(4) Different grades cannot cover each other.

Material groups **Table 4.1.5.2**

Grade	Group	Alloy type	Typical examples in CCS rules
Low carbon steel	1	Low carbon steel with yield strength <265N/mm^2, not used in hull structure	360A ~ 410B steels for boilers and pressure vessels, steel pipes with strength levels of 320 ~ 410 N/mm^2
Low alloy steels	1	Low alloy higher strength steels with yield strength of 265 ~ 390N/mm^2, not used in hull structure	460A ~ 490B steels for boilers and pressure vessels, steel pipes with strength levels of 460 ~ 490 N/mm^2
Chromium molybdenum steel	1	0.75% ≤ Cr ≤ 1.5%, Mo ≤ 0.7%	1Cr0.5Mo
	2	1.5% < Cr ≤ 3.5%, 0.7% < Mo≤1.2%	2.25Cr1Mo
	3	3.5% < Cr ≤ 7.0%，0.4% < Mo ≤ 0.7%	–①
	4	7.0% < Cr ≤ 10%，0.7% < Mo ≤ 1.2%	–①
Duplex stainless steel	1	Cr≤24%	022Cr22Ni5Mo3N(S22253), 022Cr23Ni5Mo3N(S22053)
	2	Cr>24%	03Cr25Ni6Mo3Cu2N(S25554), 022Cr25Ni7Mo4N(S25073)
Ferritic and Martensitic stainless steels	1	Ferritic stainless steel	–①
	2	Martensitic stainless steel	–①
Austenitic stainless steel②	1	Cr≤19%, Ni≤31%, without other alloying elements	022Cr19Ni10(S30403)
	2	Cr≤19%, Ni≤31%, Mo added	022Cr17Ni12Mo2(S31603), 022Cr19Ni13Mo3(S31703)
	3	Cr≤19%, Ni≤31%, Nb added	06Cr18Ni11Nb(S34778)

Notes: ① Seldom used in ships, thus not covered by CCS rules.
② The material of group 2 for austenitic stainless steel can cover that of group 1.

4.1.5.3 Titanium alloy groups and coverage are to satisfy the requirements of 3.1.4.4 of Chapter 3, PART THREE of CCS Rules for Materials and Welding.

4.1.5.4 For groups and coverage of other materials, refer to relevant specifications of Sections 3, 4, 5 of this Chapter respectively.

4.1.5.5 The coverage of joint types is as follows:
(1) The welding of butt joints covers the full penetration and partial penetration fillet welding appropriate to the weld metal thickness in the same welding conditions.
(2) The welding of butt joints covers the fillet welding in corresponding welding conditions for steels having a required minimum yield strength less than 355 N/mm^2.

4.1.5.6 For the coverage of different joint types and welding positions, refer to Table 4.1.5.6.

Coverage of welding positions **Table 4.1.5.6**

Test assembly		Applicable welding positions①②			
Joint type	Welding position①	Butt welding of plates	Butt welding of pipes	Fillet welds of plates③	Pipe-to-plate fillet welding③
Butt welding of plates	F	F		FF	
	H	H		FF、FH、FHa	
	Vu	Vu		FVu	
	Vd	Vd		FVd	
	O	O		FO、FOa	
	H+V	F、H、V、O		FF、FH、FHa、FVu、FO、FOa	
Butt welding of pipes④	1G	F	1G	FF	1FG
	2G	H	2G	FF、FH、FHa	2FG
	5G	F、V、O	1G、5G	FF、FVu、FO、FOa	1FG、4FG、5FG
	2G+5G	F、H、V、O	1G、2G、5G、6G	FF、FH、FHa、FVu、FO、FOa	1FG、2FG、4FG、5FG、6FG
	6G	F、H、V、O	1G、2G、5G、6G	FF、FH、FHa、FVu、FO、FOa	1FG、2FG、4FG、5FG、6FG

	6GR	F、H、V、O	1G、2G、5G、6G、6GR	FF、FH、FHa、FVu、FO、FOa	1FG、2FG、4FG、5FG、6FG
Fillet welds of plates	FF			FF	
	FH/FHa			FF、FH、FHa	
	FVd			FVd	
	FVu			FVu	
	FO/FOa			FO、FOa	
	FH+FVu			FF、FH、FHa、FVu、FO、FOa	
Pipe-to-plate fillet welding	1FG			FF	1FG
	2FG			FF、FH、FHa	2FG
	4FG			FO、FOa	4FG
	5FG			FF、FVu、FO、FOa	5FG
	2FG+5FG			FF、FH、FHa、FVu、FO、FOa	1FG、2FG、4FG、5FG、6FG
	6FG			FF、FH、FHa、FVu、FO、FOa	1FG、2FG、4FG、5FG、6FG

Notes: ① See 4.3.7.1, Section 3, Chapter 4, PART THREE of CCS Rules for Materials and Welding for indications of welding positions.

② For the permissible angle deviation of different welding positions in production application, see the requirements of ISO6947.

③ The coverage of fillet joints by butt joints is limited to the scope given in 4.1.5.5 of this Section.

④ The butt welding in pipes covers butt welding in plates at corresponding welding positions only in the case of pipes with external diameter greater than 25 mm.

Section 2 APPROVAL OF WELDING PROCEDURES OF STAINLESS STEEL AND STAINLESS STEEL-CLAD PLATES

4.2.1 Application

4.2.1.1 This Section applies to the approval of welding procedures of austenitic stainless steel, duplex stainless steel, lean duplex stainless steel plates or pipes and of stainless steel-clad plates.

4.2.1.2 Welding processes used are normally shielded metal arc welding, metal-arc inert gas welding (MIG), tungsten inert gas (TIG) welding, CO_2 welding with flux-cored wires and submerged arc automatic welding, etc.

4.2.2 Methods of welding procedure approval test for butt welding of austenitic stainless steels, duplex stainless steels and leanduplex stainless steels

4.2.2.1 The dimensions and preparation of test assemblies are to comply with the requirements in 3.2.2, Section 2, Chapter 3, PART THREE of CCS Rules for Materials and Welding. Test plates are to be cut with the weld parallel to the rolling direction of the plates.

4.2.2.2 Prior to sampling, visual examination, X-ray examination and dye penetrant testing are to be carried out.

4.2.2.3 The test items for butt welding of austenitic stainless steel, duplex stainless steel and lean duplex stainless steel with their test results are to be in compliance with the requirements of 3.2.7, Section 2, Chapter 3, PART THREE in CCS Rules for Materials and Welding.

4.2.3 Methods of welding procedure approval test for fillet welding of austenitic stainless steels, duplex stainless steels and lean duplex stainless steels

4.2.3.1 The preparation of test assemblies is to satisfy the requirements in 3.3.2, Section 3, Chapter 3, PART THREE of CCS Rules for Materials and Welding.

4.2.3.2 Prior to sampling, visual examination and dye penetrant testing are to be carried out.

4.2.3.3 The test items for fillet welding are as follows:
(1) two macrosections (one at the mid-length of the test assembly and the other at stop/restart points);
(2) one fracture test specimens;
(3) one hardness test for duplex stainless steels and lean duplex stainless steels is to be added and the test specimen is to be at stop/restart points.

4.2.3.4 Required test results are as follows:
(1) The results of visual examination and dye penetrant testing are to be in compliance with the recognized standards.
(2) The macro examination is to reveal a regular profile and full penetration of weld.
(3) The fractured surfaces of fracture test specimens are to show welds without cracks and lack of fusion. Slag inclusions or pores are to be in compliance with the recognized standards.
(4) The hardness test result of duplex stainless steels and lean duplex stainless steels is not to exceed HV420.

4.2.4 Methods of welding procedure approval test for butt welding of austenitic stainless steel-clad plates

4.2.4.1 The dimensions and orientation, preparation, post-weld visual examination and non-destructive testing of test assemblies are to be respectively in accordance with 4.2.2.1 and 4.2.2.2 of this Section.

4.2.4.2 The test items for butt welding of austenitic stainless steel-clad plates are as follows:
(1) two transverse tensile test specimens of full thickness (including clad and base);
(2) four side-bend transverse specimens, with the diameter of former and angle of bend being the same as those required for base metal (see Section 2, Chapter 1, PART THREE of CCS Rules for Materials and Welding);
(3) one set of impact specimens of welded joints of the base metal respectively at the centre of the weld, at the fusion line and at 2 mm from the fusion line in the heat-affected zone;
(4) one specimen for macro examination;
(5) intercrystalline corrosion test of the clad.

4.2.4.3 Required test results are as follows:
(1) The results of visual examination, X-ray examination and dye penetrant testing are to comply with recognized standards.
(2) The tensile strength Rm is to comply with the following formula:

$$Rm \geq \frac{t_1 R_1 + t_2 R_2}{t_1 + t_2} \quad \text{N/m}^2$$

where: t_1 – nominal thickness of base metal, in mm;
t_2 – nominal thickness of clad material, in mm;
R_1 – specified minimum tensile strength of base metal, in N/mm^2;
R_2 – specified minimum tensile strength of clad material, in N/mm^2.
(3) After bending, there is to be no crack or any other open imperfection exceeding 3 mm in any direction on the outer surface. Where delamination or cracking occurs due to the unbonded clad interface of any side-bend specimen of a stainless steel-clad plate manufactured by roll cladding or explosive bonding, new specimens are allowed for retesting.
(4)The impact test temperature and energy are to comply with the requirements for base metals.
(5) Macro-examination is to show complete fusion and freedom from cracks, without any slag inclusion or porosity beyond those allowed by recognized standards.
(6) The intercrystalline corrosion test of welds is to satisfy the requirements of Section 7, Chapter 2, PART ONE of CCS Rules for Materials and Welding.

4.2.5 Coverage of approval of welding procedures

4.2.5.1 The coverage of base metals is in accordance with the provisions of 4.1.5.2 of Section 1 of this Chapter.

4.2.5.2 The range of thickness is as follows:
(1) for austenitic and duplex stainless steels, refer to the range of thickness specified for steels in 3.1.4.5, Section 1, Chapter 3 of CCS Rules for Materials and Welding;
(2) the range of thickness for stainless steel-clad plates is to be determined respectively according to

thicknesses of clad and base of test assemblies.

4.2.5.3 Except for 4.2.5.1 and 4.2.5.2, for the coverage of other variables (e.g. joint types, welding conditions, etc.) of approval of welding procedures, the relevant provisions in Section 1, Chapter 3, PART THREE of CCS Rules for Materials and Welding may be referred to.

Section 3 APPROVAL OF WELDING PROCEDURES OF COPPER ALLOY PIPES

4.3.1 Application

4.3.1.1 This Section applies to the approval of welding procedures used in butt welding, pipe-to-pipe and pipe-to-plate fillet welding of common copper alloy pipes. For the welding of copper-nickel iron pipes and carbon steel pipes, this Section may be referred to.

4.3.1.2 Welding processes used are normally metal-arc inert gas welding (MIG), tungsten inert gas (TIG) welding, plasma welding and gas welding.

4.3.2 Methods of welding procedure approval test for butt welding of copper alloy pipes

4.3.2.1 The dimensions of test assemblies are to comply with the requirements in 3.2.2, Section 2, Chapter 3, PART THREE of CCS Rules for Materials and Welding.

4.3.2.2 Prior to sampling, visual examination, X-ray examination and dye penetrant testing are to be carried out.

4.3.2.3 The test items for butt welding of copper alloy pipes are as follows:
(1) two transverse tensile test specimens;
(2) two face bend and two root bend transverse test specimens. The angle of bend for bend test is to be 180°, and the diameter of former is to be not greater than that obtained by the following formula:

$$d = \frac{(100 \times t)}{A_5} - t$$

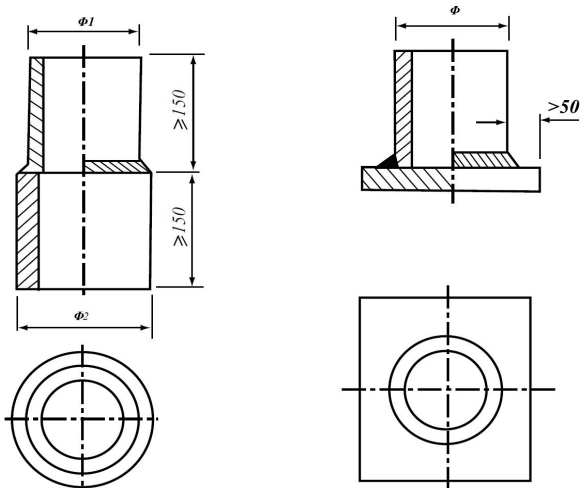
where: d – maximum diameter of former, in mm;
t – thickness of bend test specimens (including side-bend specimens), in mm;
A_5 – specified minimum elongation required by base metals (a lesser value to be taken for a weld consisting of different materials), in %.

Where base metals are dissimilar materials, the wrap-around bend test using a roller method is recommended;
(3) one specimen for macro examination.

4.3.2.4 Required test results are as follows:
(1) The results of visual examination and non-destructive testing are to comply with recognized standards.
(2) The tensile strength of joints is not to be lower than the minimum value specified for base metals. The tensile strength of butt joints consisting of two materials is not to be lower than the minimum tensile strength specified for the base metal having lower strength.
(3) After bending, there is to be no crack or any other open imperfection exceeding 3 mm in any direction on the outer surface.
(4) The macrographic section is to show complete fusion and freedom from cracks, without any slag inclusion or porosity beyond those allowed by recognized standards.

4.3.3 Methods of welding procedure approval test for fillet welding of copper alloy pipes

4.3.3.1 The test assemblies of fillet welding of copper alloy pipes can be pipe-to-pipe or pipe-to-plate fillet welding according to the actual conditions. For specific dimensions see Figure 4.3.3.1(1) and (2).



(1) pipe-to-pipe fillet weld assembly

(2) pipe-to-plate fillet weld assembly

Figure 4.3.3.1 Fillet weld assembly of copper alloy pipe

4.3.3.2 The preparation and welding of test assemblies are to comply with the requirements of the preliminary welding procedure specification.

4.3.3.3 Prior to sampling, visual examination and dye penetrant testing are to be carried out.

4.3.3.4 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 4.3.3.3(1) or (2). Each weld is to be subjected to macro examination (at least one cross section is to include stop/restart points).

4.3.3.5 Required test results are as follows:
(1) The results of visual examination and dye penetrant testing are to be in compliance with the recognized standards.
(2) The macro examination is to reveal a regular profile and full penetration of weld.

4.3.4 Coverage of approval of welding procedures

4.3.4.1 The coverage of base metals of copper alloy pipes is specified in Table 4.3.4.1.

Coverage of approval for base metals of copper alloy pipes Table 4.3.4.1

Copper alloys used for approval tests	Coverage of materials
Aluminium brass	Aluminium brass
90/10 Cu-Ni-Fe	90/10 Cu-Ni-Fe
70/30 Cu-Ni-Fe	90/10 Cu-Ni-Fe,70/30 Cu-Ni-Fe
Pure copper	Pure copper

4.3.4.2 The range of thickness is specified in Table 4.3.4.2.

Range of wall thickness of copper alloy pipes Table4.3.4.2

Thickness of test piece t (mm)	Range①
$t \leq 3$	(0.5~2) t
$3 < t \leq 20$	3 mm ~$2t$
$t > 20$	≥0.8 t

Note: ① For automatic single-run procedures, the approved maximum penetration is the maximum penetration during test.

4.3.4.3 For the coverage of joint types and welding conditions, relevant provisions in CCS Rules for Materials and Welding may be referred to.

Section 4 APPROVAL OF WELDING PROCEDURES OF TITANIUM ALLOYS

4.4.1 Application

4.4.1.1 This Section applies to the approval of welding procedures of titanium and titanium alloys.

4.4.1.2 Welding processes used are normally metal-arc inert gas welding (MIG), tungsten inert gas (TIG) welding and plasma welding, etc.

4.4.2 Methods of welding procedure approval test for butt welding of titanium and titanium alloys

4.4.2.1 The dimensions and preparation of test assemblies for butt welds in plates and pipes are to comply with the requirements in 3.2.2, Section 2, Chapter 3, PART THREE of CCS Rules for Materials and Welding; the specific plate thickness (wall thickness of pipes), external pipe diameter, groove angle and gap may be determined by the preliminary welding procedure specification developed by the manufacturer.

4.4.2.2 Prior to sampling of test assemblies of butt welding, visual examination, X-ray examination and dye penetrant testing are to be carried out.

4.4.2.3 Non-destructive testing is to be carried out after the completion of the post-weld heat treatment.

4.4.2.4 The test items for butt welding are as follows:
(1) two transverse tensile test specimens;
(2) two face bend and two root bend transverse test specimens, and they may be replaced by 4 side-bend specimens where the thickness of the test assembly is equal to or exceeds 12 mm. The bend angle and diameter of former are to comply with the values given in Table 3.4.3.4 in Chapter 3 of the Guidelines;
(3) each group at the centre of the weld, at the fusion line and in the heat-affected zone 2mm from the fusion line (three specimens for each group, except for 5mm impact test specimen which cannot be prepared);
(4) one specimen for macro examination.

4.4.2.5 Required test results are as follows:
(1) The results of visual examination and non-destructive testing are to comply with recognized standards;
(2) Unless otherwise specified, the tensile strength of joints is not to be lower than the minimum value specified for base metals;
(3) After bending, there is to be no crack exceeding 3 mm in any direction;
(4) The energy of impact tests at ambient temperature is not to be lower than the minimum value specified for or considered in the design of base metals;
(5) The results of macro examination are to comply with recognized standards.

4.4.3 Methods of welding procedure approval test for fillet welding of titanium and titanium alloys

4.4.3.1 The dimensions and preparation of plate-to-plate, pipe-to-pipe and pipe-to-plate fillet weld assemblies are to comply with the requirements in 3.3.2, Section 3, Chapter 3, PART THREE of CCS Rules for Materials and Welding; the specific plate thickness and root gap may be determined by the preliminary welding procedure specification developed by the manufacturer.

4.4.3.2 Prior to sampling of fillet weld assemblies, visual examination and dye penetrant testing are to be carried out.

4.4.3.3 Non-destructive testing is to be carried out after the completion of the post-weld heat treatment.

4.4.3.4 Two macrographic sections taken after each end of the test assembly is discarded for a length about 25 mm. The specimens are to clearly reveal the fusion line, heat-affected zone and the build-up of the runs. Take one fracture specimen.

4.4.3.5 Required test results are as follows:
(1) The results of visual examination and dye penetrant testing are to comply with recognized standards, and the color of welds and adjacent zones is to be silver white or yellow.
(2) The macro examination is to reveal a regular profile and full penetration of weld and to comply with recognized standards.
(3) The fractured surfaces of fracture test specimens are to show welds without cracks and lack of fusion. Slag inclusions or pores are to be in compliance with the recognized standards.

4.4.4 Coverage of approval of welding procedures

4.4.4.1 The coverage of base metals of titanium and titanium alloys is specified in Table 4.4.4.1.

Coverage of approval for titanium and titanium alloys **Table 4.4.4.1**

Titanium alloys used for approval tests	Coverage of materials
Pure titanium - Pure titanium	Pure titanium - Pure titanium
α alloys - α alloys	α alloys - α alloys
αβ alloys - αβ alloys	αβ alloys - αβ alloys
β alloys - β alloys	β alloys - β alloys
Pure titanium – α alloys	Pure titanium –α alloys，Pure titanium - Pure titanium
Pure titanium – αβ alloys	Pure titanium – αβ alloys，Pure titanium - Pure titanium
Pure titanium – β alloys	Pure titanium – β alloys，Pure titanium - Pure titanium
α alloys - αβ alloys	α alloys - αβ alloys，α alloys - α alloys
α alloys - β alloys	α alloys - β alloys，α alloys - α alloys
αβ alloys - β alloys	αβ alloys - β alloys，αβ alloys - αβ alloys

4.4.4.2 Except for 4.4.4.1,the coverage of other variables (e.g. thickness of base metals, pipe diameters, welding processes, joint types, welding positions, welding conditions, etc.) of approval of welding procedures of titanium alloys satisfy relevant requirements for steels in 3.1.4, Chapter 3, PART THREE of CCS Rules for Materials and Welding.

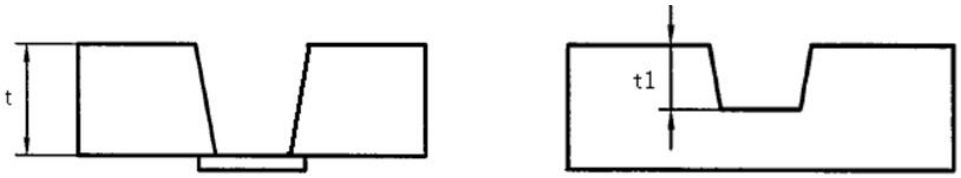
Section 5 APPROVAL OF SPECIAL WELDING PROCEDURES

4.5.1 Application

4.5.1.1 This Section applies to the approval of special welding procedures, such as repair welding of carbon and carbon-manganese steels castings intended for hull and machinery structures, brazing of copper alloy pipes, fillet welding of steel-aluminium transition joints to structural components.

4.5.2 Approval of repair welding procedures of steel castings

4.5.2.1 The test assembly is to be welded by one side with steel backing or by making a catching groove at the middle of the casting in the flat position, and the plate thickness t (or the groove depth t1) is to be not less than 15 mm, as detailed in Figure 4.5.2.1(a) and (b). The recommended root gap is 5 to 15 mm and the recommended groove angle is 10° to 40°. The dimensions of test assemblies are to comply with the requirements of 3.2.2.3, Chapter 3, PART THREE of CCS Rules for Materials and Welding.



(a) Steel backing (b) Catching groove

Figure 4.5.2.1 Edge preparation of steel casting test assembly

4.5.2.2 The welding processes, welding consumables, preheating, interpass temperatures and post-weld heat treatment used for the welding of test plates are to be determined according to the specific conditions for weld repairs of products.

4.5.2.3 After completion of welding, the test assembly is to be 100% inspected visually, tested by magnetic particles and by ultrasonic testing. If post-weld heat treatment is required, the non-destructive testing is to be carried out thereafter.

4.5.2.4 Test items are specified as follows:
(1) two transverse tensile test specimen. The base metal included in the thickness of a specimen having a catching groove is to be removed;
(2) if required for the base metal, three sets of impact specimens (not more than 2 mm from surface) respectively at the centre of the weld, at the fusion line and at 2 mm from the fusion line in the heat-affected zone;
(3) two transverse side-bend specimens. The angle of bend for bend test is to be 180°, the diameter of former is to be 4t for $A_5 \geq 20\%$, otherwise the diameter is to be determined by the formula in 4.3.2.3(2);
(4) one macrographic section. When the yield strength is equal to or greater than 355 N/mm^2, one hardness test specimen is to be added. one hardness test row is to be near surface and another at root. A minimum of 3 individual points in each area of the weld, the fusion line, the heat-affected zone and the base metal are to

be measured, as detailed in Section 2, Chapter 1, PART THREE of CCS Rules for Materials and Welding.

4.5.2.5 Test results are to comply with the following requirements:
(1) The results of visual examination and non-destructive testing are to comply with recognized standards.
(2) The tensile strength of joints is to be not lower than the minimum value specified for base metal. If the test specimen is cut from the base metal outside the fusion line, its tensile strength is allowed to be not less than 95% of the minimum value specified for the base metal.
(3) The temperature and energy of Charpy V-notch impact test are to comply with the requirements for the base metal.
(4) After bending, there is to be no crack or any other open imperfection exceeding 3 mm in any direction on the outer surface.The macrographic section is to show complete fusion and freedom from cracks, without any slag inclusion or porosity beyond those allowed by recognized standards.
(5) Required hardness test results: Where the specified minimum yield strength of the base metal is not greater than 420 N/mm^2, the hardness is generally not to exceed HV350; where the specified minimum yield strength of the base metal is greater than 420 N/mm^2, the hardness is generally not to exceed HV420.

4.5.2.6 Coverage of approval of welding procedures
(1) The range of thickness of base metals is specified in Table 4.5.4.5(1).

Application for thickness of test assemblies for repair welding of casting steels Table 4.5.4.5(1)

t (mm)	Application
15≤t≤30	3mm ~2t
t>30	≥0.5t

(2) For the coverage of materials of base metals, welding consumables, welding positions, welding conditions, refer to relevant provisions of Section 1, Chapter 3, PART THREE of CCS Rules for Materials and Welding. When neither impact nor hardness requirements are specified, welding in any one position qualifies for welding in all positions. For steels with C ≥ 0.23% or Ceq ≥ 0.45%, the WPQT on which the WPS is based is to be qualified on a base material having a Ceq as follows: the Ceq of the base material is not to fall below more than 0.02% of the material to be welded.

4.5.3 Copper alloy pipe brazing

4.5.3.1 The thicknesses and pipe diameters of test assemblies, joint types and welding positions (solder flow direction) are to be selected according to actual products. The dimensions of test assemblies are to be referred to those required for butt weld joints of pipes in Section 2, Chapter 3, PART THREE of CCS Rules for Materials and Welding.

4.5.3.2 The test items of pipe brazing joints are specified as follows:
(1) two tensile test specimens of joints;
(2) two test specimens of macrographic sections.

4.5.3.3 Where required for products, a hydraulic test may be added.

4.5.3.4 Test results are to comply with the following requirements:
(1) the tensile strength is to be not less than the minimum value specified for the base metal;
(2) macrographic sections are to clearly show the fusion within the lap length. The accumulated length of solder penetration is to be not less than 80% of the lap length.

4.5.3.5 The coverage of approval of welding procedures is as follows:
(1) for the coverage of base metals, refer to Table 4.3.4.1;
(2) for the range of wall thickness of pipes, refer to Table 4.3.4.2;
(3) the joint types and welding conditions in actual production are to be same as in procedure approval.

4.5.4 Fillet welding of steel-aluminium transition joints to structural components

4.5.4.1 The dimensions of test assemblies and joint types are shown in Figure 4.5.4.1 where A and B are temperature measuring holes of the bonding interface (aluminium alloy-titanium interface where the interlayer is titanium; steel-aluminium interface where the interlayer is aluminium), located just below the steel and aluminium weld.

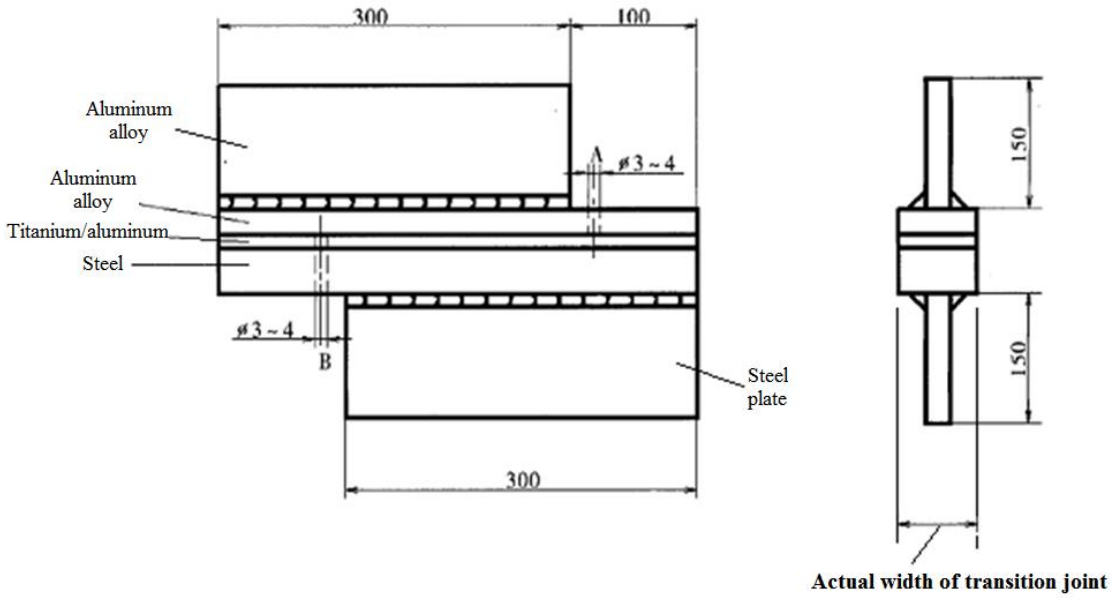


Figure 4.5.4.1 Dimensions of test assembly and joint types

4.5.4.2 The welding process is to comply with the following requirements:
(1) in general, aluminium side is to be welded first and then the steel side. All four welds are to be continuous fillet welds, and leg lengths are to be as designed;
(2) the interface temperature of the transitional layer is to be measured during the welding process, ensuring that the critical temperature (350 ℃ for aluminium-titanium-steel joints and 300 ℃ for aluminium-aluminium-steel joints) will not be exceeded.

4.5.4.3 After completion of welding, test assemblies are to be 100% inspected visually and tested by dye penetration.

4.5.4.4 Test items are specified as follows:
(1) two cross tensile test joints, the dimensions of which are shown in Figure 4.5.4.4(1). The maximum tensile force for tensile test is to be not less than the minimum value calculated according to the minimum tensile strength required by butt welding procedure qualification for hull structural components (aluminium plates);

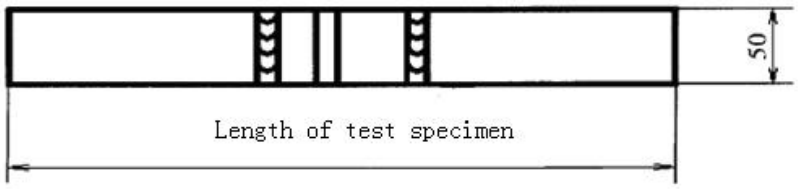


Figure 4.5.4.4(1) Cross tensile test joint

(2) one test specimen of macrographic sections.

4.5.4.5 Required test results are as follows:
(1) the results of visual examination and dye penetrant testing are to comply with recognized standards;
(2) the transitional joint is free from fracture after the tensile test;
(3) the macrographic section is to show good profile and complete fusion, without peeling and other imperfections at the clad interface of transitional joints.

4.5.4.6 The coverage of approval of welding procedures is as follows:

(1) Steel-aluminium transitional joints of different materials and thickness are subjected to procedure approval tests separately. The applicable thickness range of the aluminum plates of the fillet welded joint hull structural members is equal to or less than the thickness at the time of the approval test.
(2) The heat input of welding is not to be greater than that used in the procedure approval test.
(3) For the coverage of welding consumables, weld dimensions, etc., the relevant provisions of Section 1, Chapter 3, PART THREE of CCS Rules for Materials and Welding may be referred to.

Section 6 APPROVAL OF LASER BEAM WELDING PROCEDURES

4.6.1 General provisions

4.6.1.1 This Section is applicable to the welding procedure approval for laser beam welding and laser-arc hybrid welding of normal strength and higher strength hull structural steels required in Section 2 and Section 3 of Chapter 2, PART One of the CCS Rules for Materials and Welding.

4.6.2 Butt welding procedure approval test

4.6.2.1 The test assemblies and sampling positions are shown in Figure 4.6.2.1. The direction in which test pieces are cut from rolled steel is to be determined as required for impact tests and unless otherwise stipulated, the weld of the test pieces is to be vertical to the rolling direction (longitudinal impact) of the base metal.

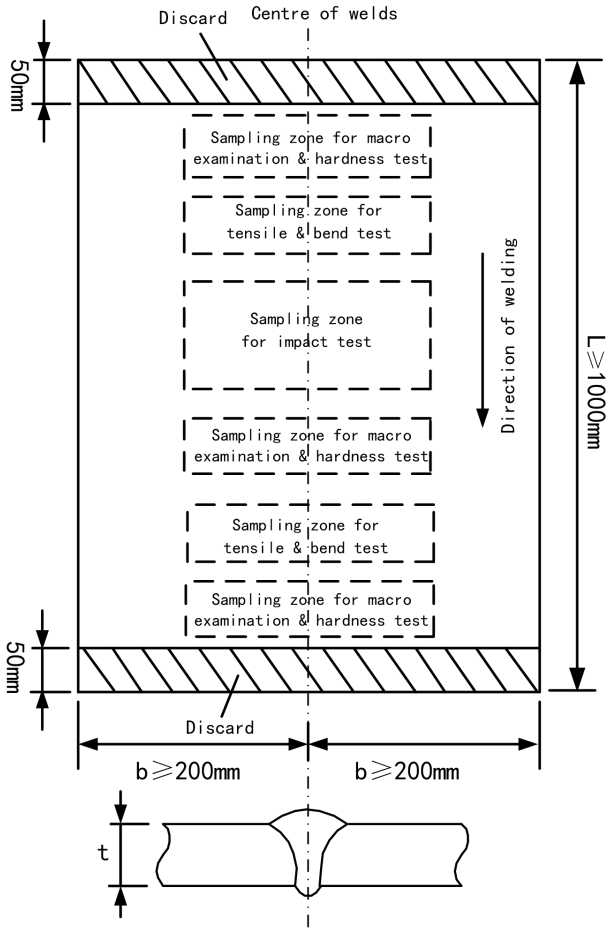


Figure 4.6.2.1 Diagram of butt weld test assembly and sampling positions

4.6.2.2 Visual inspection and non-destructive test. 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. The appearance and NDT of laser beam welds are to meet the requirements of level B of ISO 13919 or other equivalent standards. The appearance and non-destructive testing of laser-arc hybrid welds are to meet the requirements of level B of ISO 12932 or other equivalent standards. The acceptance requirements of welding process with multiple welding processes are to be specially considered and approved by CCS.

4.6.2.3 Items of butt welding procedure test are shown in Table 4.6.2.3.

Items of butt welding procedure test **Table 4.6.2.3**

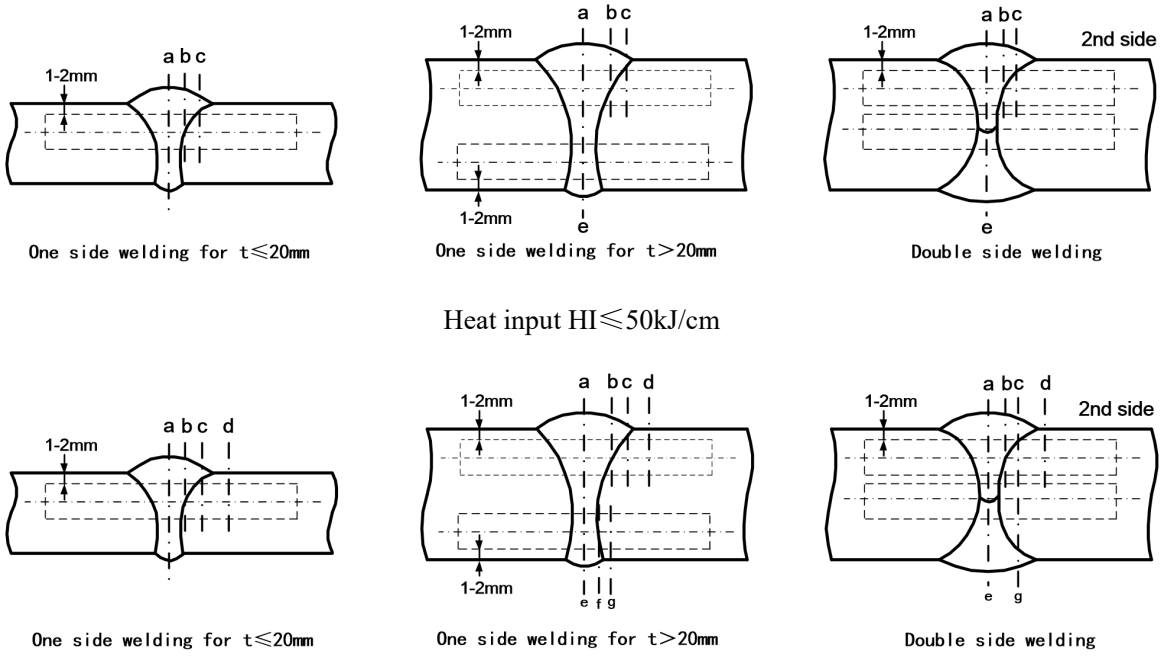
Specimen for transverse tensile	Specimen for transverse bending①	Specimen for weld impact②	Specimen for macro examination	Specimen for hardness test
2	2 for face bend 2 for root bend	3~7 groups	3	3

Notes: ① Where the plate thickness is 12mm or over, two face bend specimens and two root bend specimens can be substituted by four side bend specimens. Longitudinal face and root bend specimens may be used for test pieces welded by materials with different strength.

② The specific number of sampling is to be in accordance with the requirements of 4.6.2.5.

4.6.2.4 The sampling and test process for tensile test, bend test and impact test are to be in accordance with the requirements of Section 2, Chapter 1, PART THREE in CCS Rules for Materials and Welding.

4.6.2.5 The sampling positions of impact test are shown in Figure 4.6.2.5, three samples are to be taken for each group. Where the joint is combined with other welding processes, the welds and heat affected zone of different welding processes are to be sampled respectively. Where the sample cannot be taken separately due to dimension limitation, the specimen for impact test is to be sampled from the weld metal and heat affected zone involving all processes. When the thickness of test assembly is too small to prepare 5mm specimen, impact test may be exempted.



Sampling position: a—cenre of weld b—fusion line c—fusion line + 2mm d—fusion line + 5mm
e— centre of weld at root f— fusion line at root g— fusion line at root + 2mm

a, b, c and d are notch locations of impact specimens.

Figure 4.6.2.5 Diagram of sampling for impact specimens

4.6.2.6 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.

4.6.2.7 Hardness specimens are usually to be taken at the weld joint, and may be cut in accordance with that of macro ones and the fractured surface of joint is to be ground, polished so as to conduct hardness test. The hardness measurements are to be carried out by means of a Vickers hardness tester, normally applying a force of 98N. A minimum of 3 individual points in each area of the weld metal, the heat affected zone on both sides and the base metal on both sides are to be measured and two measurement points are to be added

in fusion line area.The distance between measuring points is to be such that they will not interfere with each other (the distance between two adjacent indentation centres are to be at least 3 times the diagonal length of the indentation). When the plate thickness is less than or equal to 5 mm, the test is carried out at a position below 2 mm from the upper surface. When the plate thickness is greater than 5 mm, the tests are carried out at positions below 2 mm from both the upper and lower surfaces respectively. When welding from both sides, the test is to be carried out at the middle root. When parallel distribution is not possible due to the narrow test area, the measurement points may be distributed in parallel to the fusion line.The diagram of testing positions is shown as Figure 4.6.2.7.

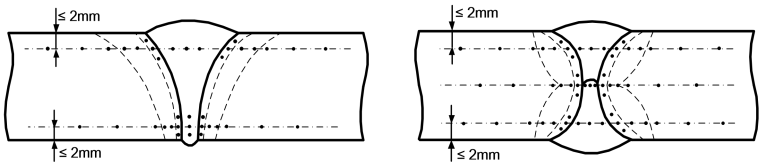


Figure 4.6.2.7 Example of arrangement of hardness test points for butt weld

4.6.2.8 Butt welding procedure test results

a) 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 of the joint is not to be less than that required for base metals having lower strength.

b) After bending, the test specimens are not to reveal crack exceeding 3 mm in length on the outer surface or other imperfection.

c) The impact test results are to meet the requirements of automatic weld impact test in Section 2, Chapter 3, PART THREE of CCS Rules for Materials and Welding. The butt joint made of materials with two different toughness grades is to be sampled from the side with lower toughness and meet the requirements of lower toughness.

d) The macro examination is to reveal the absence of cracks, incomplete penetration and lack of fusion, without any slag inclusion or porosity beyond those allowed by recognized standards.

e) Vickers hardness (HV10) is not to be more than 380.

4.6.3 Full penetration fillet welding procedure approval test

4.6.3.1 The test assembly and sampling position of full penetration fillet weld are shown in Figure 4.6.3.1.

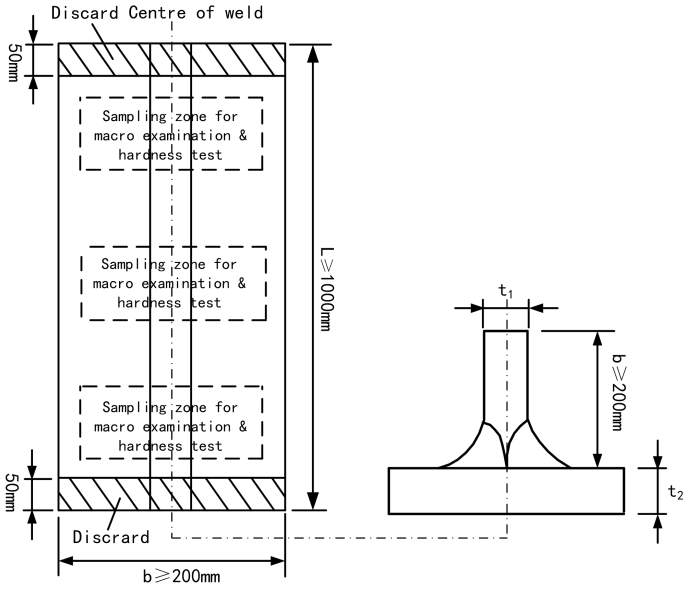


Figure 4.6.2.1 Diagram of full penetration fillet weld test assembly and sampling positions

4.6.3.2 Visual inspection and non-destructive test. 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 (for

the internal testing, the test assembly with the plate thickness less than 8mm may refer to advanced NDT methods in Appendix 2, PART THREE of CCS Rules for Materials and Welding). The appearance and NDT of laser beam welds are to meet the requirements of level B of ISO 13919 or other equivalent standards. The appearance and non-destructive testing of laser-arc hybrid welds are to meet the requirements of level B of ISO 12932 or other equivalent standards. The acceptance requirements of welding process with multiple welding processes are to be specially considered and approved by CCS.

4.6.3.3 Items of full penetration fillet welding procedure test are shown in Table 4.6.3.3. The macro examination and hardness test may refer to 4.6.2.6 and 4.6.2.7 of this Section. The example of arrangement of hardness test points is shown in Figure 4.6.3.3. There may be two measurement points in welds zones and heat affected zones.

Items of full penetration fillet welding procedure test Table 4.6.3.3

Specimen for macro examination	Specimen for hardness test
3	3

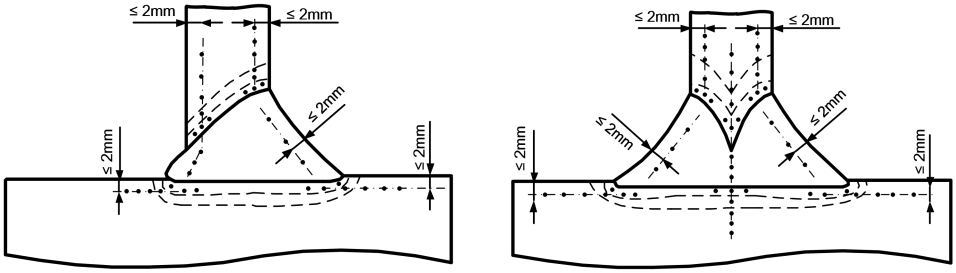


Figure 4.6.3.3 Example of arrangement of hardness test points for full penetration fillet weld

4.6.3.4 The macro examination is to reveal the absence of cracks, incomplete penetration, lack of fusion, without any slag inclusion or porosity beyond those allowed by recognized standards. Vickers hardness (HV10) is not to be more than 380.

4.6.4 Incomplete penetration fillet welding procedure approval test

4.6.4.1 The test assembly and sampling position of incomplete penetration fillet weld are shown in Figure 4.6.4.1.

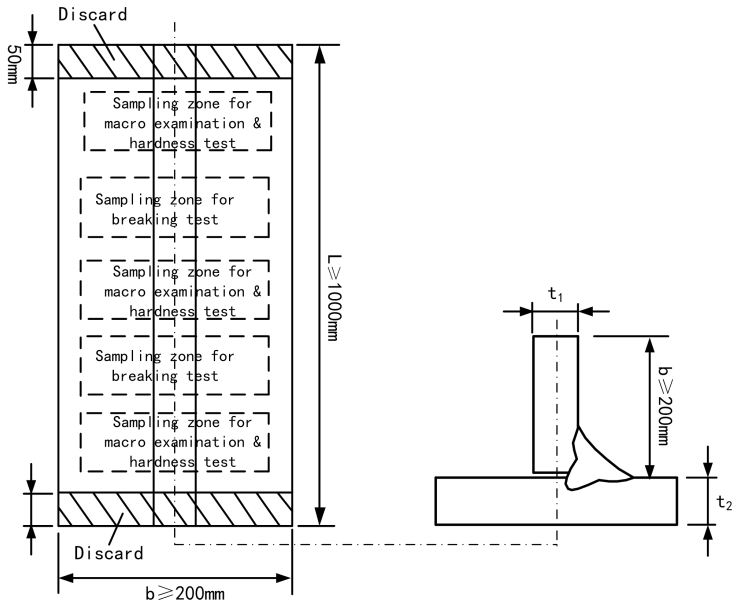


Figure 4.6.4.1 Diagram of incomplete penetration fillet weld test assembly and sampling positions

4.6.4.2 Visual inspection and non-destructive test. Test assemblies are to be examined by 100% visual

testing and by 100% non-destructive surface test prior to the cutting of test specimens. The appearance and NDT of laser beam welds are to meet the requirements of level B of ISO 13919 or other equivalent standards. The appearance and non-destructive testing of laser-arc hybrid welds are to meet the requirements of level B of ISO 12932 or other equivalent standards. The acceptance requirements of welding process with multiple welding processes are to be specially considered and approved by CCS.

4.6.4.3 Items of incomplete penetration fillet welding procedure test are shown in Table 4.6.4.3.

Items of incomplete penetration fillet welding procedure test Table 4.6.4.3

Specimen for fracture test	Specimen for macro examination	Specimen for hardness test
2	3	3

4.6.4.4 The fracture test is to be carried out in accordance with the requirements of Section 2, Chapter 1, PART THREE in CCS Rules for Materials and Welding.

4.6.4.5 The macro examination and hardness test are to refer to 4.6.2.6 and 4.6.2.7 of this Section. The example of arrangement for hardness test points is shown in Figure 4.6.4.5. There may be two measurement points in welds zones and heat affected zones.

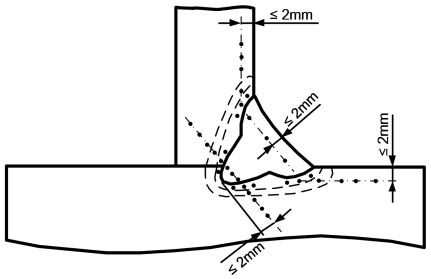


Figure 4.6.4.5 Example of arrangement of hardness test points for incomplete penetration fillet weld

4.6.4.6 Welding procedure test results

a) The fractured surfaces of fracture test specimens are to show welds without cracks and lack of fusion. The slag inclusions or pores of laser beam welds are to meet the requirements of level B of ISO 13919 or other equivalent standards. The slag inclusions or pores of laser-arc hybrid welds are to meet the requirements of level B of ISO 12932 or other equivalent standards.

b) The macro examination is to reveal a sufficient root penetration and the absence of cracks and lack of fusion, without any slag inclusion or porosity beyond those allowed by recognized standards. Vickers hardness (HV10) is not to be more than 380.

4.6.5 Application of approved welding procedures

4.6.5.1 The application of strength for base metal is as follows:

a) For each strength level, welding procedures are considered applicable to the same and lower toughness grades as that tested.

b) Except for those stipulated in above-mentioned (a), the strength is applicable to the same and two lower strength levels as that tested. (The grade H27 steel is not regarded as an individual grade, i.e.: the welding procedure of grade AH36 steel is applicable to grade AH32, grade AH27 and grade A steels).

c) For high heat input processes over 50 kJ/cm, the welding procedure is only applicable to that toughness grade tested and one strength level below.

4.6.5.2 The application of thickness of base metal is as follows:

a) The applicable range of thickness for butt welded base metal is shown in Table 4.6.2.5 (1). In case of butt welds between plates having unequal thickness, the lesser thickness is the ruling dimension.

b) For full penetration fillet welding and incomplete penetration fillet welding, the thicknesses of web and bottom plate are to meet Table 4.6.2.5 (2) respectively. Where the thickness of web exceeds the thickness of bottom plate, each combination of different plate thicknesses is to be evaluated individually and only applicable to the corresponding combination mode.

Application of thickness for butt welded base metals Table 4.6.2.5(1)

Thickness of tested plating t	Applicable thickness range
＜5mm	t
⩾5mm	(0.8~1)t

Application of thickness for full penetration and incomplete penetration fillet welded base metals Table 4.6.2.5(2)

	Thickness of tested plating	Applicable thickness range
Web t_1	＜5mm	t_1
	⩾5mm	(0.8~1)t_1
Bottom plating t_2	＜5mm	(1~2)t_2
	⩾5mm	(0.8~2)t_2

4.6.5.3 The welding consumables cover other approved welding consumables having the same grade mark (including all suffixes) as the welding consumables tested (except high heat input processes over 50 kJ/cm) and with the same specifications. Any variation of the composition of the shielding gas or the mixing ratio of mixed gases is not to be greater than the grouping range in Table 2.5.1.3, PART THREE of CCS Rules for Materials and Welding.

4.6.5.4 Weld bead placement and welding sequence are to be the same as those of the approval test.

4.6.5.5 Different types of welded joint (butt weld, full penetration fillet weld, incomplete penetration fillet weld, etc.) are not to be covered by each other.

4.6.5.6 Approval for a test made in any position is restricted to that position.

4.6.5.7 The upper limit of heat input approved is 15% greater than that used in the welding procedure qualification 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. The heat input formula is as following:

$$\mathrm{HI(kJ/cm)} = \frac{(P_L + U \times I) \times 60}{v \times 1000}$$

Where: P_L — power of laser (W);

U — arc voltage (V);

I — welding current (A);

v — rate of welding (cm/min).

4.6.5.8 The approved welding process is only applicable to that with the same methods (such as laser self-fusion welding, laser wire filling welding and laser-arc hybrid welding), main equipment (including laser type, laser beam transmission and focusing system, etc.), arc welding (such as single arc or multi arc is used), laser-arc hybrid mode (such as axis or side axis, etc.) and the relative position of laser and arc with workpieces as the approval test.

4.6.5.9 The laser spot diameter, laser beam mode, defocusing amount, the distance between the laser beam and the wire, type and polarity of arc welding current, characteristics of laser or arc welding pulse (if any) are to be the same as those of the approval test.

4.6.5.10 The preheating temperature is not to be less than the minimum preheating temperature of the approval test, and the interpass temperature is not to be higher than the maximum interpass temperature in the process of approval test.

4.6.5.11 Variables in surface condition (with or without shop primer) are not to be covered by each other.

4.6.5.12 The application for other relevant variables may be in accordance with the requirements of CCS Rules for Materials and Welding or the relevant provisions of recognized national and international standards.

Section 7 APPROVAL OF FRICTION STIR WELDING PROCEDURES

4.7.1 General provisions

4.7.1.1 This Section is applicable to butt welding procedure approval of friction stir welding of aluminum alloy plates and sections and not applicable to lap welding.

4.7.2 Friction stir welding procedure approval test

4.7.2.1 The test assemblies and sampling positions of butt welding procedure approval are shown in Figure 4.7.2.1.

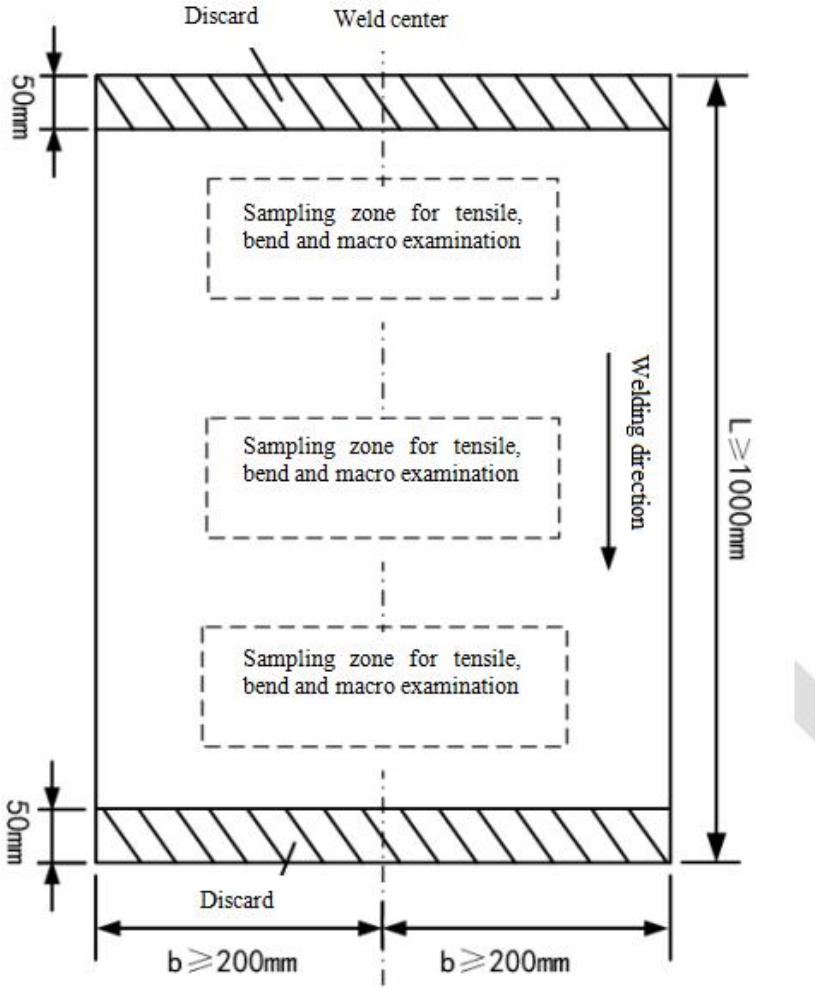


Figure 4.7.2.1 Diagram of test assembly size and sampling positions

4.7.2.2 Visual inspection and non-destructive test. 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. The appearance and non-destructive testing are to meet the requirements of ISO 25239-5 or other equivalent standards.

4.7.2.3 As shown in Figure 4.7.2.1, the items of procedure test are as follows:

(1) Three transverse tensile specimens (to be cut from the head, middle and tail of the test assembly respectively);

(2) Three transverse bending specimens for both face bending and root bending (to be cut from the head, middle and tail of the test assembly respectively). Where the test assembly thickness is 12mm or over, one face bend specimen and one root bend specimen can be substituted by two side bend specimens. Longitudinal face and root bend specimens may be used for test pieces welded by materials with different strength.

(3) Three macro examination specimens (to be cut from the head, middle and tail of the test assembly respectively).

4.7.2.4 The sampling of specimens and the test process are to be in accordance with the requirements of

Section 2, Chapter 1, PART THREE in CCS Rules for Materials and Welding. The requirements for test results are as follows:

(1) The tensile strength of the joint is to meet the requirements in Table 4.7.2.4. When a butt joint is composed of two different materials, its tensile strength is to be not lower than the minimum tensile strength requirement of the base metal with lower strength.

(2) After the bending test, there is to be no open cracks with a length exceeding 3 mm in any direction on the tensile surface of the specimen.

(3) The results of macro examination of the weld is to meet the requirements of Appendix A of ISO 25239-5 or other equivalent standards.

Requirements for tensile strength of butt joints **Table 4.7.2.4**

Material type	Delivery condition of base metal	Post-weld condition	Tensile strength not less than①②
5000 series aluminum alloy	All temper condition	As welded	R_m of the O condition
6000 series aluminum alloy (with the plate thickness less than or equal to 5 mm)	T4	Natural ageing	$0.8R_m$
		Artificial ageing	$0.8R_m$
	T5 and T6	Natural ageing	$0.7R_m$
		Artificial ageing	$0.8R_m$
6000 series aluminum alloy (with the plate thickness greater than 5 mm)	T4	Natural ageing	$0.7R_m$
		Artificial ageing	$0.7R_m$
	T5 and T6	Natural ageing	$0.6R_m$
		Artificial ageing	$0.7R_m$

①R_m is the minimum tensile strength specified for the base metal.

② Requirements for natural ageing condition is to be met if heat treatment is not carried out after welding,

4.7.3 Application of approved welding procedures

4.7.3.1 The base metal is only applicable to the aluminum alloy grades used in the approval test. For aluminum alloys of the same grade, it is applicable to those with the same or lower strength levels as the test base metal.

4.7.3.2 The applicable thickness range of the base metal is 0.9 to 1.1 times the thickness of the test base metal, but with an increment not exceeding 1 mm.

4.7.3.3 The stirring tool is to be the same as that used in the approval test (including the material of the stirring tool, shoulder diameter, probe diameter, probe shape, presence or absence of threads, etc.).

4.7.3.4 The variation in the rotational speed of the stirring tool is not to exceed ±5% of that in the approval test, the variation in the axial pressure is not to exceed ±10% of that in the approval test, the variation in the heel plunge depth is not to exceed ±10% of that in the approval test, and the variation in the dwell time at the start is not to exceed ±5% of that in the approval test.

4.7.3.5 The rotation direction, tilt angle, side tilt angle and lateral offset of the stirring tool are to be the same as those in the approval test.

4.7.3.6 The applicable range of the welding speed is ±5% of that in the approval test.

4.7.3.7 The preheating temperature is to be not lower than *Tp*-30℃ (where *Tp* is the preheating temperature used in the approval test).

4.7.3.8 If post-weld heat treatment is required in the approval test, the corresponding post-weld heat treatment is also to be carried out in production.

Section 8 APPROVAL OF STUD WELDING PROCEDURES

4.8.1 General provisions

4.8.1.1 This Section is applicable to the approval of the welding procedures for studs subject to static or dynamic loads in the hull structure.

4.8.1.2 The welding methods generally used are shielded metal arc welding, gas shielded arc welding, drawn arc stud welding and capacitor discharge stud welding.

4.8.2 Procedure approval test

4.8.2.1 The test assemblies of stud welding procedure approval are shown in Figure 4.8.2.1.

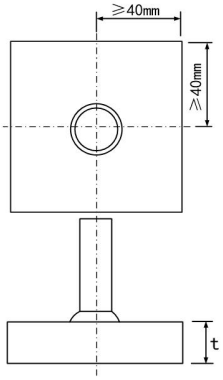


Figure 4.8.2.1 Test assemblies of stud welding procedure approval

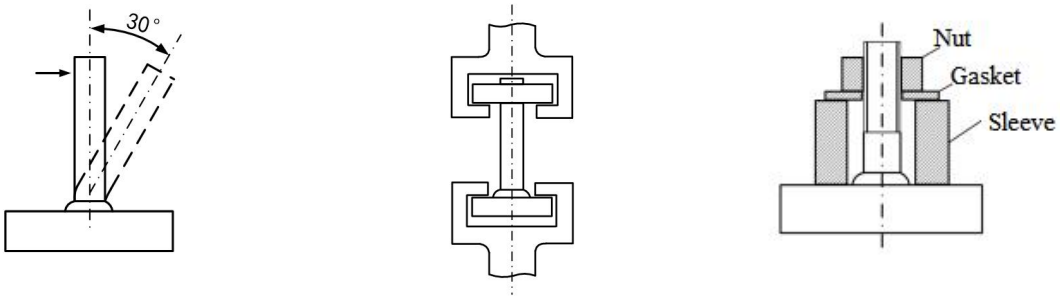
4.8.2.2 Visual inspection. Test assemblies are to be examined by 100% visual testing prior to the cutting of test specimens. The welds are to be uniform and full, free from imperfection such as porosity, cracks and lack of fusion. The weld dimensions are to meet the design requirements. The depth of undercut is to be less than or equal to 0.5 mm, and the maximum length is not to exceed the diameter of the stud. The maximum deviation of the height after welding is to be ±2 mm, and the inclination of the stud is not to be greater than 5°.

4.8.2.3 As shown in Figure 4.8.2.3, the items of procedure test are as follows:

(1) Five bending specimens. The bending test is shown in Figure 4.8.2.3(1), and the specimens are bent to 30°.

(2) Two macro specimens, which are cut along the diameter of the stud.

(3) Five tensile or torque specimens (selected according to the technical requirements). The joint tensile test is shown in Figure 4.8.2.3(2), and the torque test is shown in Figure 4.8.2.3(3).



(1)Bend test (2)Tensile test (3)Torque test

Figure 4.8.2.3 Test diagram

4.8.2.4 The requirements for test results are as follows:

(1) There are to be no cracks at the welded parts after the bending test.

(2) The macro examination of the joint shows that the total length of all imperfection is not to exceed 20% of the weld width. Undercut is not to exceed 5% of the weld width, but it needs to pass the bending test. Imperfection with a spacing greater than 0.5 mm and a maximum size not exceeding 0.5 mm can be ignored.

(3) The tensile strength of the joint in the tensile test is to be not lower than the minimum tensile strength specified for the stud base metal or the minimum tensile strength/minimum tensile force requirements specified in the design. The torque of the joint in the torque test is to be not less than the design requirements.

(4) If necessary, the surveyor may require tests such as joint hardness and microscopic metallographic structure.

4.8.3 Application of approved welding procedures

4.8.3.1 The base metals of studs and attached plates are applicable to materials with lower yield strength or fewer alloying elements. Stainless steel studs are applicable to other stainless steel materials in the same group.

4.8.3.2 The diameter of the stud is only applicable to the diameter of the test stud, and the applicable thickness range of the attached plate is not to be less than the thickness of the test base metal.

4.8.3.3 The ceramic ferrule material is only applicable to the material used in the test. When arc welding is used, the welding material is only applicable to the welding material used in the test.

4.8.3.4 For the drawn arc stud welding, the horizontal welding position can cover the flat welding and overhead welding positions, and the overhead welding position can cover the flat welding position. The welding position during the capacitor discharge stud welding test is applicable to all welding positions. For the arc welding method, the horizontal welding and vertical welding can cover other positions (except for the vertical downward welding).

4.8.3.5 The welding method is only applicable to the welding method used in the test. The variation ranges of the stud protrusion, lift, welding time, current and voltage are ±5% of those in the test.

4.8.3.6 The preheating temperature is within the range of 20 ℃ lower than or 50 ℃ higher than that during the test.

Appendix 4A Preliminary Welding Procedure Specification

FORM： PWPS-1/3

焊接工艺计划书(PWPS)
Preliminary Welding Procedure Specification

工作控制号：
No.

基本参数
Essential parameters

焊接工艺名称及编号 Name and serial number	
制造厂名称及地址 Manufacture's name and address	

焊接方法： Welding process		单道焊 ☐ Single pass	单面焊 ☐ One side
接头形式： Joint type		多道焊 ☐ Multi pass	双面焊 ☐ Double side
焊接位置： Welding position		组合焊 ☐ Multi process	背面清根 ☐ Back gouging
母材级别/交货状态： Base metal grade /delivery condition		焊接设备的型号： Welding equipment	
母材厚度 Thickness	车间底漆： Shop primer	管子外径尺寸： Pipe outside Dia.	气体种类： Gas type

坡口设计(草图) Test joint details (sketch with dimensions)	焊道布置和焊接顺序(草图) Bead sequence details(sketch)

焊接参数
Welding parameters

焊道 Run	焊接方法 Process	填充金属直径 Size of filler metal (mm)	电流种类和极性 Type of current & polarity	焊接电流 Current (A)	电弧电压 Voltage (V)	焊接速度* Travel speed* (cm/min)	热输入* Heat input* (kJ/cm)	气体流量 Gas flow rate (1 / min)

*如有必要时
*If required

FORM： PWPS-2/3

焊接工艺计划书(PWPS)(续)
Preliminary Welding Procedure Specification(continued)

焊接材料(型号/规格/等级)： Welding consumable (type /size / grade)						
衬垫材料： Backing material					施焊环境： Welding site conditions	
焊前预热温度 Preheat temperature		道间温度 Interpass temperature			焊后热处理： Postweld heat treatment	
最低值 Min.	℃	最低值 Min.	℃	最高值 Max.	℃	
预热方法： Preheat method						
其他有关特殊要求*： Other information*						

*如最大摆动宽度、焊道清洁方式、脉冲电流特性等

*E.g. Weaving(max. width of run), method of interpass cleaning, characteristic of pulse current etc.

试验项目

Test items

1、非破坏性检查 **Non-destructive examination**									
目检 Visual	☐	射线探伤 Radiography	☐	超声波探伤 Ultrasonic	☐	磁粉探伤 Magnetic particle	☐	渗透探伤 Penetrate	☐
2、破坏性试验 **Destructive examination**									
1)拉伸试验 **Tensile tests**		横向拉伸 Transverse	☐	纵向拉伸 Longitudinal	☐				
2)弯曲试验 **Bend tests**		正弯 Face	☐	反弯 Root	☐	侧弯 Side	☐		
3)冲击试验 **Impact tests**						试验温度： Test temperature	℃		
焊缝根部 Root of weld	焊缝中心 Center of weld ☐	熔合线 Fusion line ☐	距熔合线 2mm 2mm from FL ☐						
焊缝表面 Face of weld	焊缝中心 Center of weld ☐	熔合线 Fusion line ☐	距熔合线 2mm 2mm from FL ☐	距熔合线 5mm 5mm from FL ☐		距熔合线 mm mm from FL ☐			
4)宏观检查 **Macro examination** ☐		5)硬度试验 Hardness test ☐		6)角接焊破断试验 Fillet weld frature ☐					
3、其他检查和试验 **Additional test(s)**		焊缝金属的化学成分 Chemical analysis of weld ☐		母材的化学成分 Chemical analysis of base metal ☐					
		接头金相照片（×　　倍） Metallograph of the joint (×　) ☐							
		点蚀试验 Pitting test ☐		晶间腐蚀试验 Intercrystalline corrosion test ☐					

签　名：

Signature

制造厂代表　　**日期**

Manufacturer _____　　**Date** _____

FORM： PWPS-3/3

焊接工艺计划书(PWPS)(续)
Preliminary Welding Procedure Specification (continued)

以下由验船师填写：
The following is to be filled in by the Surveyor:

上述焊接工艺计划书经审核，同意按本焊接工艺计划书进行焊接工艺试验 ……..... ☐
The above-mentioned PWPS has been reviewed and implementation of WPT in accordance with this PWPS is approved.

上述焊接工艺计划书经审核，审核意见如下：(请及时回复并与担当验船师联系)…… ☐
The above-mentioned PWPS has been reviewed with comments as follows: (Please reply and contact the attending Surveyor as soon as possible)

签 名：
Signature

CCS 验船师 **日期**
CCS Surveyor _____ **Date** _____

填写说明：
Remarks:

☒ ———— 适用 Applicable ☐ ————不适用 Not applicable

下列缩写可用于表格填写：
The following abbreviation may be used in this form.
焊接方法：Welding process:
手工电弧焊：SMAW； 埋弧焊：SAW； 金属极气体保护焊：GMAW；
钨极气体保护焊：GTAW； 药芯焊丝气体保护焊：FCAW； 气电立焊：EGW
焊接位置：Welding position：
平焊： F； 立焊(上行)： Vu； 立焊(下行) ： Vd； 横焊： H； 仰焊： O
电流种类和极性：Type of current & polarity：
交流： AC； 直流正接： DCEN； 直流反接： DCEP； 脉冲电流：Pulsed

Appendix 4B　Welding Procedure Qualification Record

FORM： WPQR-1/4

焊接工艺认可试验报告(WPQR)
Welding Procedure Qualification Record

工作控制号：
No._____

焊接工艺名称及编号 **Name and serial number**						
制造厂名称及地址 **Manufacture's name and address**						
焊接方法： Welding process 接头形式： Joint type 焊接位置： Welding position	单道焊 ☐ Single pass 多道焊 ☐ Multi pass 组合焊 ☐ Multi process	单面焊 ☐ One side 双面焊 ☐ Double side 背面清根 ☐ Back gouging				坡口设计(草图) Test joint details (sketch with dimensions) of weld preparation
母材(等级/厚度/交货状态)： Base metal(grade/thickness/delivery condition)						焊道布置和焊接顺序(草图) Bead sequence details(sketch)
焊接材料(型号/规格/等级)： Welding consumable (type/size / grade)						
衬垫材料： Backing material	保护气体(种类/纯度) Shielding gas(type/purity)					
管子外径尺寸： Pipe outside diameter	焊剂： Flux					
预热及热处理 **Preheat and postweld heat treatment**						
焊前预热温度 Preheat temperature		道间温度 Interpass temperature				
最低值 Min.	℃	最低值 Min.	℃	最高值 Max.	℃	
焊后热处理 Postweld heat treatment						
其他说明 [1]： **Other information***						

施焊细节
Welding details

焊道 Run	焊接方法 Process	填充金属直径 Size of filler metal (mm)	电流种类和极性 Type of current & polarity	焊接电流 Current (A)	电弧电压 Voltage (V)	焊接速度 [2] Travel speed[2] (cm/min)	热输入 [2] Heat input[2] (kJ/cm)	气体流量 Gas flow rate (l/min)
焊工姓名 Welder's name		试验日期 Date		环境温度 Temperature	℃	相对湿度 Humidity	%	

FORM： WPQR-2/4

焊接工艺认可试验报告(续)
Welding Procedure Qualification Record (continued)

试验项目及结果 Test items and results

1. 非破坏性试验 Non-destructive examination

目检 Visual	☐	射线探伤 Radiography	☐	超声波探伤 Ultrasonic	☐	磁粉探伤 Magnetic particle	☐	渗透探伤 Penetrate	☐

2. 破坏性试验 Destructive examination

拉伸试验 Tensile tests

试样 Test piece	抗拉强度 Tensile strength (N/mm^2)	屈服强度 Yield point (N/mm^2)	伸长率 Elongation %	断面收缩率 Reduction of area %	断裂位置 Location of rupture	试验温度 Test temperature ℃
横向拉伸 1 Transverse 1						
横向拉伸 2 Transverse 2						
纵向拉伸 Longitudinal						

弯曲试验 Bend tests

试样 Test piece	压头直径/弯曲角度 Former / angle	结果 Result
正弯/反弯/侧弯 Face / root /side		
正弯/反弯/侧弯 Face / root /side		
正弯/反弯/侧弯 Face / root /side		
正弯/反弯/侧弯 Face / root /side		
正弯/反弯/侧弯 Face / root /side		
纵向弯曲 Longitudinal		

角接焊破断试验 Fillet weld frature

1.

2.

3.

焊缝断面宏观检验(照片和结果)
Macro examination

冲击试验 Impact tests 试验温度 Temp. ℃

要求：Requirement 尺寸：Size 类型：Type	缺口位置 Notch location	试验值 Values (J) 1 2 3	平均值 Average (J)	备注 Remarks	缺口位置 Notch location	试验值 Values (J) 1 2 3	平均值 Average (J)	备注 Remarks
复试 Retest								

硬度测试 Hardness test

测试形式和载荷： Type and load		测试位置示意图 Location of hardness measurements(sketch)
区域 Area	硬度范围 Hardness range	
母材 Base material		
熔合线 Fusion line		
热影响区 H.A.Z		
焊缝 Weld		

FORM： WPQR-3/4

焊接工艺认可试验报告(续)
Welding Procedure Qualification Record (continued)

附加试验(规范 3.2.4.3 款要求): **Additional test(s) and result(s)(According to 3.2.4.3 of Rules for Materials and Welding)**

注：
Remarks :
1、如焊条/焊丝最大摆动宽度、焊道清洁方式等
1、E.g. Weaving(max. width of run), method of interpass cleaning, etc.
2、如有必要时
2、If required

☒ ——— 适用 Applicable ☐ ——— 不适用 Not applicable

下列缩写可用于表格填写：
The following abbreviation may be used in this form.
焊接方法：Welding process:
手工电弧焊： SMAW； 埋弧焊:SAW； 金属极气体保护焊： GMAW；
钨极气体保护焊： GTAW； 药芯焊丝气体保护焊： FCAW； 气电立焊： EGW
焊接位置：Welding position：
平焊： F； 立焊(上行) ： Vu； 立焊(下行) ： Vd； 横焊： H； 仰焊： O
电流种类和极性：Type of current & polarity：
交流： AC； 直流正接： DCEN； 直流反接： DCEP； 脉冲电流： Pulsed

兹证明本焊接工艺认可过程和试验结果，符合中国船级社《材料与焊接规范》的要求。
THIS is certify that the test process and results were found to be in compliance with the relevant requirements of "Rules for Material and Welding" promulgated by China Classification Society.

签 名：
Signature

制造厂代表 日期
Manufacturer _____ Date _____

CCS 验船师 日期
CCS Surveyor _____ Date _____

FORM： WPQR-4/4

附件
Appendix

为了保证焊接工艺认可试验的质量，并使其具有可追溯性，应提交下列文件的复印件(必要时也可进行增减)。
In order to insure the quality of welding procedure approval test and make it traceable, copies of the documents listed below are to be submitted. (Items in the list may be added or deleted as necessary).

文件清单
List of Documents

序号 No.	文 件 名 称 Document name		备 注Remarks
1	母材质量证明书 **Certification of base material**	☐	
2	焊接材料质量证明书 **Certification of welding consumable**	☐	
3	无损检测报告 **NDT reports**	☐	
4	试验报告(包括拉伸、弯曲、冲击、硬度等) **Test reports** **(Tensile tests, Bend tests,Impact tests, Hardness test, etc.)**	☐	
5	焊缝断面宏观检验报告(照片和结果) **Macro examination reports (Photo and result)**	☐	
6	外观检查照片 **Photos of weld surface**	☐	
7	力学性能试样照片 **Photos of test pieces**	☐	
8	施焊焊工CCS能力认证证书(如有时) **Welders' Certificates issued by CCS(If any)**	☐	
9			
10			

Appendix 4C　Welding Procedure Specification

FORM：WPS-1/2

焊接工艺规程(WPS)
Welding Procedure Specification

工作控制号：
No._____

焊接工艺名称及编号 **Name and serial number**				
制造厂名称及地址 **Manufacture's name and address**				
适用板材(钢管)规格/材质： Base material range				
焊接方法： Welding process		单道焊 ☐ Single pass	单面焊 ☐ One side	
接头形式： Joint type		多道焊 ☐ Multi pass	双面焊 ☐ Double side	
焊接位置： Welding position		组合焊 ☐ Multi process	背面清根 ☐ Back gouging	
母材级别/交货状态： Base metal grade / delivery condition		焊接设备的型号和主要性能参数： Welding equipment		
母材板厚： Thickness	车间底漆： Shop primer	管子外径尺寸： Pipe outside Dia.	气体种类： Gas type	
坡口设计(草图) Test joint details (sketch with dimensions)		焊道布置和焊接顺序(草图) Bead sequence details(sketch)		

焊接参数
Welding parameters

焊道 Run	焊接方法 Process	填充金属直径 Size of filler metal (mm)	电流种类和极性 Type of current & polarity	焊接电流 Current (A)	电弧电压 Voltage (V)	焊接速度* Travel speed* (cm/min)	热输入* Heat input* (kJ/cm)	气体流量 Gas flow rate (1 / min)

* 如有必要时
* If required

FORM：WPS-2/2

焊接工艺规程(WPS)(续)
Welding Procedure Specification (continued)

<table>
<tr><td colspan="7">焊接材料(型号/规格/等级)：
Welding consumable (type /size / grade)</td></tr>
<tr><td colspan="4">衬垫材料：
Backing material</td><td colspan="3">施焊环境：
Welding site conditions</td></tr>
<tr><td colspan="2">焊前预热温度(℃)
Preheat temperature</td><td colspan="3">道间温度(℃)
Interpass temperature</td><td colspan="2" rowspan="3">焊后热处理：
Postweld heat treatment</td></tr>
<tr><td>最低值
Min.</td><td></td><td>最低值
Min.</td><td></td><td>最高值
Max.</td><td></td></tr>
<tr><td colspan="4">预热方法
Preheat method</td></tr>
<tr><td colspan="7">其他有关特殊要求*：
Other information*</td></tr>
</table>

*如最大摆动宽度、焊道清洁方式、脉冲电流特性等
*E.g. Weaving(max. width of run), method of interpass cleaning, characteristic of pulse current, etc.

注：
Remarks :
下列缩写可用于表格填写：
The following abbreviation may be used in this form.
焊接方法：Welding process:
手工电弧焊： SMAW； 埋弧焊： SAW； 金属极气体保护焊： GMAW；
钨极气体保护焊： GTAW； 药芯焊丝气体保护焊： FCAW； 气电立焊： EGW
焊接位置：Welding position：
平焊： F； 立焊(上行) ： Vu； 立焊(下行) ： Vd； 横焊 H； 仰焊 O
电流种类和极性：Type of current & polarity：
交流： AC； 直流正接： DCEN； 直流反接： DCEP； 脉冲电流： Pulsed
☒ ——— 适用 Applicable ☐ ——— 不适用 Not applicable

签名：
Signature

制 造 厂 代 表 日期
Manufacturer _____ Date _____

CCS 验船师 日期
CCS Surveyor _____ Date _____

CHAPTER 5 DESIGN OF WELDING PROCEDURES OF HULL STRUCTURES

Section 1 GENERAL PROVISIONS

5.1.1 Application

5.1.1.1 This Chapter applies to ships and offshore installations for which CCS is requested to carry out surveys during their construction.

5.1.2 Welding procedure specifications and design requirements

5.1.2.1 Prior to commencement of construction, the following technical documents and data are to be provided by the builder to CCS for approval and confirmation:
(1) NDE plans;
(2) Welding consumable details;
(3) Welding procedure specifications;
(4) Welding plans or details.

5.1.2.2 Ships are to be constructed in such a sequence that their structures are assembled at all construction stages of assemblage, blocks and erection under continuous inspection and control.

5.1.2.3 The welding sequence is to be aimed at reducing residual stress, minimizing welding deformation and preventing cracking.

5.1.2.4 The structural design is to ensure the maximum flexibility (by soft toes) and the minimum weld shrinkage strain of structural members.

5.1.2.5 When high-energy beam welding methods such as laser welding are used, the leg length of fillet welds can be reduced provided that the effective throat thickness is ensured. However, verification certificates and relevant quality control measures are to be provided.

Section 2 WELD ARRANGEMENT AND TYPICAL STRUCTURAL JOINTS OF HULL

5.2.1 General requirements

5.2.1.1 The down-hand position is to be applied so far as possible and the overhead position avoided in arranging hull weld positions.

5.2.1.2 Butt welds are to be located so far as possible in hull areas where stresses are small.

5.2.1.3 Local concentration of welds is to be avoided so far as possible, and any intersection of welds with an acute angle is to be avoided to reduce the stress concentration induced by welding.

5.2.1.4 In arranging weld positions, all longitudinal and transverse welds in a plane are required to be aligned.

5.2.2 Weld arrangement for main areas

5.2.2.1 End joints of deck plating are preferably not to be arranged at any of the four corners of a large opening, and any plate joint is to be at least 760 mm or one frame spacing, whichever is the greater, distant from the transverse end of the hatch.

5.2.2.2 Deck plate joints are to be prevented from coinciding with or being to close to welds of structural members above or below the deck plating, generally requiring a distance over 50 mm between them.

5.2.2.3 Where the sheer strake is connected to the stringer plate at the right angle, the upper edge of the sheer strake is to be dressed smooth, and other welded fittings are to be avoided within 0.5 L amidships.

5.2.2.4 Where a rounded sheer strake is adopted, deck fittings welded directly to the rounded sheer strake within 0.5 L amidships are to be avoided. Where any structural member is to be welded outside 0.5 L amidships, it is to be connected by lap joints. Such joints are not allowed to be positioned in the area of the

rounded sheer strake and are to be at least 10 mm distant from the butt weld connecting the rounded sheer strake and deck, e.g. the connection of pontoons to deck for semi-submersible ships.

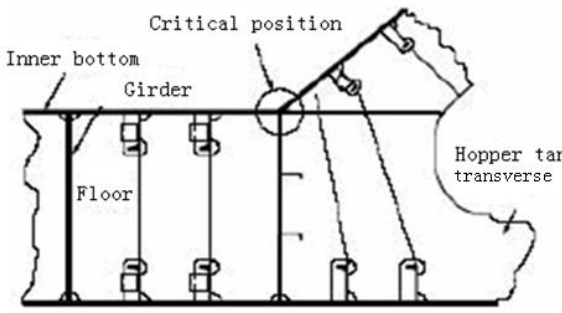
5.2.2.5 When arranging end joints of shell plating, construction techniques applied for hull blocks and full use of plate length are to be taken into account. The end joints of external strakes are to be arranged within the same cross section so far as possible, and end welds amidships may be longer and those at fore and aft ends shorter.

5.2.2.6 When arranging side joints of shell plating, the arrangement of longitudinal members such as deck plating, girders, longitudinals and inner bottom margin plates are to be taken into account, avoiding coincidence of the side joints with fillet welds of longitudinal members or their intersection to an excessively small angle.

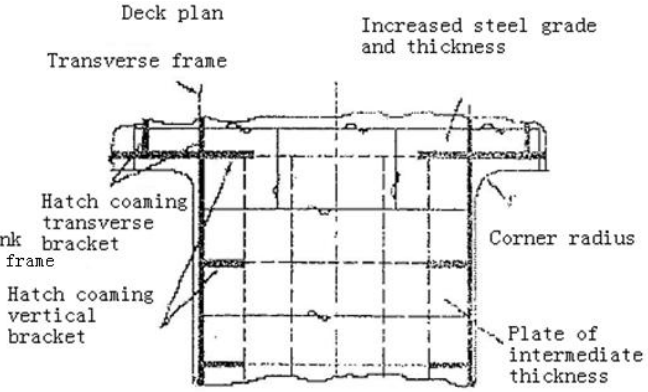
5.2.3 Typical structural joints

5.2.3.1 For the design of hull structural joints within high stress areas or at critical positions, attention is to be given to the effective transmission of forces of structural members, avoiding excessive stress concentration. During construction, good alignment of structural members and their assembling and welding quality are to be assured.

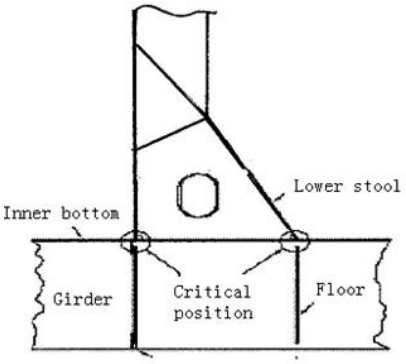
Typical joints of hull structures are shown in Figure 5.2.3.1 (which shows only schematic diagrams and is a not mandatory requirement).



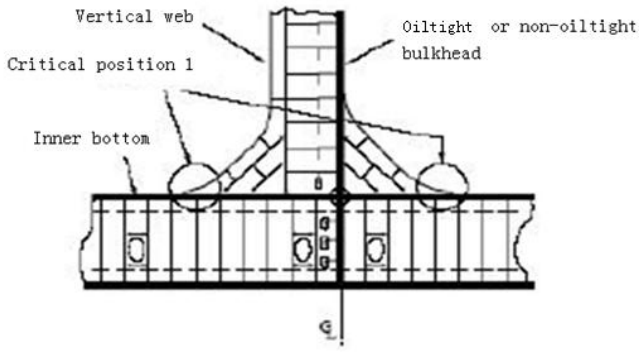
(1) Connection of sloped inner bottom/inner bottom/hopper tank girder



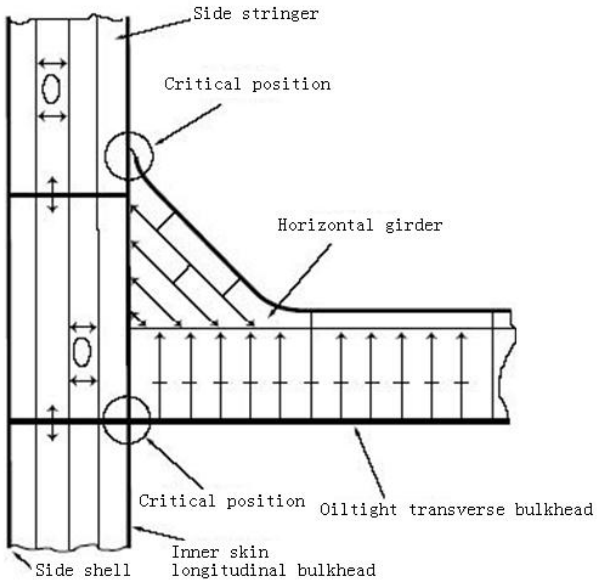
(2) Transition between different plate thicknesses of hatch corners and both sides



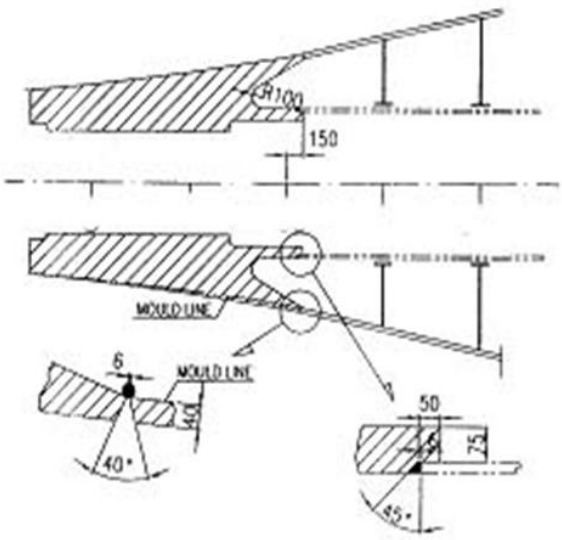
(3) Connection of corrugated bulkhead lower stool to double bottom



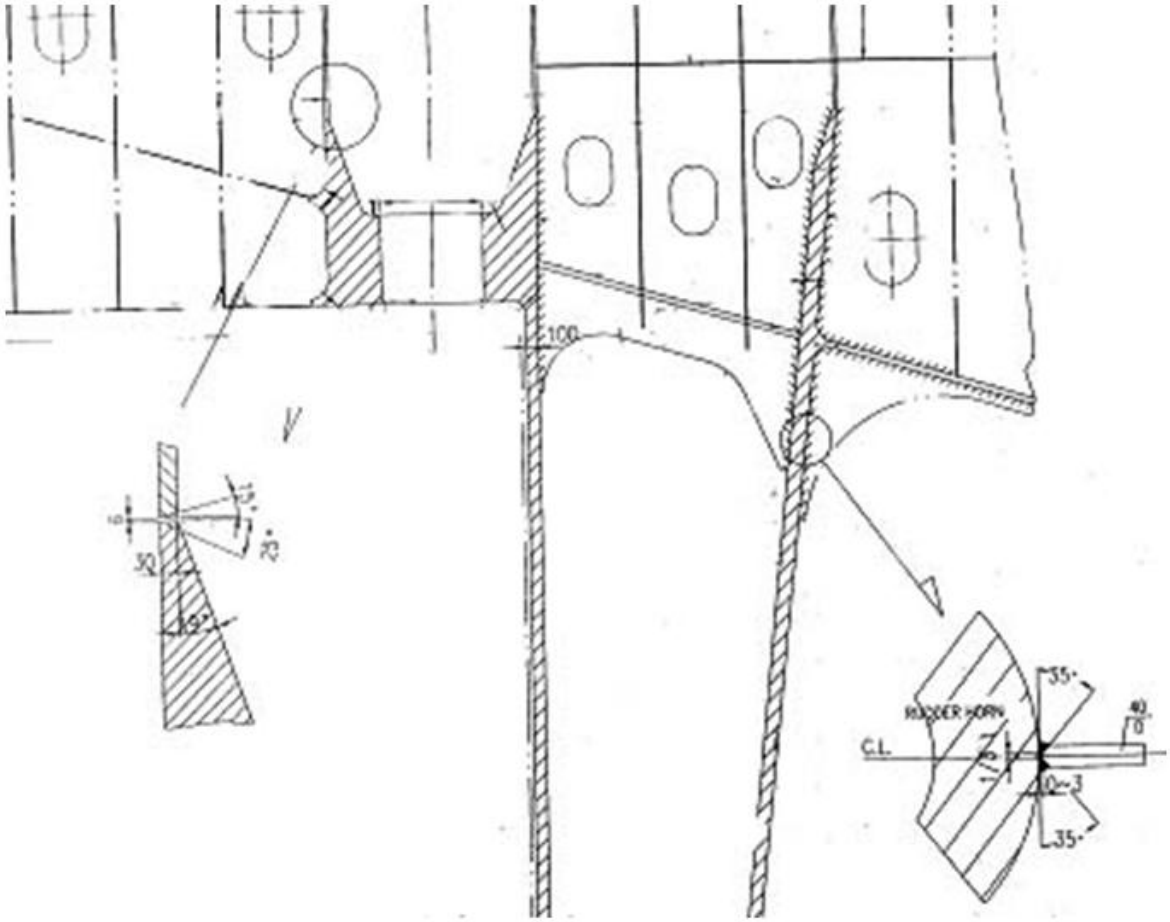
(4) Connection of end bracket toe end of centerline bulkhead vertical web to double bottom floor



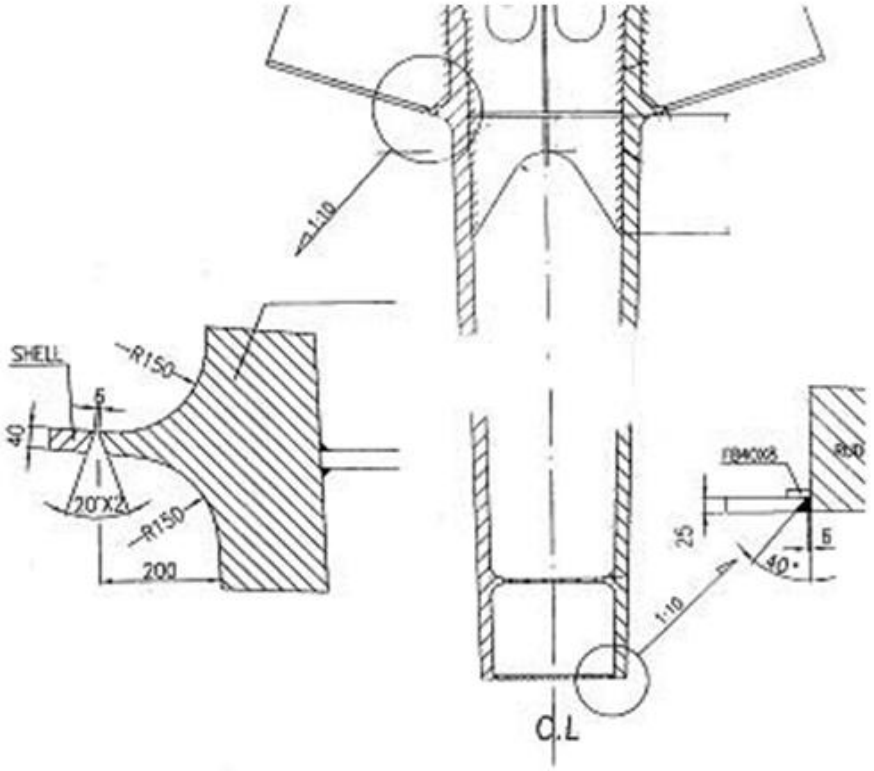
(5) Connection of end bracket toe end of horizontal girder to side stringer



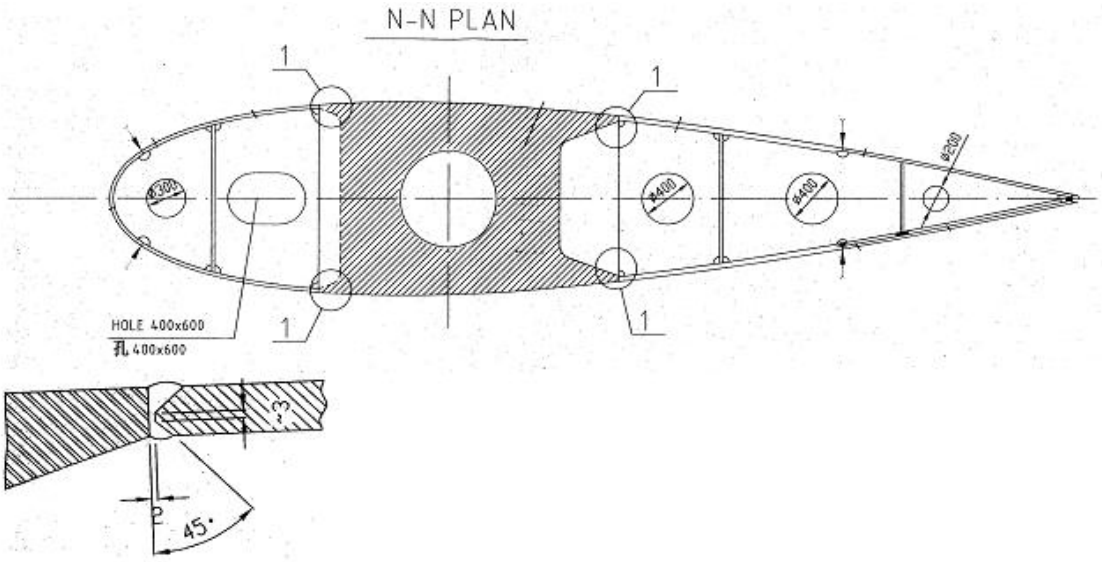
(6) Connection of cast rear shaft hub of stern tube to shell plating



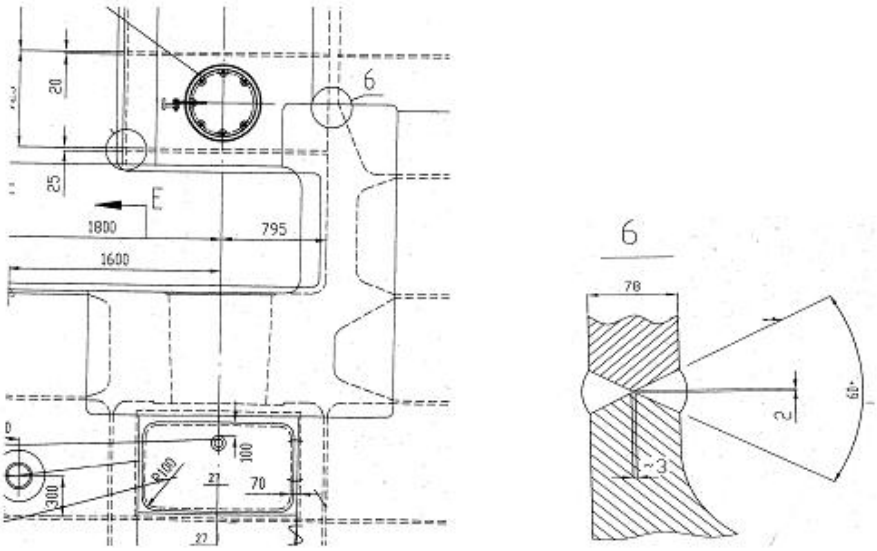
(7) Connection of cast steel rudder horn to stiffening bracket and internals



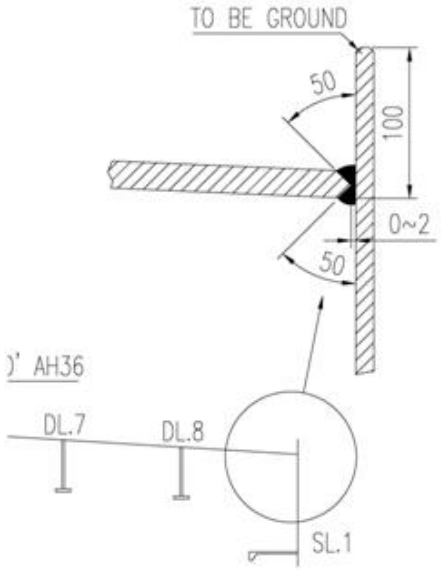
(8) Connection of cast steel rudder horn to hull envelope and lower closing plate



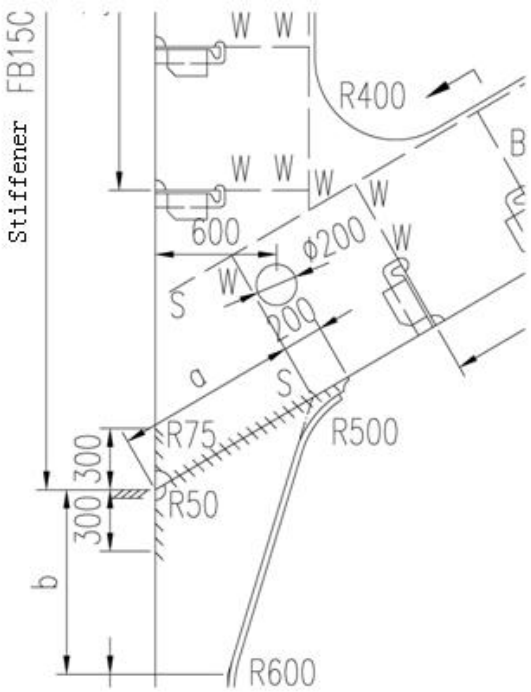
(9) Connection of rudder stock housing associated with rudder blade to upper closing plate



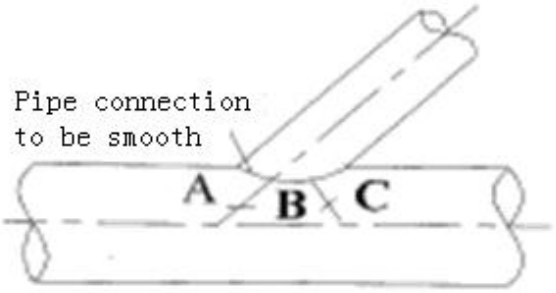
(10) Connection of rudder blade pintle to vertical web plates



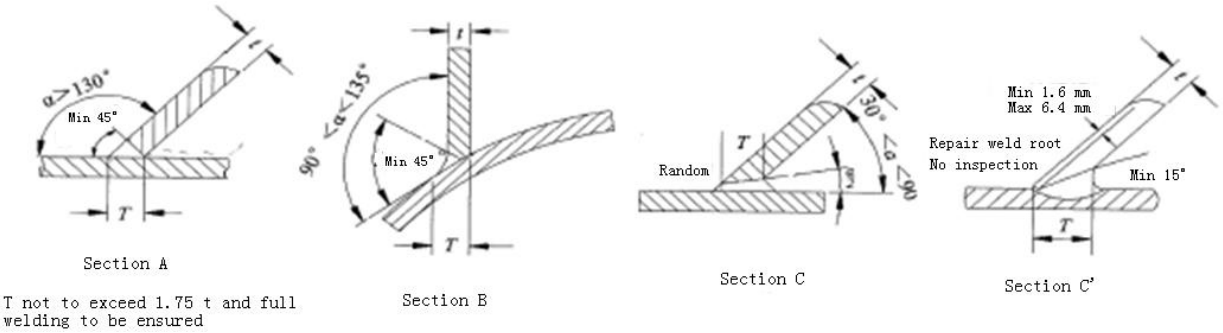
(11) Connection of top strake to main deck plating



(12) Connection of side frame to hull envelope and topside (hopper) tank sloping plate

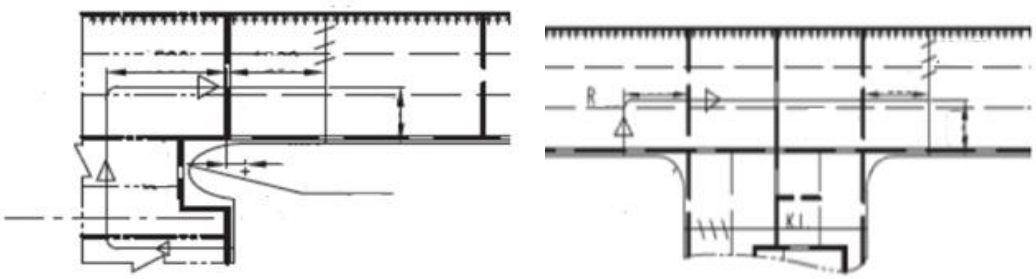


Typical connection
where angle α is formed by crosstie and chord at any point of their intersection with external surface of the connection

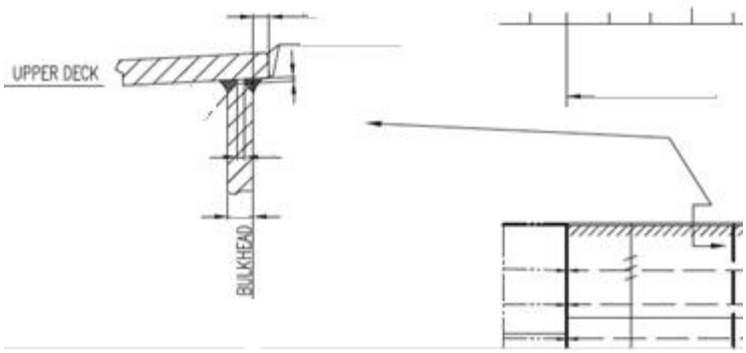


where size "*T*" does not include the concave formed to ensure smooth transition from weld surface to base metal

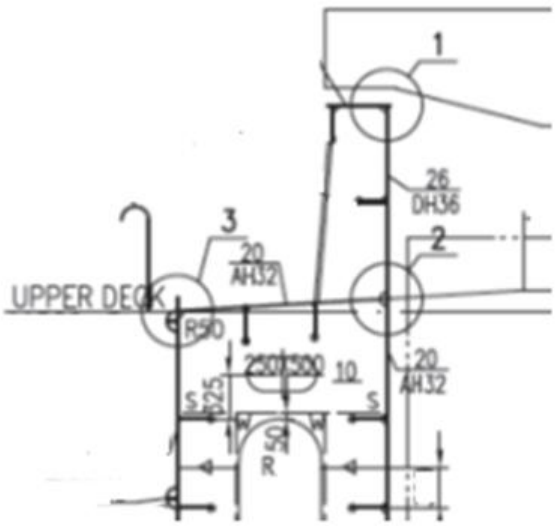
(13) Connection of pipes of structures of fixed offshore installations

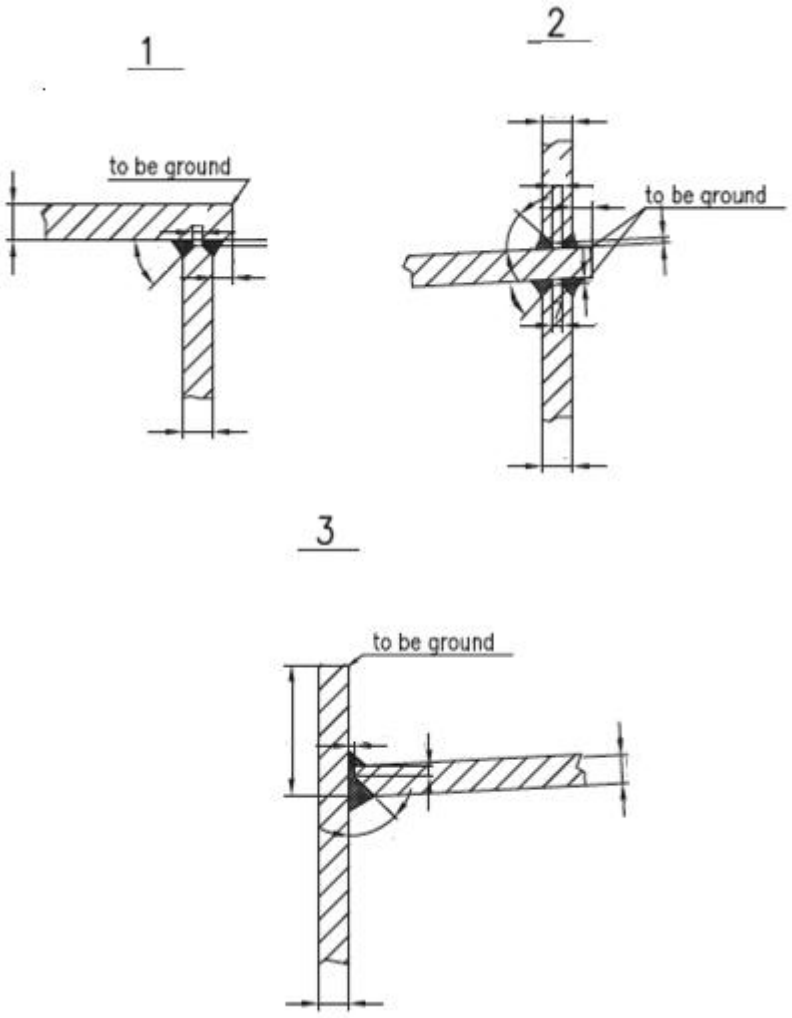


(14) Upper deck Hatch



(15) Main deck and longitudinal bulkhead





(16) Transverse midship section

Figure 5.2.3.1 Typical joints of hull structures

CHAPTER 6 WELDING OF HULL STRUCTURES

Section 1 GENERAL PROVISIONS

6.1.1 Application

6.1.1.1 This Chapter applies to the welding of hull and offshore installation steels, stainless steels, aluminum alloys, copper alloy propellers and stainless steel-clad materials.

6.1.2 Welding procedure specifications

6.1.2.1 Prior to welding, the intended welding procedure specifications are to be submitted by the manufacturer to CCS and such specifications may be used only after approval by CCS. See Chapter 3, PART THREE of CCS Rules for Materials and Welding for details.

6.1.3 Personnel

6.1.3.1 Welding personnel engaged in shipbuilding are to hold a "Qualification Certificate of Welder" issued or approved by CCS, and to be engaged in welding operations appropriate to their respective certificates.

6.1.3.2 Personnel engaged in assembly and visual examinations in shipbuilding are to be those employees of the manufacturer who have rich experience and have been internally trained in their respective specialties.

6.1.4 Pre-weld preparations

6.1.4.1 Welding consumables, edge sizes and assembly accuracy are to comply with approved welding procedures and relevant criteria.

6.1.4.2 Welding areas are to be free from rust, scales, grease and other impurities.

6.1.4.3 Before cutting or welding marine steel plates, shaped steels and molded pieces coated with rust-inhibitive primer, the primer is to be qualified by CCS, otherwise the primer is to be removed.

6.1.4.4 Welders engaged in tack welding are to hold a Qualification Certificate of Welder, and such welding is to be performed according to approved welding procedure specifications and in compliance with the requirements for finished welds.

6.1.5 Welding equipment

6.1.5.1 Welding equipment and devices are to be suitable for the intended purposes and maintained in an effective working condition. Qualified facilities for storing welding consumables used in production are to be set up near the welding workplace. And such equipment and facilities are to be inspected by CCS, if necessary.

Section 2 WELDING OF STEEL HULL STRUCTURAL MEMBERS

6.2.1 General requirements

6.2.1.1 The welding procedure approval test is required for the welding procedure applied in ship construction or repair, and the welding procedure test report and welding procedure specification are to be submitted to CCS for approval.

6.2.1.2 The welding procedure is to comply with that approved by CCS or recognized national or international standards. The procedure approval methods specified in other standards are to comply with CCS requirements. If any other approval is to be adopted, the relevant information and reports are to be submitted to CCS for evaluation.

6.2.1.3 Welding operation and inspection are to be carried out in accordance with design plans and technological documents approved by CCS.

6.2.2 Edge preparation and preheating

6.2.2.1 The details of welding joint may refer to the requirements of Appendix 2, Chapter 4, PART ONE in CCS Rules for Classification of Sea-going Steel Ships.

6.2.2.2 Preheating and interpass temperatures are to be determined by the factors such as steel grade, carbon equivalent, thickness of welded piece, welding condition, welding process and constraint of structures, as well as the results of welding procedure approval test. However, the following requirements are to meet:

(1) Where the preheating temperature of the structural member to be welded is determined according to its chemical composition and thickness, the preheating temperature may be generally selected in accordance with Table 6.2.2.2 (1). For automatic welding processes utilising higher heat input e.g. submerged arc welding, the preheating temperatures may be reduced by 50℃. For re-welding or repair of welds, the preheating temperatures are to be increased by 25℃;

Recommended minimum preheating temperature Table 6.2.2.2(1)

Carbon equivalent①	$T \leqslant 50$mm②	50mm$< T \leqslant$70 mm②	$T >$70mm②
$Ceq \leqslant 0.39$	—	—	50℃
$0.39 < Ceq \leqslant 0.41$	—	—	75℃
$0.41 < Ceq \leqslant 0.43$	—	50℃	100℃
$0.43 < Ceq \leqslant 0.45$	50℃	100℃	125℃
$0.45 < Ceq \leqslant 0.47$	100℃	125℃	150℃
$0.47 < Ceq \leqslant 0.50$	125℃	150℃	175℃

Notes: ① Ceq=C+Mn/6+(Ni+Cu)/15+(Cr+Mo+V)/5 (%).
② $T = t_1 + t_2 + t_3 + t_4$ as shown in Figure 6.2.2.2.

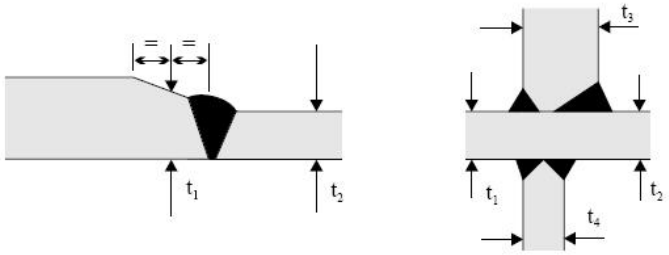


Figure 6.2.2.2 Diagram of thickness for structural member to be welded

(2) Where the approved welding procedure specification does not provide preheating requirement and the welding environment temperature is lower, the preheating temperature of the steel plate to be welded is generally to meet the requirements of Table 6.2.2 (2);

Preheating for welding of hull steels under low temperature Table 6.2.2.2(2)

Items	Standard range	
	Ambient temperature	Minimum preheating temperature①
Normal strength steel (A,B,D,E)	＜-5℃	20℃
TMCP higher strength steel (AH27~EH27,AH32~EH32,AH36~EH36)	＜0℃	
Conventional higher strength steel (AH27~EH27,AH32~EH32,AH36~EH36)	＜0℃	

Note: ① This preheating temperature is to be used unless a higher temperature is specified by the approved welding procedure.

(3) In general, the interpass temperature is not to be lower than the preheating temperature but not higher than 250℃.

6.2.3 Principles for determination of welding sequence

6.2.3.1 The welding sequence is to be selected properly according to the following requirements so as to reduce residual deformation and residual stress induced by welding;
(1) The possibility of free contraction of the steel plate at its weld joint is to be ensured;
(2) The welds which will not exert a rigid fastening effect to other welds are to be applied first;

(3) Where both butt and fillet welds are to be applied for an intersection of a framing and the joint of a plate, butt welds are to be applied before fillet welds;
(4) For the welding of blocks or general blocks, welders are to be arranged in pairs so far as possible to operate gradually from the middle of the block to right and left and fore and aft in a symmetrical manner, thus ensuring a uniform contraction of the structure;
(5) Where structural members and a large joint are located in the same section, the butt weld of the large joint is to be applied first, followed by the butt welds of such structural members, and then their fillet welds, thereby reducing the residual stress of the large joint;
(6) The fillet welds of the frame and bulkhead adjacent to the large joint are generally to be applied after the welding of the large joint.

6.2.4 Hull welding

6.2.4.1 The welding is to be performed in the welding process and condition required by the welding procedure specification, and restraining deformation is to be provided before welding.

6.2.4.2 A welding procedure is to be developed for areas subjected to high stresses, covering the plate edge preparation, root gap and welding sequence.

6.2.4.3 Welded joints are to be arranged to facilitate flat welding position so far as possible. Welding sequence is to be reasonably arranged:
(1) In general, the welds which will cause more contraction are to be applied first, then the welds which will cause less contraction. And the welding is to be performed with a minimum restraint so far as possible;
(2) For the internals of double bottom blocks, butt welds are generally to be applied first, followed by vertical fillet welds, and then flat fillet welds. In addition, the welding is to start from the center of the joint and continue outwards, or start outwards from the centre of the assembly along its periphery, enabling each component to freely move in one or more directions;
(3) The welding for hull erection is to be performed by welders in pairs simultaneously at both sides of the hull in a symmetrical manner, and the number of welders is to be determined according to the tonnage of the ship;
(4) The welding of stiffener members, including transverses, frames, girders, etc., to welded plate panels by automatic processes is to be carried out in such a way as to minimize angular distortion of the stiffener.

6.2.4.4 The total shrinkage caused by the welding procedure specification used in association with fit-up separations, plates and assemblies is to be taken into account so as to ensure construction accuracy of the ship.

6.2.4.5 Randomly striking arc and applying short runs are to be avoided during welding. Where a temporary fitting is welded, the surface is to be ground smooth after removing the temporary fitting and if necessary, a non-destructive testing may be required to the surface.

6.2.4.6 Welds are to be made flush in way of the faying surface where stiffening members, attached by continuous fillet welds, cross the completely finished butt or seam welds. Similarly, butt welds in webs of stiffening members are to be completed and made flush with the stiffening member before the fillet weld is made. The ends of the flush portion are to run out smoothly without notches or sudden changes of section. Where these conditions cannot be complied with, a scallop is to be arranged in the web of the stiffening member. Scallops are to be of a size, and in a position, that a satisfactory return weld can be made.

6.2.4.7 An un-welded length of 300 mm of fillet joints is to be left at fore and aft ends of the framing of all deck blocks, side blocks, double bottom blocks as well as large and medium-sized erections. After completion of faying two adjacent blocks, such length will be welded.

6.2.4.8 Before the welding of cast steel portions of the rudder horn, stern frame and rudder blade as well as hull plates, the surface of castings is to be ground clean and smooth, free from pores, cracks, shrinkage holes, burrs, scabs, slag inclusions, etc. Low-hydrogen welding consumables are to be used and preheated to 100℃ to 120℃ within 200 mm from both sides of the edge. After welding, the weldment is to be tempered at 200℃ to 250℃ for a holding time not less than 2 hours, depending on plate thickness. A non-destructive test is to be performed after 48 hours from completion of welding.

6.2.4.9 Welding operators are to hold qualification certificates for their respective operations; a sufficient number of inspectors are to be provided to ensure an effective quality monitoring during assembling and welding.

6.2.4.10 During welding, the back step method (generally each length not exceeding 2 m) is to be used

for long welds or such method is to be applied by welders in pairs starting from the center of the seam and welding outwards. The welding procedure parameters are to be as approved without any significant change.

6.2.4.11 In a multi-run welding, the surface of deposited metal at each run is to be completely cleaned and the welding slag removed before the following run is performed.

6.2.4.12 For double continuous butt and full penetration welds, the original root run is to be cut back to sound metal and suitable gouged as required by the welding procedure before a back sealing run is applied. Where carbon arc air gouging is used, carbonization or overheat of the base metal as well as the weld seam is to be avoided, otherwise grinding is to be employed.

6.2.4.13 In addition to the requirements of 6.2.2.2, attention is to be paid to heat preservation and slow cooling after welding in a low temperature environment.

6.2.5 Rectification after welding

6.2.5.1 In the process of ship construction, the groove of weldment is different from the design value due to the influence of assembly, precision control, welding and other factors, therefore, rectification is to be taken before or after welding so as to meet the design requirements. For specific requirements, see Appendix 2, Chapter 4, PART FOUR in CCS Rules for Classification of Sea-going Steel Ships.

Section 3 WELDING OF STAINLESS STEEL PLATES

6.3.1 General requirements

6.3.1.1 This Section applies to the welding of stainless steels complying with the requirements of CCS Rules for Materials and Welding.

6.3.1.2 The welding procedure specifications of stainless steels are to be submitted to CCS for approval

6.3.1.3 Welders engaged in the welding of stainless steels (including welders engaged in tack welding) are to comply with the provisions of 6.1.3.1 of this Chapter.

6.3.1.4 Austenitic stainless steels are of good weldability and their weld joints are to have the corrosion resistance equivalent to that of the base metal, capable of preventing general corrosion, intercrystalline corrosion, pitting corrosion, grooving corrosion and stress corrosion.

6.3.1.5 Welding consumables are to be reasonably selected and practicable welding procedures developed to avoid thermal cracks during welding of austenitic stainless steels.
The selection of welding consumables may be referred to Schaeffler’s diagram of stainless steel (Figure 6.3.1.5).

6.3.1.6 Duplex stainless steels are of high strength, good weldability and thermal crack resistance and their weld joints are to have the strength and corrosion resistance equivalent to that of the base metal, capable of preventing general corrosion, gap corrosion, pitting corrosion and stress corrosion.

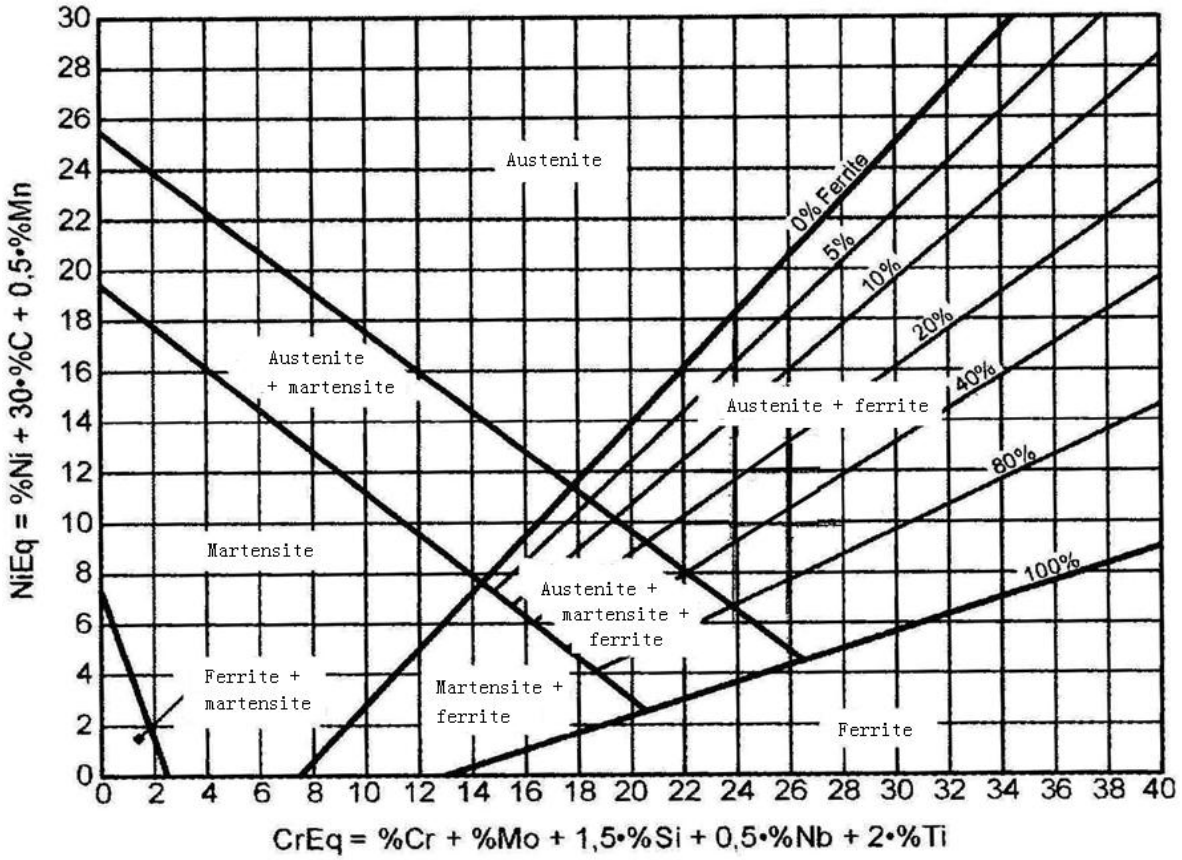


Figure 6.3.1.5 Diagram of stainless steel

6.3.2 Preparation for welding

6.3.2.1 Plate cutting is generally performed by means of plasma and nitrogen or hydrogen argon plasma is to be used instead of fuel gas. The cut edge is to be machined to remove the heat-affected zone; if plate cutting is performed by mechanical shearing, the sheared edge is also to be machined to remove the cold-work hardened zone.

6.3.2.2 Special tools are to be used to cut and fit stainless steels. Grinding disks, saw blades, files or clamping apparatus that have been used on carbon steels are not to be reused on stainless steels.

6.3.2.3 Stainless steel welding grooves and edges are to be prepared by machining. Protection measures are to be taken for the surfaces of stainless steels (including unfinished surfaces) to avoid cuts during construction.

6.3.2.4 The form of edge bevel may be I-shaped, V-shaped or U-shaped groove based on the plate thickness. According to welding processes, edge sizes may be referred to relevant national standards.

6.3.2.5 Prior to welding, the areas within 20 to 30 mm from both sides of the edge are to be cleaned with acetone and coated with lime powders to prevent steel surfaces from being damaged by splatters. The parts to be welded must be free from defects which will affect the strength of welded structures, e.g. burr, wear, slag inclusion and crack.

6.3.2.6 Cutting equipment is to be adjusted in such a way as to make smooth cuts. Notches or gouges on cut surfaces not exceeding 2 mm for materials less than 16 mm in thickness or 10% of the material thickness for materials of 16 mm or greater in thickness need not be repaired, unless specially required by the Surveyor or contractually specified. Notches or gouges exceeding the above limits are to be repaired as specified in 6.3.2.7 to 6.3.2.10.

6.3.2.7 Notches, gouges, or other material discontinuities may be repaired by grinding or machining provided the depth of the notch or gouge does not exceed 3 mm or 20% of the material thickness. Repairs are to be blended smoothly into the surrounding surfaces.

6.3.2.8 Notches or gouges exceeding those specified in 6.3.2.7 are to be repaired by excavation and welding in accordance with the repair procedure approved by the Surveyor. Repaired surfaces are to be

cleaned to bright metal after completing the repair.

6.3.2.9 If discontinuities other than notches or gouges are observed during the cutting operation, the indications are to be explored and repaired as required. Excavation of defective areas is to be limited to a depth of 1/3 of plate thickness without prior approval by the Surveyor.

6.3.2.10 Defect excavation or repairs exceeding 1/3 of plate thickness may be done only with prior approval and direction from the Surveyor. Defect exploration or repairs anticipated to exceed a depth of 1/3 of plate thickness is to be examined by methods specified by the Surveyor to determine the extent of the defect before exceeding that depth.

6.3.2.11 If the plate thickness is not greater than 6 mm, the weld length of tack welding is to be greater than 20 mm; If the plate thickness is greater than 6 mm, the weld length of tack welding is to be greater than 25 mm; Where both sides welding is used, the start and end of tack welding welds are to be ground clean； Where one-side welding without backing is used, the welds of tack welding are to be removed completely before welding; Where one-side welding with backing is used, the tack welding is not to be used.

6.3.2.12 The relevant requirements for the selection of welding consumables for stainless steels are given in Chapters 2 and 5, PART THREE of CCS Rules for Materials and Welding.

6.3.2.13 See Appendix 6A of this Chapter for common joint types of stainless steel hull structures.

6.3.3 Fit-up separations

6.3.3.1 Parts to be joined by fillet welds are to be brought into alignment. Fit-up separations are generally 2 mm, not exceeding 5 mm.

6.3.3.2 The separations between the faying surfaces of lap joints, plug and slot welds, and butt joints landing on a backing are not to exceed 2 mm. The lapped portions of lap joints are to be lapped closely together so far as possible.

6.3.3.3 The welding grooves, root gaps and root face sizes of parts to be welded are to be in accordance with the approved welding procedure specification.

6.3.3.4 Root openings greater than those permitted in the approved WPS, but not greater than twice the thickness of the thinner part, may be corrected by welding to acceptable dimensions prior to joining the parts by welding.

6.3.4 Welding of stainless steels

6.3.4.1 The stainless steel welding processes commonly used in the shipbuilding industry are gas tungsten arc welding, shielded metal arc welding and gas metal arc welding. In order to improve the welding efficiency, submerged arc welding and flux cored metal arc welding may also be used.

6.3.4.2 The requirements for stainless steel welding are given in Section 4, Chapter 5, PART THREE of CCS Rules for Materials and Welding.

6.3.4.3 The retention time of austenitic stainless steels for welding within 450-850℃ is to be shortened to avoid precipitation of chromium carbide. The phenomenon of chromium deficiency occurs on the grain surface of grain boundary which results in inter-granular corrosion.

6.3.4.4 Where the thickness of the welded structural members of duplex stainless steel is not less than 25 mm and/or high degree of restraint, uniform preheating can be used for the heater band.

6.3.4.5 The cooling rate of duplex stainless steel welding is to be properly controlled by means of joint design, welding process, preheating, welding heat input and interpass temperature control to avoid welding defects.

6.3.4.6 Characteristics and application of gas tungsten arc welding:
(1) The thermal power of the electric arc is low, the travel speed is slow, the time required for cooling joints in the dangerous area is long and corrosion resistance is poor;
(2) Suitable for backing weld of plate structures not exceeding 8 mm in thickness or pipes of up to 60 mm in diameter and thick pieces.

The edge preparation of joints is shown in Table 6.3.4.6.

Edge preparation of stainless steel butt joints made by GTAW Table 6.3.4.6

Thickness of weldment *t* (mm)	Edge preparation	Edge size		Remarks
		Gap a (mm)	Root face p (mm)	
2.4	I-shaped	0 ~ 1	—	One-side welding
3.2	I-shaped	0 ~ 2	—	Welding by both sides (Pipes: One-side welding)
4	I-shaped	0 ~ 2	—	Welding by both sides
6	V-shaped	0 ~ 2	0 ~ 2	Back gouging
	V-shaped	0 ~ 2	0 ~ 2	Backing plate
	V-shaped	3 ~ 5	–	Backing plate
12	V-shaped	0 ~ 2	0 ~ 2	Back gouging
	V-shaped	0 ~ 2	0 ~ 2	Backing plate
	V-shaped	3 ~ 5	–	Backing plate
22	Double side V-shaped	0 ~ 1	–	Back gouging
38	Double side V-shaped	0 ~ 2	2 ~ 3	Back gouging

6.3.4.7 Characteristics and application of shielded metal arc welding:
(1) The current is small, the travel speed quick and the welding quality easy to guarantee;
(2) Where a multi-run welding is required, slag inclusions between runs are to be removed, and the interpass temperature is to be below 100℃;
(3) The welds in contact with any corrosive medium are to be made last;
(4) After completion of welding, forced cooling may be applied to accelerate cooling of joints;
(5) Suitable for procedures used for various welding positions and different plate thicknesses.
The edge preparation of joints is shown in Table 6.3.4.7.

Edge preparation of stainless steel butt joints made by shielded metal arc welding Table 6.3.4.7

Thickness of weldment *t* (mm)	Edge preparation	Edge size		Remarks
		Gap a (mm)	Root face p (mm)	
2	I-shaped	0 ~ 1	—	Back repair by grinding disk
3	I-shaped	2	—	
5	V-shaped 75°	2	2	
6	V-shaped 75°	2	2	
9	V-shaped 75°	2	2	
12	V-shaped 75°	2	2	
16	V-shaped 75°	2	2	
22	V-shaped 60°	2	2	

6.3.4.8 Characteristics and application of submerged arc welding:
(1) The current density is great, the heat is concentrated, unfilled cavities are large, and burning-through occurs easily where a gap is big;
(2) In practice, a backing plate is often attached to the back of the weldment to prevent burning-through and in addition, a back sealing run is done by shielded metal arc welding;
The edge preparation of butt joints made by double submerged arc welding is shown in Table 6.3.4.8.

Edge preparation of stainless steel butt joints made by double submerged arc welding Table 6.3.4.8

Thickness of weldment *t* (mm)	Edge preparation	Root face *p*(mm)	Remarks
6-12	I-shaped	--	
13-16	Double side 90° V-shaped	4-7	
>16	Double side 90° V-shaped	4-7	

6.3.4.9 Characteristics and application range of fluxed-cored arc welding:
(1) The current density is great and the deposition efficiency is high;
(2) The welding gun is put forward while welding in flat position and oscillating wire-feed means are not recommended;
(3) Where pure CO_2 is selected as shielding gas, the occurrence of recarburization is to be strictly controlled;
(4) Applicable to welding of various positions and different thickness.

For edge preparation of joints, see Table 6.3.4.9.

Edge preparation of stainless steel butt joints made by fluxed-cored arc welding Table 6.3.4.9

Thickness of weldment *t* (mm)	Edge preparation	Edge size		Remarks
		Gap a (mm)	Root face p (mm)	
3-6	I-shaped	0-3	—	
5-16	One-side V-shaped 60°-70°	0-3	1-2	Welding by both sides, grinded on the back
5-16	One-side V-shaped 40°-50°	3-5	1-2	One-side welding, backed with ceramic
>16	Double side 60°-70°V-shaped	0-3	1-3	
>25	Double side 10°-15°U-shaped	0-3	1-3	

6.3.5 Cleaning and post-weld treatment of stainless steel welds

6.3.5.1 All welds and adjacent base metals are to be cleaned by brushes made of stainless steel wires or other suitable means.

6.3.5.2 Arc strikes are to be removed by stainless steel grinding tools or other suitable means. Cracks or blemishes and other post-weld surface defects caused by arc strikes are to be ground to a smooth contour and examined visually (dye penetrant testing is to be carried out where necessary) to assure complete removal.

6.3.5.3 The welded stainless steel parts are to be polished and passivated to improve their surface corrosion resistance. The external surface of passivated stainless steels is silvery white and highly resistant against corrosion.

6.3.5.4 Weldments, which are complex in their structural design or the joints of which tend to stress corrosion cracking, may be treated for stress relief or solution treatment.

Section 4 WELDING OF ALUMINUM ALLOYS

6.4.1 General requirements

6.4.1.1 This Section applies to the welding of aluminum alloys complying with the requirements of CCS Rules for Materials and Welding.

6.4.1.2 The welding procedure specifications of marine aluminum alloys are to be submitted to CCS for approval

6.4.2 Characteristics of aluminums and aluminum alloys

6.4.2.1 Due to their strong oxidizing property, great heat conductivity and specific heat capacity, significant thermal cracking tendency, easy blistering, joints of different strengths, easy burning-through of weldments, evaporation and burning loss of alloy elements, the welding of aluminum alloys is more difficult than that of low carbon steels.

6.4.3 Preparation for the welding of aluminums and aluminum alloys

6.4.3.1 Aluminums and aluminum alloys are to be cut and beveled by machining, or cut by means of plasma or laser.

6.4.3.2 The greasy dirt is to be removed by organic solvents such as acetone and carbon tetrachloride; the oxide film is to be removed by chemical or mechanical means. The cleaned parts are to be welded within 24 hours, otherwise they are to be re-cleaned.

6.4.3.3 Graphite, stainless steel or carbon steel backing plates may be used to ensure full penetration and prevent the burning-through or collapse of the weldment.

6.4.3.4 In order to reach the required temperature near the joint so as to reduce deformation and pores etc., parts greater than 8 mm in thickness are to be preheated to a temperature beyond the temperatures which would make the alloy susceptible to corrosion. Where a multi-run welding is required, the interpass temperature is to be kept not below the preheating temperature. Aluminum magnesium alloys are not to be

held too long within the temperature range of 65℃ to 200℃.

6.4.4 Welding of aluminums and aluminum alloys

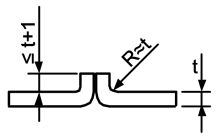
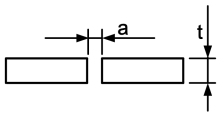
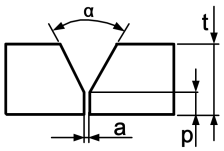
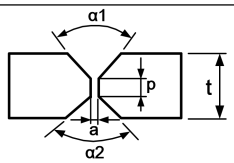
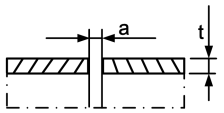
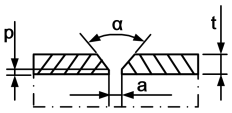
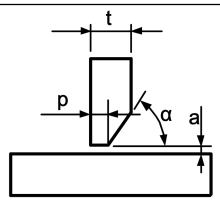
6.4.4.1 The plates of hull and superstructures may be joined by gas tungsten arc welding and gas metal arc welding. For the fillet welds of hull plating and framing, gas metal arc welding is applied to weld aluminum alloy structures.

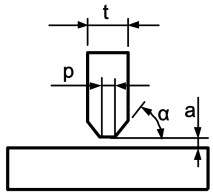
6.4.4.2 Aluminum alloys are to be welded and repaired in accordance with the requirements of Section 2, Chapter 11, PART THREE of CCS Rules for Materials and Welding.

6.4.4.3 Characteristics and application of gas tungsten arc welding: The heat of the electric arc is concentrated, the arcing is stable, the weld profile and joint quality are good, but the production efficiency is low. It is widely applied in welded marine aluminum structures. T-shaped welds are to be used in joining hull envelope plates and cruciform ones avoided so far as possible.

6.4.4.4 The joint types and edge sizes for the gas tungsten arc welding are to be determined mainly according to the structure of the product, the thickness of parts to be welded and the welding procedure. The typical edge preparation for the gas tungsten arc welding of aluminums and aluminum alloys is shown in Table 6.4.4.4.

Typical Edge Preparation for GTAW of Aluminums and Aluminum Alloys **Table 6.4.4.4**

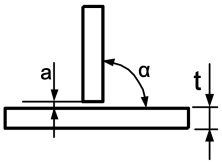
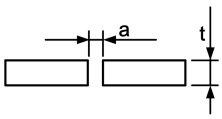
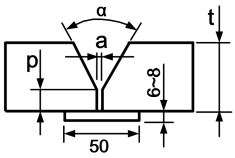
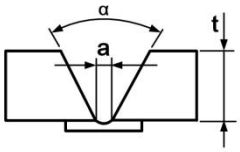
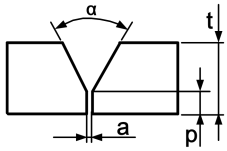
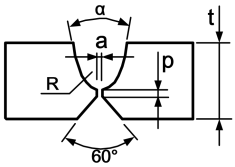
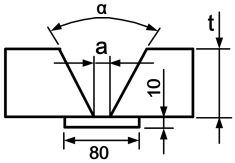
Thickness of weldment *t*(mm)	Edge preparation	Edge size			Remarks
		Gap *a* (mm)	Root face *p* (mm)	Angle α(°)	
≤2		-—	-—	—	Without filler wires or rods
1 ~ 3 3 ~ 5		0 ~ 0.5 1 ~ 2	—	—	Welding by both sides, back gouging
3 ~ 5 6 ~ 10 12 ~ 20		0 ~ 1 1 ~ 3 1.5 ~ 3	1 ~ 1.5 1 ~ 2.5 2 ~ 3	70 ± 5 70 ± 5 70 ± 5	Welding by both sides, back gouging
14 ~ 25		1.5 ~ 3	2 ~ 3	*α1*: 80±5 *α2*: 70±5	Welding by both sides, back gouging, 2 or more layers on each side
Pipe wall thickness ≤ 3.5		1.5 ~ 2.5	—	—	Welding of pipes at rotatable flat position
3 ~ 10 (external pipe diameter 30 ~ 300)		< 4	< 2	75 ± 5	Fixed backing plate may be used for inner pipe wall
4 ~ 12		1 ~ 2	1 ~ 2	50 ± 5	

8 ~ 25		1 ~ 2	1 ~ 2	50 ± 5	

6.4.4.5 Characteristics and application of gas metal arc welding: The power of the electric arc is great, the heat is concentrated, the deformation is minor, the heat-affected zone is small and the production efficiency is high. It is commonly applied for plates having a medium thickness not less than 3 mm, with the power source being direct current electrode negative.

The edge preparation for the gas metal arc welding of aluminums and aluminum alloys is shown in Table 6.4.4.5.

Edge preparation for gas metal arc welding of aluminums and aluminum alloys **Table 6.4.4.5**

Thickness of weldment *t*(mm)	Edge preparation	Edge size			Remarks
		Gap *a*(mm)	Root face *p*(mm)	Angle α(°)	
1.5 ~ 3		0	—	90	Semi-automatic welding
3 ~ 8		0 ~ 1			
3 ~ 8		0 ~ 1	—	—	Semi-automatic welding
8 ~ 15		3 ~ 6	2 ~ 3	40	Semi-automatic welding with backing
8 ~ 15		2 ~ 4	—	70	Semi-automatic welding with ceramic backing
5 ~ 15		0 ~ 0.5	3 ~ 8	60	Automatic welding
16 ~ 25		1 ~ 2	6 ~ 10	70	
18 ~ 25		1 ~ 2	7	70	Automatic welding R = 14
15 ~ 25		6 ~ 10	—	40	Automatic welding with backing

6.4.5 Post-weld cleaning of aluminums and aluminum alloys

6.4.5.1 After completion of welding, the residual solvent and welding slag left at welds and in the vicinity need to be removed in time.

Section 5 WELDING OF STAINLESS STEEL PIPES

6.5.1 General provisions

6.5.1.1 This Section applies to the welding of austenitic and austenitic/ferritic duplex stainless steel pressure pipes as required by CCS Rules for Materials and Welding.

6.5.1.2 The welding procedure specification of stainless steel pipes is to be submitted to CCS for approval.

6.5.1.3 Welders engaged in the welding of stainless steel pipes is to comply with the requirements of 6.1.3.1.

6.5.1.4 In addition to satisfying the requirements of Section 3 of this Chapter and relevant requirements for stainless steels of Rules for Materials and Welding, the welding of stainless steel pipes is also to comply with the requirements of this Section.

6.5.2 Preparations before welding

6.5.2.1 Pipe sections are generally taken by machining, and pipes are to be cut smoothly and free from excessive burrs.

6.5.2.2 The verticality between end face and pipe outer surface is to comply with relevant standards after the pipe is cut.

6.5.2.3 The types of welding grooves are in general classified as I-shaped and V-shaped grooves based on the thickness of pipe wall. The welding grooves and root gap of the pipe to be welded are to comply with the approved welding procedure specification (WPS) and recognized standards.

6.5.2.4 Before welding, the grooves and an area within the scope of at least 20 mm from the grooves of the pipe are to be free from rust and grease. If rust, grease and oxides exist, a special stainless brush may be used to remove the oxides on the working surface and the surface is to be cleaned with acetone.

6.5.3 Tack welding

6.5.3.1 Shielded metal arc welding (SMAW) or manual TIG welding may be used for tack welding. Generally, shielding gases are not required to be filled into the pipe when shielded metal arc welding (SMAW) is used, but the slag crust on the back of the tack welding is to be removed. Shielding gases must be filled before TIG tack welding.

6.5.3.2 The spacing between welding points of tack welding is to be determined according to the designation, thickness and joint types of the materials to be welded.

6.5.4 Welding of stainless steel pipes

6.5.4.1 At present the common welding processes for welding of stainless steel pipes in shipbuilding include argon-shielded tungsten arc welding, shielded metal arc welding (SMAW), metal argon-shielded arc welding, metal CO2 welding with flux-cored wires and root run with argon-shielded tungsten arc welding and shielded metal arc welding (SMAW) by capping run.

6.5.4.2 Welding of stainless steel pipes 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 avoid swing on both sides.

6.5.4.3 Multi-layer and multi-run welding with low deposition rate is to be used for welding of duplex stainless steel pipes so as to ensure the organization and property of weld joints.

6.5.4.4 For welding of duplex stainless steel pipes, interpass temperatures are to be kept as low as practicable. Generally, the highest interpass temperature of duplex stainless steel is 150℃ and that of super duplex stainless steel is 100 ℃. The welding procedure parameters are to be in accordance with the

requirements for approval of procedures so as to avoid embrittlement at 475℃ and forming of δ phase.

6.5.4.5 Before welding of stainless steel pipes of different thickness, the grooves of joint are to comply with the design requirements so as to avoid incomplete penetration, overlap or unweldable situations.

6.5.4.6 Before welding the branches, the size of plate-cutting, angle of edge, assembly gap and diameter of openings of the pipes connected are to comply with the design requirements.

6.5.5 Cleaning of stainless steel welds and post-weld treatment

6.5.5.1 Welds and base metals in adjacent areas are to be cleaned by stainless steel brush or other appropriate methods.

6.5.5.2 Welds and surrounding oxide scale and welding spot are to be removed by grinding or other appropriate ways after welding of stainless steel pipes to ensure that the welds and adjacent areas are clean.

6.5.5.3 Acid dip or passivating is to be carried out for welded stainless steel pipes so as to achieve sound corrosion resistance in surface areas.

Section 6 WELDING OF AUSTENITIC STAINLESS STEEL-CLAD PLATES

6.6.1 General requirements

6.6.1.1 This Section applies to the welding of austenitic stainless steel-clad plates

6.6.1.2 The welders engaged in the welding of austenitic stainless steel-clad plates are to be trained in and certified for relevant operations. In addition, the welding consumables approved by CCS are to be used.

6.6.1.3 Weld joints are to have the same corrosion resistance as the clad metal, and the corrosion-resistant deposited metal is to be at least of the same thickness as the cladding of the original clad plate.

6.6.2 Welding consumables

6.6.2.1 The welding consumables selected for the base metal and cladding metal are to be respectively suitable for the separate welding of the base metal and cladding metal. The welding procedure used is to be also the same.

6.6.2.2 The welding of the transitional layer is that of dissimilar steels, and the welding consumables are to be selected accordingly. In order to reduce the dilution of the weld metal of the cladding by the base metal and to make up the alloy elements burnt during welding, the Cr and Ni contents of welding consumables are to more than those of the stainless steel cladding.

6.6.3 Pre-weld preparations

6.6.3.1 A proper groove shape in connection with a correct welding sequence is to be employed. The usual edge preparation is shown in Figure 6.6.3.1.
For important components which are stressed, a transitional groove is to be used.

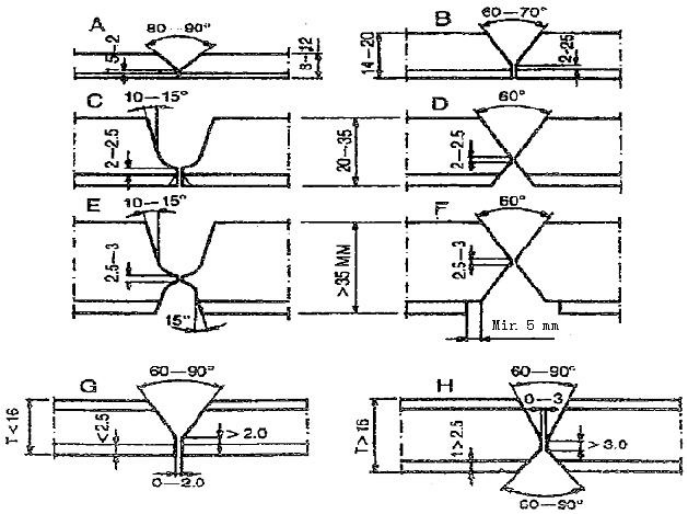


Figure 6.6.3.1 Usual edge preparation

6.6.3.2 Grooves are to be cut and edges prepared preferably by means of cold work.

6.6.3.3 Where a shearing machine is used to shear austenitic stainless steels, the cladding material is to face upwards.

6.6.3.4 Where grooves are to be cut and edges prepared by means of hot work, plasma cutting is to be employed so far as possible. The cut surfaces which affect the welding quality are to be removed by cold work.

6.6.3.5 Where grooves are cut and edges prepared by means of plasma, the cladding material is to face upwards and to be cut first; where flame cutting is employed, the cladding material is to face downwards and the cutting is to start from the base metal.

6.6.3.6 Where grooves are to be cut and edges prepared by means of hot work, cut slags are to be prevented from being splattered onto the cladding.

6.6.3.7 The base metal is to be cleaned by a carbon wire brush and the cladding by a stainless steel brush.

6.6.3.8 Preheating and tack welding
(1) When the base metal or the cladding needs to be preheated, the total thickness of the clad steel is to be used as the thickness parameter for determining the preheating temperature;
(2) When the base metal or the cladding needs to be preheated, the transitional weld must also be preheated;
(3) Tack welds are to be made on the base metal.

6.6.4 Welding procedure

6.6.4.1 In general, the welding sequence of clad steel plates is to be such that the base metal is welded first, followed by a transitional weld, and the cladding is welded last.

6.6.4.2 No carbon steel or low alloy steel welding consumables are to be used for the cladding metal, transitional weld and cladding weld.

6.6.4.3 The transitional weld is to simultaneously fuse the base metal weld, base metal and cladding metal, and cover the base metal weld and base metal.

6.6.4.4 When welding clad materials, the mixing of base metal and weld deposit, as well as the mixing of two types of high alloyed weld deposit is to be held at a minimum. Low welding current and small welding consumable dimensions are to be used. The degree of dilution is preferably to be kept below 30%. The degree of dilution is to be calculated as follows:

$$\text{Degree of dilution} = \frac{B}{B+W} \times 100\%$$

where: B – volumetric percentage of base metal in the weld metal;
W – volumetric percentage of weld deposit in the weld metal.

6.6.4.5 For the welding of stainless steel-clad plates, the carbon steel base is to be welded first, with at least two alloy layers being deposited, then the stainless steel clad is to be chipped to a curvature till the

base metal weld and ground clean to prevent insufficient penetration. Then the transitional weld is to be made to fuse one layer of the stainless steel clad, achieving an effect of separation. The clad material on the transitional layer is to be welded last.

6.6.4.6 When welding pipes where there is access only from the outside, the entire cross section is to be built up by alloyed weld metal corresponding to the cladding. The sides of the groove are preferably to be covered with an over-alloyed consumable (buttering) before joining.

6.6.5 Post-weld treatment and weld inspection

6.6.5.1 The relevant requirements for the post-weld treatment and weld inspection are given in Section 4, Chapter 5, PART THREE of CCS Rules for Materials and Welding.

Section 7 WELDING OF ALUMINIUM-STEEL TRANSITION JOINTS

6.7.1 General provisions

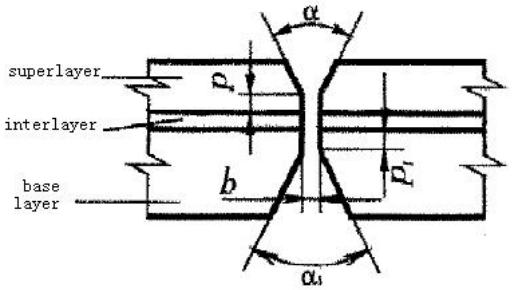
6.7.1.1 This Section applies to the welding between aluminium-steel transition joints (hereinafter referred to as transition joints) in compliance with the requirements of Section 5, Chapter 8, PART ONE of CCS Rules for Materials and Welding as well as welding of transition joints to structural members.

6.7.1.2 The welding procedure specification of transition joints is to be submitted to CCS for approval.

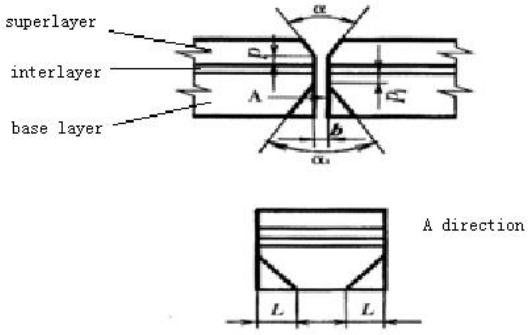
6.7.1.3 The welders engaged in the welding of transition joints are to be trained and certified for steel and aluminium alloy welding qualification respectively.

6.7.2 Welding joint types between transition joints

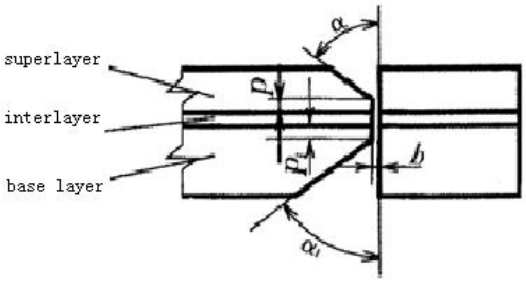
6.7.2.1 Welding joint types between transition joints are butt joints and fillet joints. The specific edge preparations are as follows:
(1) turnable free butt joint, see Figure 6.7.2.1(1);
(2) non-turnable restrained butt joint, see Figure 6.7.2.1(2);
(3) Tee joint, surfaces of transition joints on the same side, see Figure 6.7.2.1(3);
(4) corner joint, surfaces of transition joints vertical to each other, see Figure 6.7.2.1(4).



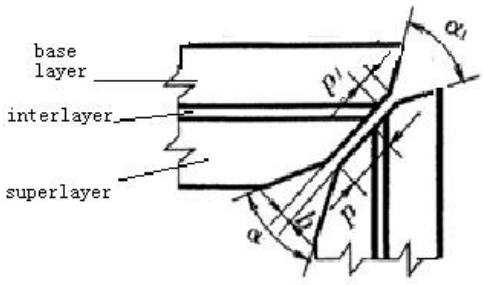
(1) Turnable free butt joint



(2) Non-turnable restrained butt joint



(3) Tee joint, surfaces of transition joints on the same side



(4) Corner joint, surfaces of transition joints vertical to each other

Figure 6.7.2.1 Edge preparations between transition joints

6.7.2.2 For the welding between special transition joints the interlayer of which is aluminium and relatively thick, the edges may be beveled to the interlayer. Typical butt joints are shown in Figure 6.7.2.2.

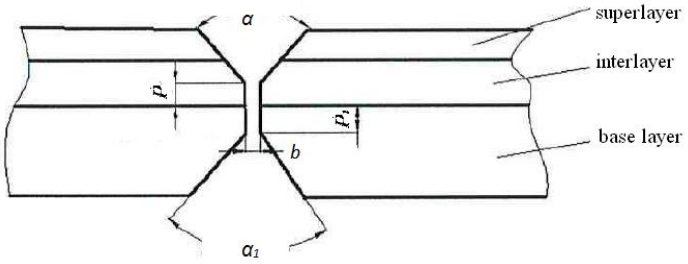


Figure 6.7.2.2 Edge preparation for welding between special transition joints

6.7.2.3 Welding between transition joints and structural members is mainly fillet joints. There are two types of connection between the base layer of transition joints and structural members as follows:
(1) transition joints welded directly to the structural members, see Figure 6.7.2.3(1);
(2) transition joints first welded to the steel coaming and then welded to the structural members, see Figure 6.7.2.3(2).

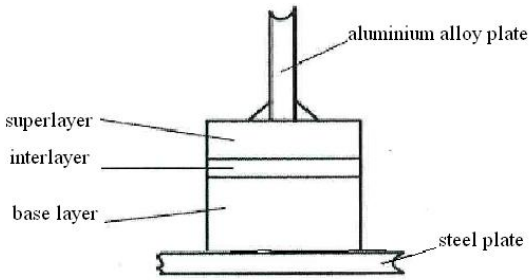


Figure 6.7.2.3(1) Welded to hull structure directly

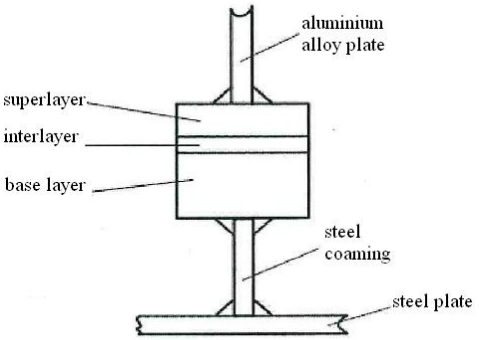


Figure 6.7.2.3(2) Welding using steel coaming

6.7.3 Approval requirements of welding procedures

6.7.3.1 For welding between transition joints, materials corresponding to the base steel and cladding aluminium alloy are to be subjected to welding procedure approval tests respectively. The approval test and its coverage are to comply with relevant provisions of Chapter 3, PART THREE of CCS Rules for Materials and Welding.

6.7.3.2 For welding of transition joints to structural members, relevant steels and aluminium alloy are to be subjected to welding procedure approval tests respectively. The approval test and its coverage are to comply with relevant provisions of Chapter 3, PART THREE of CCS Rules for Materials and Welding. In addition, when transition joints of a different type are used for the first time, additional welding procedure approval tests are to be carried out in accordance with the requirements of 4.5.4, Section 5, Chapter 4 of these Guidelines.

6.7.4 Preparations before welding

6.7.4.1 Plate cutting and edge preparation of transition joints are to be by mechanical means or other means not affecting the bonding performance of clad interface.

6.7.4.2 The edge preparations of transition joints are specified in Figure 6.7.2.1 or Figure 6.7.2.2. The specific dimensions are specified in Table 6.7.4.2. The lower limit of root face and the upper limit of gap are to be strictly controlled.

Edge dimensions for welding of transition joints Table 6.7.4.2

α	α_1	p (mm)	p_1 (mm)	b (mm)	L (mm)
60°～70°	50°～60°	3～4	3～4	≤1.5	8～10

6.7.4.3 The weldment edge and the area within 30 mm of the edge are to be removed of impurities such as rust, water, oil. The aluminium oxide film is to be removed by mechanical or other effective means.

6.7.4.4 Avoid forced assembly of transition joints. During assembly, necessary jigs may be used and care is to be taken to protect the surface of aluminium alloy. For the assembly between transition joints, the misalignment from the interlayer is to be less than 0.5 mm.

6.7.4.5 The base layer and superlayer between transition joints are both to have tact welds. Tact welding of transition joints to hull structures may be on one side or both sides of the member.

6.7.5 Welding

6.7.5.1 The general requirements for welding of transition joints are as follows:
(1) The principle that base layer is welded to base layer and superlayer to superlayer is to be followed.
(2) During welding operations, the interface temperature of interlayers is not to exceed the critical temperature (for aluminium-titanium-steel joints, 350℃; for aluminium-aluminium-steel joints, 300℃), the surface temperature measured in the process of welding test may be used to assist judgment;
(3) Welding procedures and parameters with lower heat input are to be used;
(4) Welding consumables used are to be appropriate to the base and cladding materials respectively;
(5) Where multi-run welding is used, the interpass temperature is not to exceed 60℃;
(6) Generally the aluminium side is welded before the steel side. If this sequence cannot be followed, the steel side can be welded first. However, effective means are to be taken to keep the welding area on the aluminium side clean.

6.7.5.2 The welding between transition joints are to satisfy the following requirements in addition to those specified in 6.7.5.1:
(1) Run-on and run-off tabs are to be used during welding operations, and means are to be taken to avoid deformation;
(2) Shielded metal arc welding (SMAW) or CO_2 semi-automatic welding may be used for base layers, and inert gas-shielded arc welding (TIG or MIG welding) for superlayers;
(3) During welding operations, care is to be taken to avoid fusion of interlayers (except for the edge preparation specified in 6.7.2.1(3)). Welding parameters used are to be as close to the lower limit of heat input determined by welding procedure approval carried out in accordance with 6.7.3.1 as possible;
(4) Finished joints are to be machined flush and both sides of joints are to be remedied;
(5) If a watertight joint is required, the unwelded area at either side of the interlayer is to be drilled or hammer peened and then sealed with sealant.

6.7.5.3 Welding of transition joints to hull structures is to satisfy the following requirements in addition to those specified in 6.7.5.1:
(1) The welding operations are to be carried out in the downhand position as much as practicable;
(2) For the steel side, CO_2 semi-automatic or automatic welding is recommended; for the aluminium alloy side, MIG semi-automatic or automatic welding is recommended;
(3) To minimize welding deformation, welding with back step sequence or starting at the center of the seam and welding outward symmetrically is preferred. The length of continuous weld is generally not to exceed 500 mm.

6.7.6 Post-weld treatment

6.7.6.1 After welding, impurities such as slag, overlap and spatter on the surface of the weldment are to be removed. Local remedial is to be carried out to welds when necessary.

6.7.6.2 After welding, the interface of the transition joint is not to show defects such as peeling or meltdown. Once such defects are shown, this part of the transition joint is to be replaced and rewelded. The minimum length of replacement is 500 mm.

Appendix 6A Common joint types of stainless steel hull structure

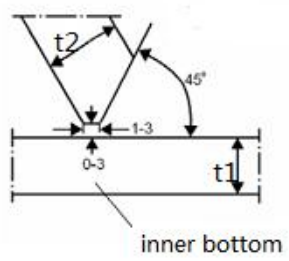


Figure 6A.1 Joint design between lower sloping plate, bulkhead stool sloping plate and inner bottom

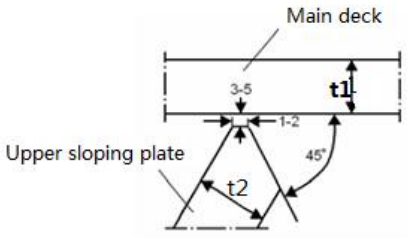


Figure 6A.2 Joint design between main deck and upper sloping plate

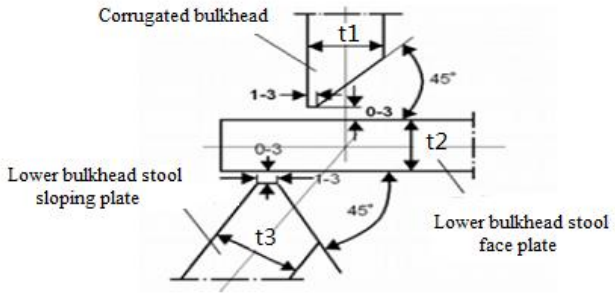


Figure 6A.3 Joint design in way of face plate of lower bulkhead stool of corrugated bulkhead

CHAPTER 7 INSPECTION OF WELDS

Section 1 GENERAL PROVISIONS

7.1.1 Application

7.1.1.1 This Chapter applies to the non-destructive testing (NDT) of welded structures during the construction and repair of ship and offshore installation structures.

7.1.1.2 The non-destructive test techniques referred to in the Guidelines are also applicable to non-destructive tests of defects of metal structures other than hull structures.

7.1.1.3 The methods mentioned in the Guidelines for non-destructive tests are visual testing (VT), radiographic testing (RT), ultrasonic testing (UT), magnetic particle testing (MT) and penetrant testing (PT).

7.1.2 Responsibilities

7.1.2.1 The visual examination and non-destructive testing of hull welds is to be performed by the shipyard or manufacturer in accordance with the inspection specifications developed by him or the relevant requirements of the Guidelines. CCS Surveyor may require to witness the testing of some areas or parts for essential areas.

7.1.2.2 The shipyard or manufacturer is to be responsible to assure that testing specifications and procedures are adhered to during the construction and repairs and that the test report is prepared in the format acceptable to CCS on the findings made by the non-destructive testing.

7.1.2.3 The shipyard or manufacturer is to be responsible for the report of NDT results.

7.1.3 Testing organizations and personnel

7.1.3.1 The organizations engaged in the non-destructive testing are to comply with relevant applicable provisions of CCS Guidelines for Management of Approval of Suppliers and Personnel Qualification.

7.1.3.2 Non-destructive testing personnel is to hold the corresponding level of non-destructive testing personnel qualification certificate issued or recognized by CCS and comply with the relevant applicable provisions of CCS Guidelines for Management of Approval of Suppliers and Personnel Qualification.

7.1.4 Selection of NDT method

7.1.4.1 Except as specified in rules, the NDT method used for hull structures is to be selected according to the tested materials, joint shape, structural configuration and testing purpose. After CCS has approved the advanced nondestructive testing (ANDT) technology adopted by shipyards or manufacturers, the advanced testing technology may be implemented according to Appendix 2, PART THREE of CCS Rules for Materials and Welding.

7.1.4.2 The test methods for the surface or close-to-surface testing of different materials are given in Table 7.1.4.2. The applicable methods for ferromagnetic materials are to comply with the requirements of Appendix 1, PART THREE of CCS Rules for Materials and Welding. It is recommended that magnetic particle testing be preferred over penetrant testing for general steel structures of hull.

Methods for surface or close-to-surface testing of different materials Table 7.1.4.2

Material	Surface	Close to surface
Austenitic steel	VT, PT, ET	ET
Aluminum	VT, PT, ET	ET
Copper	VT, PT, ET	ET

Note: ET means eddy current testing.

7.1.4.3 The methods for the internal testing of weld joints with full penetration for different materials are given in Table 7.1.4.3. The applicable methods for ferromagnetic materials are to comply with the requirements of Appendix 1, PART THREE of CCS Rules for Materials and Welding.

Methods for internal testing of weld joints with full penetration for different materials

Table 7.1.4.3

Material	Type of joint	Material thickness of tested area (mm)		
		$t \leq 8$	$8 < t \leq 40$	$t > 40$
Austenitic steel	Butt joint	RT (or UT)	RT or (UT)	RT or (UT)
	T-joint	(UT) or (RT)	(UT) or (RT)	(UT) or (RT)
Aluminium alloy	Butt joint	RT	RT or UT	RT or UT
	T-joint	(UT) or (RT)	(UT) or (RT)	UT or (RT)
Copper alloy	Butt joint	RT	(UT) or RT	(UT) or RT
	T-joint	(UT) or (RT)	(UT) or (RT)	(UT) or (RT)

Note: Parentheses indicate that the method is applicable but the results may provide limited information, unless specific techniques are employed.

7.1.5 NDT equipment and conditions for its use

7.1.5.1 The NDT equipment and the conditions for its use are to comply with recognized national or international standards, or other technical documents acceptable to CCS.

7.1.5.2 The non-destructive testing is usually to be carried out at ambient temperature. Where the test needs to be conducted at a temperature other than ambient, the effects of the temperature on test results are to be considered and appropriate measures taken.

7.1.5.3 The non-destructive testing by means of instruments and devices are to be conducted away from any strong electromagnetic, dusty, high temperature or corrosive environment, so far as possible.

7.1.6 NDT documents

7.1.6.1 The NDT organization is to prepare an operation procedure specification for each NDT technique according to its conditions and submit it to CCS for information. The basic elements contained in various test methods are specified in subsequent Sections of this Chapter.

7.1.6.2 The extent of testing is to be planned by the inspection department of the shipyard according to the ship type, structural significance and welding processes used to determine the test methods and acceptance criteria for different areas, and such plan is to be submitted to CCS for approval. Particular attention is to be paid to highly stressed areas in the preparation of the plan which is at least to include the following:

(1) Calculation of the number of tests of the entire hull structure and a diagram or table of specific test areas.

(2) The test methods and appropriate acceptance criteria for each test area.

(3) A NDT agreement reached between parties concerned, if any.

7.1.6.3 Prior to commencement of construction of each sister ship from the same series, the shipyard is to prepare a modified NDT plan and submit it to CCS for approval, and the plan is not to be released to production departments. In the implementation of the plan, the Surveyor may increase or reduce tests in a small extent or make minor adjustments to test positions.

7.1.6.4 A NDT identification system is to be established by the shipyard or manufacturer and used in the NDT documentation to identify the exact locations and lengths of welds examined.

7.1.6.5 The NDT implementing unit is to clearly present test results in the test report. The test report is also to explain suspect indications found in test areas and where an indication is determined as a defect, its location and size is to be given. If necessary, a presentation by a sketch, photo or any other convenient means may be added.

7.1.6.6 The test report together with the evidence indicated by the test are to be submitted to the Surveyor for verification and upon his confirmation, retained by the shipyard or manufacturer. Copies of the relevant test report are to be respectively sent to CCS and the owner (if required) for information, attached to the documents for delivery of the ship.

7.1.7 Acceptance criteria

7.1.7.1 The acceptance criteria for the non-destructive testing of hull structures are to be determined according to hull structural materials, structural significance and test methods used.

7.1.7.2 Where different non-destructive test methods are used for steel hull structure welds, requirements in relevant Sections of this Chapter may be referred to for test procedures. As long as the testing sensitivity is guaranteed, acceptance criteria can adopt the grades of recognized standards listed in Table 7.1.7.2 or

higher. If other standards are adopted, the applicant is to specify the requirements not lower than the minimum grade of standards listed in this Chapter.

Acceptable NDT acceptance criteria and level for steel hull structure welds (including piping system)

Table 7.1.7.2

RT		UT		MT		PT	
Standard No.	Grade	Standard No.	Grade	Standard No.	Grade	Standard No.	Grade
ISO 10675-1	1*/2	ISO 11666	2*/3	ISO 23278	2X	ISO 23277	2X
EN 12517-1	1*/2	EN ISO 11666	2*/3	EN ISO 23278	2X	EN ISO 23277	2X
CB/T 3558	II*/III	CB/T 3559	II*/III	CB/T 3958	II*/III	CB/T 3958	II*/III
JIS Z3104	II*/III	JIS Z3060	II*/III	----	----	----	----

Note: * for critical areas, which include:

1) for ships of 150 m in length and upwards, welds of strength deck, sheer strakes, bilge strakes, bottom plates, keel plates, top strakes of inner shell and of longitudinal bulkheads as well as primary members supporting these plates within 0.4L amidships, welds of continuous trunks and longitudinal hatch coamings that can be included in the sectional modulus of hull girder as well as primary members supporting these plates;
2) welds on the shell plating and strength deck that are adjacent to strong penetrations, e.g. rudder horns, rudder heels, masts, including welds that connect the penetrations to the primary members;
3) welds of members primarily subject to dynamic loading, e.g. propeller shaft brackets, rudder heels, joint flanges for rudder stocks (with the rudder body), as well as welds of main engine foundation girders;
4) full penetration welds of main hull for ships intended for navigation in low temperature regions (e.g. icebreakers and polar research vessels);
5) welds of ship piping of Class I;
6) for full penetration welds of integral tanks or independent tanks of LNG and LPG carriers, where CB or JIS standards are adopted, the acceptance criteria is to be of Grade I; where ISO standards are adopted, the grade of the acceptance criteria is to be in accordance with the requirements of key areas.

7.1.7.3 For the acceptance criteria of nondestructive testing of aluminum alloy hull structure welds, the level of recognized standards listed in Table 7.1.7.3 or higher ones may be adopted.

Acceptable NDT acceptance criteria and level for aluminum alloy hull structure welds Table 7.1.7.3

RT		UT		PT	
Standard No.	Level	Standard No.	Level	Standard No.	Level
CB/T 3929	I*/II	NB/T 47013.3	I*/II	ISO 23277	2X
NB/T 47013.2	I*/II	JIS Z3080	II*/III	NB/T 47013.5	I*/II
ISO 10675-2	1*/2				

Note: * to be used for welds at the key positions, which refer to 7.1.7.2.

7.1.7.4 For the acceptance criteria of special welding process for hull structure steels, the level of recognized standards listed in Table 7.1.7.4 or higher ones may be adopted.

Acceptable NDT acceptance criteria and level for special welding process Table 7.1.7.4

Welding process	Standard No.	Acceptance Level
Laser beam welding	ISO 13919	B*/C
Laser-arc hybrid welding	ISO 12932	B*/C

Note: * to be used for welds at the key areas, which refer to 7.1.7.2.

Section 2 Non-Destructive Testing of Hull Structures

7.2.1 General requirements

7.2.1.1 Unless specifically indicated, this Section applies to the non-destructive testing of steel hull structures of conventional ships.

7.2.1.2 The visual examination is to be carried out on all the finished welds of hull structures. When such inspection is satisfactory, the internal non-destructive testing of structural members is to be performed.

7.2.1.3 The full penetration butt welds of hull structures are preferably to be tested by radiographic or ultrasonic testing and the full penetration fillet welds and T-welds by ultrasonic testing.

7.2.1.4 For the welds of hull structural areas subjected to cyclic high-stress loading, magnetic particle or

liquid penetrant tests of a suitable number may be additionally performed as necessary.

7.2.1.5 When the ultrasonic testing is to be substituted for the radiographic testing for butt welds of hull structures, the reliability evidence verified by CCS is to be provided and the substituting percentage together with the areas covered are to be approved by CCS. In principle, such percentage is not to exceed 15% of the total number of tests within 0.6 L midships, and essential joints or areas stressed in a complicated manner are not to be tested by ultrasonic in lieu of radiographic testing.
Where advanced ultrasonic testing means capable of image formation and recording test results (e.g. phased array and time-of-flight diffraction technique (TOFD)) are to be used, the substituting percentage is subject to agreement by CCS.

7.2.2 Number of non-destructive tests

7.2.2.1 The number of NDT positions for each part of hull is to comply with the relevant provisions in 5.3.2, Section 3, Chapter 5, PART THREE of CCS Rules for Materials and Welding.

7.2.3 Test positions

7.2.3.1 In general, the non-destructive test positions are to be selected according to the following principles:
(1) the density of test positions is to be reduced according to the high-to-low grade sequence of structural steels;
(2) structural areas having an abrupt change in their cross section, which are subjected to significant welding stress or where stress concentration easily occurs, are to be preferred;
(3) positions amidships are to be more than those at fore and aft ends;
(4) in order to achieve a more random nature, test positions are to be suitably adjusted between sister ships.

7.2.3.2 In general, the test positions are to be taken at the intersections of longitudinal and transverse welds and the test length is to be parallel to transverse butt welds (perpendicular to the ship's length).

7.2.3.3 For the fitting up and joining welds of blocks, random test positions are to be suitably selected.

Section 3 PRE-TEST PREPARATION AND VISULA INSPECTION

7.3.1 General requirements

7.3.1.1 This Section contains general technical requirements for the cleaning of hull structures prior to testing, the visual examination and the non-destructive testing of welds.

7.3.1.2 After completion of welding, hull structures are to be cleaned and the dimension examination and visual examination carried out to the welds.

7.3.1.3 The higher strength steels of welded structure with specified minimum yield stress of 420 N/mm^2 and above are to be tested in accordance with the requirements of 2.4, Appendix 1, PART THREE in CCS Rules for Materials and Welding. For other steels, the delayed test time may be selected according to the temperature at which the steels were welded, the thickness of structural members and the structural restraint.

7.3.2 Cleaning before examination

7.3.2.1 Before examination, surface cleaning is to be suitably conducted to areas of structures and workpieces that are to be examined. Usually, the following that might affect test results may be removed from the tested surface by manual or mechanical means:
(1) scale, laps, loose rust etc. are to be removed from the surface of plates and forgings;
(2) scale, sand fusion etc. are to be removed from the surface of castings;
(3) all slag, splatters etc. are to be removed from the weldment by manual or mechanical means after completion of welding;
(4) attention is to be paid to removing oil, grease, dirt etc. from machined parts.

7.3.2.2 For the areas which will be subsequently subjected to dye penetrant testing, sand blasting, hammering etc. that might close open defects on the surface are to be avoided.

7.3.2.3 When weld dressing is required, overheating of the surface of weld metal or an uneven finish due to grinding is to be avoided.

7.3.2.4 The cleaning range for the tested welds is to be determined according to the test methods used and is at least to include the entire weld surface and the heat-affected zone plus 10 mm.

7.3.2.5 When heat treatment is required for the weldment (or workpiece) to be examined, the examination is usually to be carried out thereafter.

7.3.3 Visual examination

7.3.3.1 In general, the illuminance at the area of visual examination is to be not less than 350 lx. If necessary, an additional light (e.g. flashlight) can be used to increase the luminance.

7.3.3.2 For visual examination, the accessibility of the areas to be inspected is to be sufficient. If necessary, an indirect inspection may be conducted by means of a magnifying lens with magnification not great than 5 times, a camera etc.

7.3.3.3 General or special tools, as applicable, may be used to measure weld dimensions.

7.3.4 Assessment of test results

7.3.4.1 The surface of welds is to be uniform, with a smooth transition to the base metal and without excessive weld metal. The weld dimensions are to comply with the requirements of design drawings.

7.3.4.2 Unless contractually specified or specifically required for the structure, no imperfection beyond those given in Table 7.3.4.2 is allowed during visual examination.

Acceptance criteria for visual examination **Table 7.3.4.2**

Imperfection	Classification according to ISO 6520-1	Acceptance criteria	
Crack	100	Not allowed	
Lack of fusion	401	Not allowed	
Incomplete root penetration in butt joints welded from one side	4021	Not allowed	
Surface pore	2017	Single pore diameter d ≤ 0.25t for butt welds (or d ≤ 0.25a for fillet welds) with maximum diameter of 3 mm. ① 2.5d as minimum distance to adjacent pore	
Undercut	501	Butt welds	Depth ≤ 0.5 mm whatever is the length Depth ≤ 0.8 mm with a maximum continuous length of 90 mm②
		Filler welds	Depth ≤ 0.8 mm whatever is the length

Notes: ① "t" is the plate thickness of the thinnest plate and "a" the throat of the fillet weld.

② Adjacent undercuts separated by a distance shorter than the shortest undercut is to be regarded as a single continuous undercut.

Section 4 RADIOGRAPHIC TESTING

7.4.1 General requirements

7.4.1.1 This Section contains general technical requirements for the application of radiographic testing techniques in the inspection of hull structures.

7.4.1.2 This Section applies mainly to the non-destructive testing by means of conventional X rays and γ-radiography.

7.4.1.3 The radiographic testing procedure is to detail as a minimum the type of radiation source, test materials and their thicknesses, film system and intensifying screens used (if any), films overlapping, type and position of image quality indicators (IQI), image quality, exposure conditions, scattered radiation control, film processing, film density and viewing conditions.

7.4.1.4 A position identification system is to be used for the radiographic testing to exclusively identify the exact test positions. Such positions may be identified in NDT diagrams of hull structures submitted for information or on the hull during testing. The exclusive identification of testing positions is to be clearly shown on radiographs.

7.4.1.5 A radiation protection system is to be established at the radiographic testing site/location

according to relevant national standards.

7.4.2 Radiographic testing apparatus

7.4.2.1 The type of the radiation source is to be selected by the testing party according to their testing needs and service experience. It is recommended that X rays be used so far as practicable.

7.4.2.2 The films to be used in the radiographic testing are usually to be selected according to the characteristics of test assemblies, the techniques used for testing and processing. The main characteristic criteria of common film systems are given in Table 7.4.2.2. Unless restricted by the testing position or specially required, the length of each radiograph is not to be less than 300 mm.

Main characteristics of common film systems **Table 7.4.2.2**

Type of film system	Photosensitive speed	Average gradient of characteristic curve	Photographic graininess	Minimum gradient G_{min}		Maximum graininess σ_{max}	Minimum gradient/ graininess $(G/\sigma)min$
				D = 2.0	D = 4.0	D = 2.0	D = 2.0
C1	Low	High	Tiny	4.5	7.5	0.018	300
C1	Low	High	Tiny	4.3	7.4	0.020	230
C3	Relatively Low	Relatively high	Fine	4.1	6.8	0.023	180
C4	Relatively low	Relatively high	Fine	4.1	6.8	0.028	150
C5	Medium	Medium	Medium	3.8	6.4	0.032	120
C6	High	Low	Coarse	3.5	5.0	0.039	100

Note: Film density D is the net density excluding fog density.

7.4.2.3 A wire type image quality indicator or hole image quality indicator is usually to be selected in respect to its type according to the material and thickness of the test object. The image quality indicator is to meet recognized national or international standards.

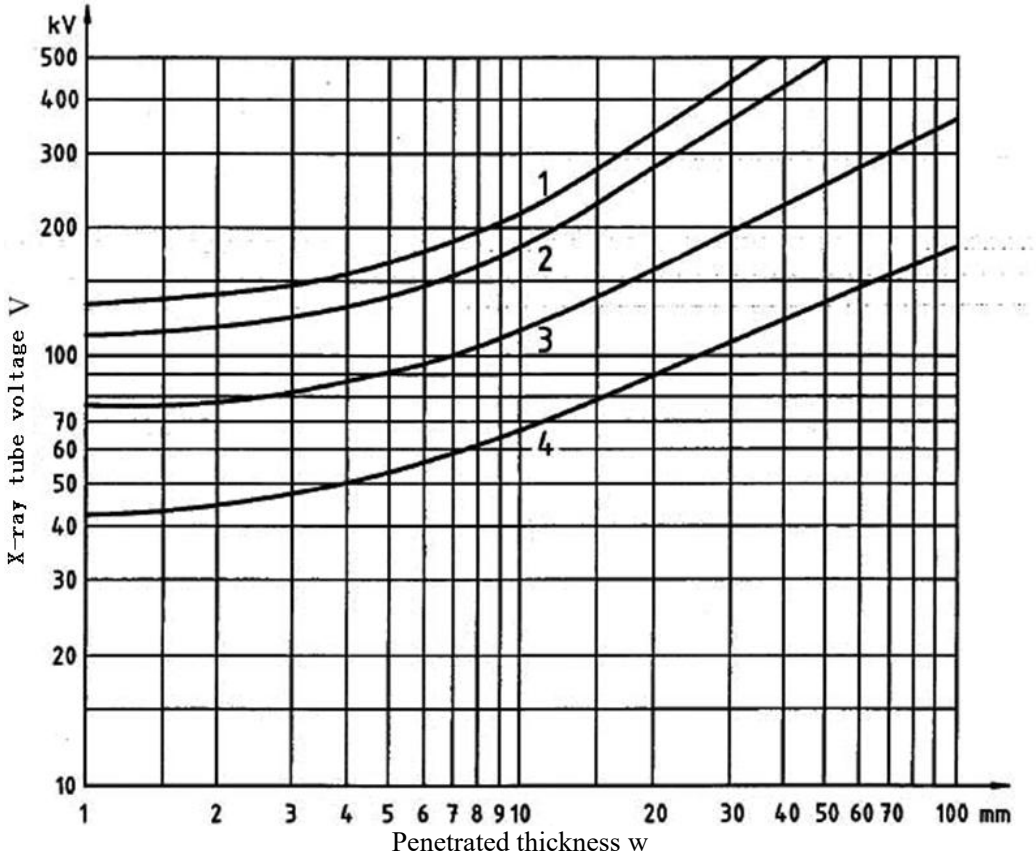
7.4.2.4 The intensifying screen is to be free from any damage such as scratch that may lead to a false defect image in the radiograph.

7.4.2.5 The luminance of the viewing light is to be continually adjustable. When the film density is less than or equal to 2.5, the luminance is not to be less than 30 cd/m^2; when the film density is greater than 2.5, the luminance is not to be less than 10 cd/m^2.

7.4.3 Preparation for testing

7.4.3.1 In order to ensure the effectiveness of testing, the surface of the test assembly is to be cleaned before testing to remove any surface imperfection that may lead to defect indication or cause misinterpretation.

7.4.3.2 Where the X ray source is used, a lowest possible tube voltage is to be selected so as to improve the detection of defects. The highest allowable tube voltages corresponding to different materials and thicknesses are not to exceed the limits shown in Figure 7.4.3.2.



1 – copper, nickel and their alloys 2 – steel 3 – titanium and its alloys 4 – aluminum and its alloys

Figure 7.4.3.2 Selection of X-ray tube voltage

Where radioisotope sources are used, the selection of the applicable radiation source may be referred to Table 7.4.3.2 according to the penetrated thickness of the test assembly.

Penetrated thickness for radioisotopes **Table 7.4.3.2**

Radiation source	Se 75	Ir 192	Co 60
Penetrated thickness t (mm)	10 ~ 40	20 ~ 90	40 ~ 150

7.4.4 Radiographic testing procedure

7.4.4.1 The single-wall exposure technique is to be used as far as practicable for the radiographic testing. The distance from the radiation source to the test assembly is at least to be more than 7 times the penetrated thickness of the test assembly (reinforcement and backing to be included in total thickness for weld).

7.4.4.2 Where the party concerned requires that testing reports be submitted together with processed films as evidence, duplicated radiographs or equivalent means may be used.

7.4.4.3 The lead numbers and/or symbols identifying the test assembly, location and date are to be placed usually not less than 10 mm from the edge of the weld, not affecting the assessment of any weld defect.

7.4.4.4 The selection and arrangement of the image quality indicator for the testing are to be determined according to the thickness, material of the test area and the type of the test assembly. In general, the wire type image quality indicator is to be selected and arranged as follows:
(1) The selection of the wire type image quality indicator is to be determined according to the radiographic sensitivity specified in Table 7.4.4.4(1), and the wire diameter visible on the film is to be located in the intermediate range of the indicator.

Required radiographic sensitivity (IQI at source side) **Table 7.4.4.4(1)**

Nominal thickness of test assembly	Wire no. visible on film (nominal diameter)
3.5mm < t ≤ 5 mm	W15 (0.125 mm)
5 mm < t ≤ 7 mm	W14 (0.16 mm)
7 mm < t ≤ 10 mm	W13 (0.20 mm)
10 mm < t ≤ 15 mm	W12 (0.25 mm)
15 mm < t ≤ 25 mm	W11 (0.32 mm)

25 mm < t ≤ 32 mm	W10 (0.40 mm)
32 mm < t ≤ 40 mm	W9 (0.50 mm)
40 mm < t ≤ 55 mm	W8 (0.63 mm)
55 mm < t ≤ 85 mm	W7 (0.80 mm)
85 mm < t ≤ 150mm	W6 (1.00 mm)
150 mm < t ≤ 250 mm	W5 (1.25 mm)

Note: When using iridium 192 sources, lower values can be accepted:
- up to 2 values for 10 mm < t ≤ 24 mm;
- up to 1 value for 24 mm < t ≤ 30 mm.

(2) At least one image quality indicator is to be placed to each radiograph, usually at the radiation source side at a distance of not more than 1/4 of the test length from the end, facing outwards with the fine diameter.

(3) For the testing of a weld, the indicator is to cross the weld (see Figure 7.4.4.4).

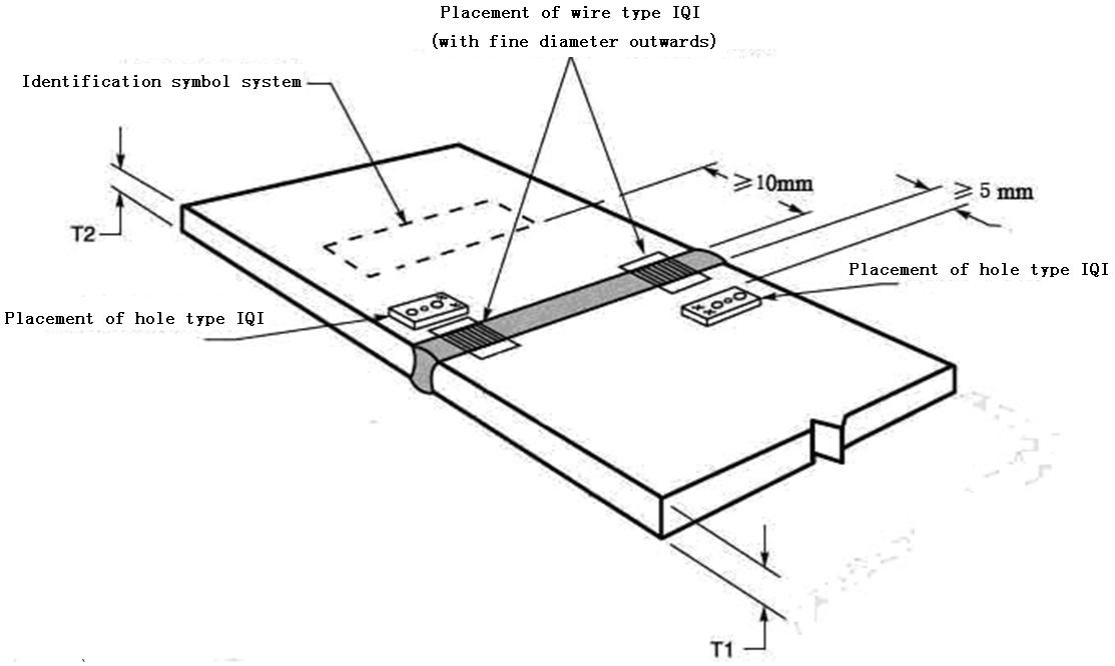


Figure 7.4.4.4 (Recommended) placement of identification system and IQI

(4) Where a circular piece is to be radiographed, at least three indicators are to be evenly arranged within the entire circle.

(5) If it is not practicable to place the indicator on the surface of the test assembly at the radiation source side, it may be placed between the test assembly and the film. In this case, the radiographic sensitivity is to comply with the requirements of Table 7.4.4.4(5) and the radiographs are to be identified by special symbols.

(6) The material of the selected IQI is to be equivalent to that of the test assembly.

Required radiographic sensitivity (IQI at film side) Table 7.4.4.4(5)

Nominal thickness of test assembly	Wire no. visible on film (nominal diameter)
3.5mm ＜ t ≤ 5mm	W15 (0.125mm)
5mm ＜ t ≤ 10mm	W14 (0.16mm)
10mm ＜ t ≤ 15mm	W13 (0.20mm)
15mm ＜ t ≤ 22mm	W12 (0.25mm)
22mm ＜ t ≤ 38mm	W11 (0.32mm)
38mm ＜ t ≤ 48mm	W10 (0.40mm)
48mm ＜ t ≤ 60mm	W9 (0.50mm)
60mm ＜ t ≤ 85mm	W8 (0.63mm)
85mm ＜ t ≤ 125mm	W7 (0.80mm)
125mm ＜ t ≤ 225mm	W6 (1.00mm)

Note: When using iridium 192 sources, lower values can be accepted:
- up to 2 values for 10 mm < t ≤ 22 mm;
- up to 1 value for 22 mm < t ≤ 38 mm.

7.4.4.5 Where an intensifying screen is to be used for the radiography, attention is to be paid to the following requirements in order to prevent any false indication due to improper use:

(1) the intensifying screen is to be uniform and smooth, free from contamination and damage;
(2) the surface of the screen is to face the film and there is to be nothing between the screen and the film so as to attain a close contact;
(3) the screen is to be placed together with the film into the film cassette. Friction between the screen and film is to be avoided so far as possible.

7.4.4.6 The exposure parameter is to be properly selected according to the test material, penetrated thickness, characteristics of the film system, required radiographic sensitivity, etc.

7.4.4.7 The tested exposed film is to be processed according to the instructions of the film manufacturer and chemical agent manufacturer. Attention is to be paid to the temperature and the time during development and processing, avoiding any effect on the judgment of defects due to failure in processing the film.

7.4.5 Interpretation of radiographs

7.4.5.1 Radiographs are to be interpreted in a dimly lighted room. The luminance of the viewing light in penetrating radiographs is to comply with the requirements of 7.4.2.5. Before interpreting radiographs, the testing personnel are to have adequate time for adaptation of their eyes to the dim room.

7.4.5.2 Unless specially specified, the optical density of radiographs is to be 2.0 to 4.0. For the welds using a small pipe diameter or section-varying test assemblies, a minimum optical density of 1.5 is allowed.

7.4.5.3 When using an IQI of wire type, the image of a wire is considered visible on the film as specified in 7.4.4.4 if a continuous length of at least 10 mm is clearly visible in a section of uniform optical density.

7.4.5.4 The exclusive identification of the test assembly, location and date by numbers and/or symbols is to be clearly shown in every radiograph.

7.4.5.5 The acceptance of radiographic testing is to satisfy the requirements of 7.1.7.2 of this Chapter.

7.4.6 Test report

7.4.6.1 After completion of testing, a test report is to be prepared according to test results and if necessary, diagrams and/or radiographs may be attached.

7.4.6.2 The format of test report is shown in Appendix 7C of this Chapter.

Section 5 ULTRASONIC TESTING

7.5.1 General requirements

7.5.1.1 This Section contains general technical requirements for the application of ultrasonic testing techniques in the inspection of steel hull structures.

7.5.1.2 This Section applies mainly to the conventional pulsed ultrasonic testing.

7.5.1.3 The ultrasonic test procedure document is at least to detail the equipment, type of probes (frequency, angle of incidence), coupling media, type of reference blocks, method for range and sensitivity setting, method for transfer corrections, scanning technique, sizing technique and intervals for calibration checks during testing.

7.5.1.4 Unless the test length is clearly specified or restricted by structural dimensions, the ultrasonic test length is in general to be 500 mm at each test position.

7.5.1.5 Where advanced ultrasonic techniques (e.g. TOFD or phased array) are to be used in the non-destructive testing, the relevant standards are to be met.

7.5.2 Ultrasonic testing equipment

7.5.2.1 Analogue or digital type A pulsed ultrasonic testers are usually used in the testing of ships, meeting the following technical criteria:
(1) the ultrasonic tester is capable of normally operating within the frequency range of 0.5 MHz to 10 MHz;
(2) the vertical linear error of the ultrasonic tester is not to exceed 5% and the horizontal one not to exceed 1%;

(3) the gain (attenuation) controller of the ultrasonic tester is to be adjustable to each scale throughout the range of 80 dB, the accuracy within any adjacent range of ±12 dB is to be below 1 dB, and the maximum accumulative error is not to exceed 1 dB.

7.5.2.2 The ultrasonic probes used in testing are usually to comply with the following requirements:
(1) the transducer is to have a sufficient area;
(2) the deviation of the actual incident angle of the angle beam probe from the nominal value is not to exceed ±2°, otherwise correction is to be made;
(3) the nominal incident angle and incident point are to be clearly marked on the angle beam probe.

7.5.2.3 Substances which are acoustically well permeable and have no corrosive action on test parts are to be used as coupling media.

7.5.2.4 The ultrasonic equipment (instrument and probes) are to be calibrated at least once every year.

7.5.3 Preparation for ultrasonic testing

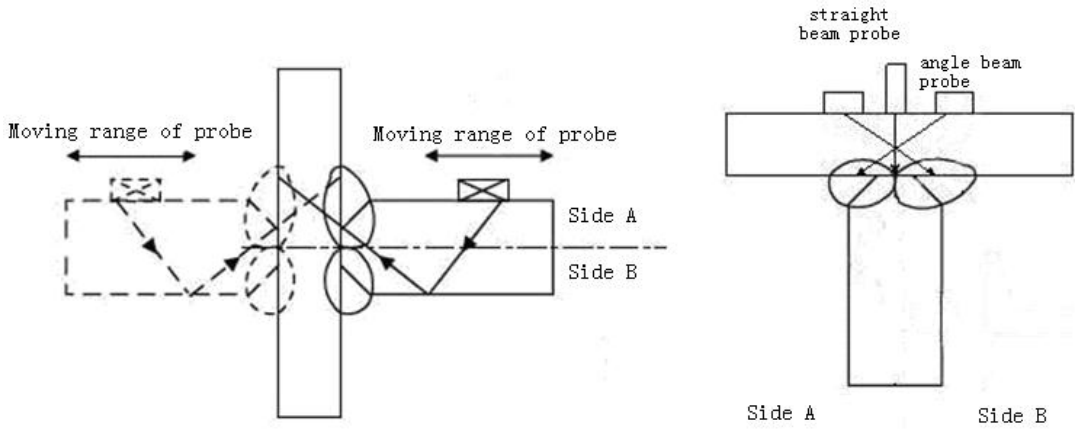
7.5.3.1 The scanning surfaces are to be clean and free from impurities like rust, paint which may interfere with probe coupling, and to have suitable profile and roughness.

7.5.3.2 The ultrasonic probes used in testing may be selected according to test purposes and materials of test assemblies, usually adhering to the following principles:
(1) the base metal is preferably to be examined with a straight beam probe to check by longitudinal waves the absence of imperfections, unless already demonstrated at a previous fabrication stage;
(2) the angle beam probe is preferably to be used to search by transverse waves for weld discontinuities. The incident angle of the sound wave of an angle probe is usually to be adjusted according to the thickness of the test assembly and weld preparation;
(3) for castings having a coarse crystalline structure, low frequency probes are preferred for avoiding excessive attenuation; for materials having a fine crystalline structure (forgings or rollings), probes with a slightly higher frequency are preferred to improve the test accuracy;
(4) as the working frequency of probes used in testing of steels is generally in the range of 2~5 MHz, for austenitic and duplex stainless steels, probes with a slightly lower frequency may be used;
(5) where close-to-surface defects are to be detected by ultrasonic testing, a twin crystal probe is preferably to be used.

7.5.3.3 Before testing, the instrument system is to be adjusted in an integrated way. The system adjustment is to be performed using a standard or reference block made of a material giving ultrasonic response equivalent to that of the material to be tested. The reference level for testing is to be set using a Distance-Amplitude-Corrected curve (DAC curve) for a series of 3 mm diameter side-drilled holes in a reference block or a Distance-Gain-Size (DGS) system based on flat-bottomed holes in the reference block. The relevant curves are to comply with the required sensitivity for testing.

7.5.4 Ultrasonic testing procedure

7.5.4.1 In order to prevent an incomplete examination, the scanning method is to be as follows:
(1) The entire specified area is to be so scanned that scanning paths are suitably overlapped to avoid incomplete scanning.
(2) The scanning range is to cover the entire volume of the weld bead and base metal for at least 10 mm on each side of the weld, or the width of the heat-affected zone, whichever is greater.
(3) In order to ensure an overall examination of full penetration fillet weld joints, usually scanning may be made by probe moving at both sides of the abutting plate or the faceplate (see Figure 7.5.4.1(3)), or different angle probes are to be used.
(4) During scanning, poor contact of probes due to movement of probes is to be avoided.



(a) Scanning at abutting plate (b) Scanning at faceplate

Figure 7.5.4.1(3) Scanning of full penetration fillet weld

7.5.4.2 For curved surfaces when scanning and locating, curvature correction is to be taken into account.

7.5.4.3 When any defect signal is found during scanning, the surface of the test assembly is to be clearly marked accordingly and a relevant record made.

7.5.4.4 During testing, the calibration of the system is to be checked at regular intervals (generally 4 to 8 hours) and whenever needed.

7.5.5 Evaluation of test results

7.5.5.1 When the Distance-Amplitude-Corrected curve technique is used, the indications with an echo height below 33% of DAC curve (DAC-10dB) may be disregarded. The indications with an echo height equal to or exceeding 33% of DAC curve are to be recorded and evaluated (the range of the excessive echo height is to be measured, the maximum echo height measured and located, and finally the equivalent defect size determined).

7.5.5.2 If necessary, some technique, such as changing probes, increasing tested surfaces, observing dynamic waveform may be used with technological characteristics of the structure to assist in determining the nature of defect indications.

7.5.5.3 The acceptance of ultrasonic testing is to satisfy the requirements of 7.1.7.2 of this Chapter.

7.5.6 Test report

7.5.6.1 After completion of testing, a test report is to be prepared according to test results and if necessary, diagrams may be attached.

7.5.6.2 The format of test report is shown in Appendix 7C of this Chapter.

Section 6 MAGNETIC PARTICLE TESTING

7.6.1 General requirements

7.6.1.1 This Section applies to detection of surface or close-to-surface defects of hull structures of ferromagnetic material.

7.6.1.2 The testing procedure is to detail as a minimum the surface preparation, magnetizing equipment, calibration methods, detection media, application of magnetic particles/suspensions, viewing conditions and demagnetization.

7.6.1.3 Where not specified in rules or the contract, the magnetic particle testing is usually to cover a weld length of 500 mm at each test position.

7.6.1.4 Where welded structures are to be subject to magnetic particle testing, it is recommended that a.c. continuous wet particle method be used as far as practicable.

7.6.1.5 Where high sensitivity is required for test assemblies (castings and forgings), it is recommended that fluorescent magnetic particle testing be applied.

7.6.2 Test equipment

7.6.2.1 Magnetic particle testing apparatuses usually include a.c. or d.c. magnetic yokes, permanent magnets, current flow magnetizing means and magnetizing coils, etc.

7.6.2.2 Magnetic particle testing apparatuses are to be capable of generating the field direction and strength required for testing. Usually, a.c. magnetic yokes are to be capable of generating a lifting force of at least 45 N, d.c. magnetic yokes or crossed yokes are to be capable of generating a lifting force of at least 177 N (magnetic pole piece spaced 0.5 mm from the surface of the test assembly).

7.6.2.3 When the residual magnetic method is applied, the a.c. test equipment is to be provided with a phase controlled circuit breaker.

7.6.2.4 When using current flow equipment with prods, copper prod tips are usually not to be used. The prod tips are preferably to be lead, steel, or aluminum-copper braid.

7.6.2.5 Magnetic particles used in testing are to comply with the following requirements:
(1) They are to be characterized by high magnetic permeability, small coercive force and low residual magnetism.
(2) Their color is to be in high contrast to the surface color of test assemblies, and the fluorescent factor of fluorescent magnetic particles is to be greater than 1.5 cd/W.
(3) The graininess of magnetic particles is to be suitable for specified conditions for their application.

7.6.2.6 In wet particle testing, water or a low-viscosity oil product having no corrosive action on test assemblies are to be used as the magnetic suspension carrier. In general, the magnetic suspension prepared with normal magnetic particles is to contain 1.2 to 3.5% magnetic particles by volume, and this percentage is to be approximately 0.1 to 0.3% for the suspension prepared with fluorescent magnetic particles.

7.6.2.7 The ultraviolet lamp used in testing is to be such that the ultraviolet irradiation measured at a distance of 400 mm from the lamp fitted with an optical filter is not less than 1000 $\mu W/cm^2$, with the visible light luminance being not greater than 20 Lx.

7.6.3 Preparation for testing

7.6.3.1 The surface to be examined is to be cleaned and at least the surface of the weld and heat-affected zones at both sides of the weld are to be free from rust, oil, grease, paint, dust and other contaminants.

7.6.3.2 A tangential magnetic field strength of 2 kA/m to 6 kA/m is commonly used in magnetic particle testing.

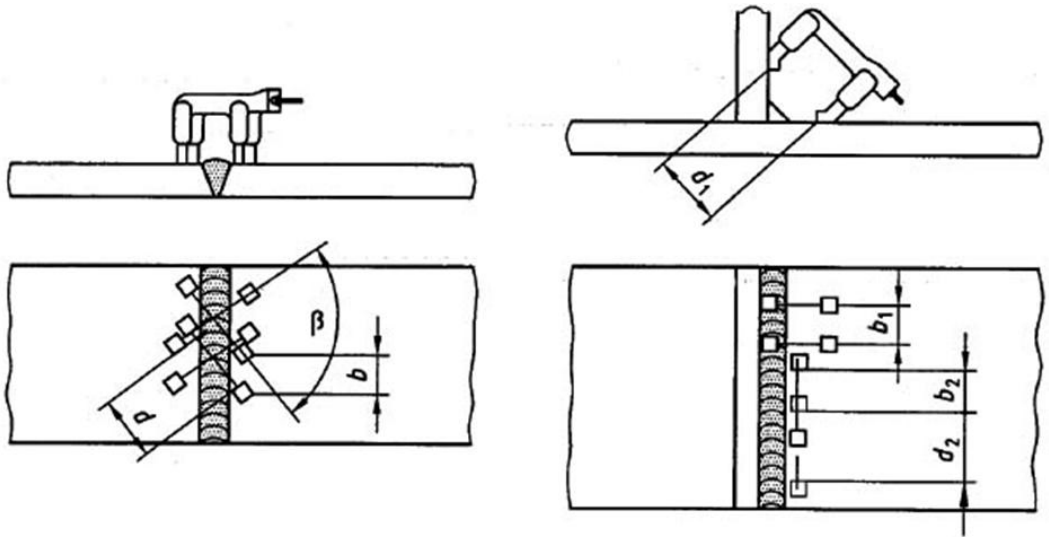
7.6.3.3 Prior to testing, an overall performance test of the system is to be carried out for ensuring the specified test sensitivity of the system.

7.6.3.4 Magnetic suspensions are to be fully homogenized before use.

7.6.4 Magnetic particle testing procedure

7.6.4.1 When using current flow equipment with prods, care is to be taken to avoid so far as practicable local damage to the surface of the material due to current flowing through contact tips.

7.6.4.2 To ensure detecting defects of any orientation, the direction of the magnetic field is usually to be changed during testing. The welds are usually to be magnetized in two directions approximately perpendicular to each other, and the angle of the weld axis with respect to the direction of one magnetic field is usually not to exceed 30° (see Figure 7.6.4.2).



where: $d \geq 75$ $d_1 \geq 75$ $b_1 \leq d_1/2$
$b \leq d/2$ $d2 \geq 75$ $b2 \leq b2 - 50$
$\beta \approx 90^{\circ}$

a. Magnetic particle testing of butt weld b. Magnetic particle testing of fillet weld

Figure 7.6.4.2 Direction of magnetization in magnetic particle testing of welds

7.6.4.3 Care is to be taken to ensure adequate overlapping of test areas during scanning. The effective test area is shown in Figure 7.6.4.3.

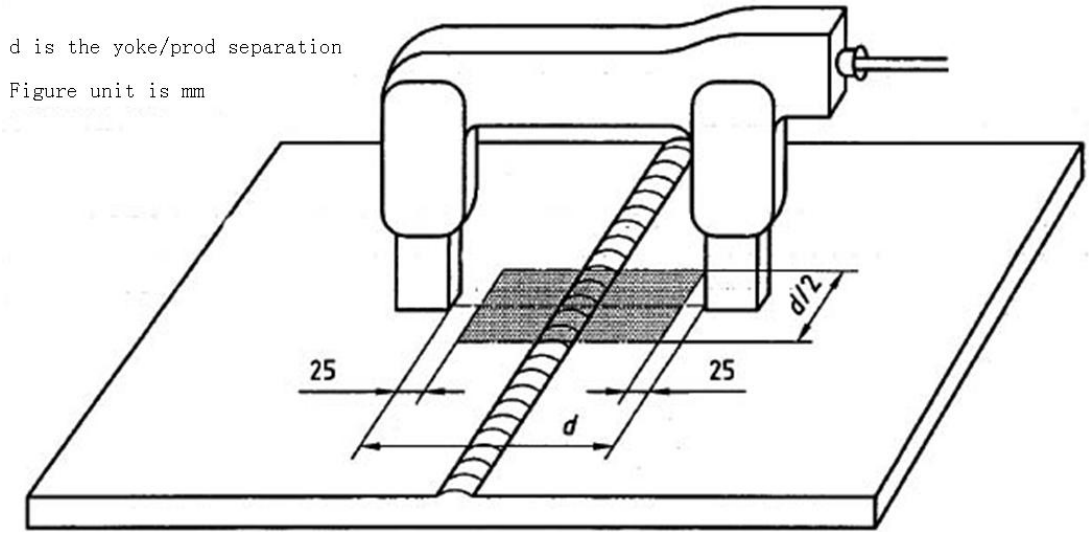


Figure 7.6.4.3 Effective test area for magnetizing with yokes or prods

7.6.4.4 The continuous wet particle method is preferably to be used for magnetic particle indication.

7.6.4.5 Magnetic particles or suspensions are to be evenly applied onto the surface of the test assembly after the magnetic field of the test assembly is established and stabilized, and magnetic particle indications are to be viewed only when such indications are stable.

7.6.4.6 Magnetic particle indications are to be viewed with a suitable illumination which is usually to be not less than 500 Lx for colour particles. Where fluorescent particles are used, the ambient illumination is to be not more than 20 Lx and the irradiation of the black lamp not less than 1000 $\mu W/cm^2$, with the wavelength being 320 to 400 nm.

7.6.4.7 In general, paramagnetic materials with much residual magnetism are to be demagnetized after testing, except those of which subsequent processing and use will not be affected.

7.6.5 Evaluation of test results

7.6.5.1 Defect indications may be recorded by means of sketches, photos and videos. A magnifying lens with 3 to 8 times magnification may be used to view fine defects.

7.6.5.2 A linear defect is an indication of a defect the length of which is more than 3 times its width. Nonlinear defects are defects the length of which is less than or equal to 3 times their width.

7.6.5.3 The acceptance of magnetic particle testing is to satisfy the requirements of 7.1.7.2 of this Chapter.

7.6.6 Test report

7.6.6.1 After completion of testing, a test report is to be prepared according to test results and if necessary, diagrams and/or photos may be attached.

7.6.6.2 The format of test report is shown in Appendix 7C of this Chapter.

Section 7 DYE PENETRANT TESTING

7.7.1 General requirements

7.7.1.1 This Section applies to the dye penetrant detection of open defects on surfaces of hull structures and machinery components.

7.7.1.2 The testing procedure is to detail as a minimum the surface preparation, cleaning and drying prior to testing, temperature and humidity range, type and brand of penetrant and cleaner as well as developer used, penetrant application and removal, penetration time, developer application and development time and lighting conditions during testing.

7.7.1.3 The location for dye penetrant testing is to be sufficiently ventilated, away from any heat source, open fire and inflammable material.

7.7.1.4 Water-washable and post-emulsifiable penetrant methods are not recommended for the testing of welded structures.

7.7.1.5 Where high sensitivity is required for test assemblies (castings and forgings), the use of the fluorescent penetrant method is to be considered.

7.7.1.6 For the use of the fluorescent penetrant method, attention is to be paid to protection of the human body from direct ultraviolet radiation.

7.7.1.7 The illumination of the test surface for the dye penetrant testing is to be not less than 500 Lx and if necessary, the illumination may be determined by a calibrated light meter.

7.7.2 Test equipment

7.7.2.1 The color of the dye penetrant used is to be in high contrast to that of the associated developer.

7.7.2.2 The ultraviolet lamp used in testing is to be such that the ultraviolet irradiation measured at a distance of 400 mm from the lamp fitted with an optical filter is not less than 1000 $\mu W/cm^2$, with the visible light luminance being not greater than 20 Lx.

7.7.3 Preparation for testing

7.7.3.1 The penetration method is to be selected according to the required test sensitivity, the surface roughness of test assemblies and the water source of the test location etc. The method by solvent-removal penetrant is recommended for the testing of hull structural welds.

7.7.3.2 Prior to formal testing, suitable test blocks are to be used to calibrate the sensitivity of the penetrant to be used for confirming compliance of the penetrant testing with the test sensitivity requirement.

7.7.3.3 The surface roughness of test areas is to comply with the test sensitivity requirement and if necessary, the test surface may be ground to the required roughness.

7.7.3.4 The working temperature of the test surface is to be between 5°C and 50°C. Outside this temperature range, special low/high temperature penetrants and reference comparator blocks are to be used.

7.7.4 Dye penetrant testing procedure

7.7.4.1 Where weld is tested, the width of the test surface is to include the weld metal and the adjacent

base metal up to a distance of 10 mm on each side.

7.7.4.2 The penetration time is to be in accordance with the manufacturer's specification and generally not less than 10 min.

7.7.4.3 For the removal of excess penetrant, the remover is preferably not to be directly sprayed on the test surface. It is recommended that the remover be sprayed on a clean piece of cloth to be used to remove the excess penetrant.

7.7.4.4 When applying developer, usually a thin coating of developer is to be evenly applied to the test surface. If a spray can is used, developer is to be applied by evenly spraying the test surface from a distance of approximately 300 mm.

7.7.4.5 The development time is to be in accordance with the manufacturer's specification recommended and normally between 10 – 30 minutes.

7.7.4.6 When viewing indications, the white light illumination at the test area is preferably not to be less than 1000 Lx.

7.7.4.7 After completion of testing, test assemblies are to be cleaned to remove any residues which will affect their subsequent use or impair their material.

7.7.5 Evaluation of test results

7.7.5.1 Defect indications may be recorded by means of sketches, photos and videos. If necessary, a magnifying lens with approximately 5 times magnification may be used to view fine defects.

7.7.5.2 An indication of a defect the length of which is more than 3 times its width is to be treated as a linear defect, while nonlinear defects are defects the length of which is less than or equal to 3 times their width.

7.7.5.3 The acceptance of dye penetrant testing is to satisfy the requirements of 7.1.7.2 of this Chapter.

7.7.6 Test report

7.7.6.1 After completion of testing, a test report is to be prepared according to test results and if necessary, diagrams or photos may be attached.

7.7.6.2 The format of test report is shown in Appendix 7C of this Chapter.

Appendix 7A Non-Destructive Testing of Marine Steel Forgings

7A.1 Application

7A.1.1 This Appendix applies to the non-destructive testing of marine steel forgings covered by Chapter 5, PART ONE of CCS Rules for Materials and Welding and PART THREE of CCS Rules for Classification of Sea-going Steel Ships. This Appendix may be also applied to the non-destructive testing of austenitic stainless steel and ferritic-austenitic (duplex) stainless steel forgings. This Appendix does not apply to fabricated forgings and weld repairs.

7A.1.2 For steel forgings other than those specified in this Appendix, the requirements in this Appendix may apply correspondingly considering their materials, types, shapes and service conditions.

7A.1.3 This Appendix covers mainly the inspection of marine steel forgings. Unless specified otherwise in this Appendix, non-destructive testing techniques used in specific tests are to comply with the relevant requirements of Chapter 7 of the Guidelines.

7A.2 General requirements

7A.2.1 Steel forgings are generally to be examined in the final delivery condition.

7A.2.2 Where intermediate non-destructive tests have been performed in manufacturing of steel forgings, the manufacturer is to furnish a test report upon the request of the Surveyor.

7A.2.3 Where a steel forging is supplied in the semi-finished condition, the manufacturer is to take into consideration the quality level of final finished machined components when selecting the test method and test positions.

7A.2.4 For small forgings produced in batches, random check may be allowed in accordance with Section 1, Chapter 5, PART ONE of CCS Rules for Materials and Welding.

7A.2.5 Where advanced ultrasonic testing methods are applied, e.g. PAUT or TOFD, requirements for testing technology are in accordance with Appendix 2, PART THREE of CCS Rules for Materials and Welding and acceptance requirements are in accordance with the requirements of this Appendix.

7A.3 Preparation for inspections and visual examination

7A.3.1 Steel forgings should be subjected to a 100% visual examination of all accessible surfaces by the manufacturer.

7A.3.2 Prior to inspection, forgings are to be cleaned to remove all scales, oil, rust, grease and other impurities and contaminants that will affect the inspection.

7A.3.3 The bores of hollow forgings should be visually examined for their internal surface imperfections uncovered by the machining operation. If necessary, auxiliary tools may be used in the inspection. The ultrasonic testing should be carried out after the steel forgings have been machined to a condition suitable for this type of testing and after the final heat treatment, but prior to the drilling of the oil bores, prior to surface hardening and the machining of bolt threads.

7A.3.4 Visual examination may be carried out in accordance with the relevant requirements of Section 3 of this Chapter.

7A.3.5 All forgings should be free of cracks, crack-like indications, laps, folds or other injurious indications affecting the subsequent use. When defect indications are found at a certain position, the inspection scope may be extended or non-destructive testing methods may be added at the request of CCS, in order to conduct a more detailed evaluation of irregularities.

7A.4 Non-destructive surface inspections

7A.4.1 Non-destructive inspections for surface of steel forgings are usually to be carried out by magnetic particle testing or liquid penetrant testing. The magnetic particle testing should be carried out with the following exceptions, when penetrant testing would be permitted: austenitic and ferritic-austenitic (duplex) stainless steels; interpretation of open visual or magnetic particle indications; at the instruction of the Surveyor. Other surface inspection methods e.g. eddy current testing, may be required by CCS as a supplementary method, e.g. for confirming the presence of indications, or for detecting the presence of undocumented weld repairs.

7A.4.2 Surface inspections by magnetic particle and/or penetrant methods generally apply to the following steel forgings:
(1) All crankshafts;
(2) Propeller shafts, intermediate shafts, thrust shafts and rudder stocks with minimum diameter not less than 100 mm;
(3) Cylinder heads, connecting rods, piston rods and crossheads as per the engine type and size requirements in PART THREE of CCS Rules for Classification of Sea-going Steel Ships;
(4) Bolts with minimum diameter not less than 50 mm, which are subjected to dynamic stresses such as cylinder cover bolts, tie rods, coupling bolts for crankshafts, crankpin bolts, main bearing bolts, and other items as per the engine type and size requirements in PART THREE of CCS Rules for Classification of Sea-going Steel Ships;

(5) Propeller blade fastening bolts which are subjected to dynamic stresses.

7A.4.3 Magnetic particle, or where permitted penetrant testing, should be carried out in zones I, II and III (as applicable) of typical essential marine forgings, as indicated in Figures 7A.4.3(1) to 7A.4.3(4).

7A.4.4 Welded connections of large forged components are to be tested over their full length using MT or PT, in addition to necessary internal quality examination.

7A.4.5 Unless otherwise specified, the magnetic particle test should be performed on a forging in the final machined surface condition and final thermally treated condition. For magnetic particle testing, attention is to be paid to the contact between the forging and the clamping devices of stationary magnetization benches in order to avoid local overheating or burning damage in its surface. Prods should not to be permitted on finished machined items.

7A.4.6 Unless otherwise agreed, the surface inspection is to be carried out in the presence of the Surveyor. For components of an assembly, the surface inspection is to be carried out before the shrink fitting.

7A.4.7 Non-destructive test for surface inspections may be carried out in accordance with Section 6 or 7 of this Chapter.

7A.4.8 The surface evaluation of hull structures and machinery components and their acceptance are to be carried out as follows:
(1) For the purpose of evaluating the acceptability of indications, the surface is to be divided into reference areas of 225 cm^2. The area for evaluation is to be taken in the most unfavorable zone relative to the indication being evaluated.
(2) Cracks are not acceptable. The allowable number and size of indications in the reference areas of 225 cm^2 are not to exceed those given in Table 7A.4.8. The following definitions relevant to indications apply:
(1) Linear indication: an indication having a length greater than three times its width (i.e. $l>3w$).
(2) Nonlinear indication: an indication having a length less than or equal to three times its width (i.e. $l\leq 3w$).
(3) Aligned indication: An alignment of indications is considered to be a unique indication and its length is equal to the overall length of the alignment, including a) Non-linear indications form an alignment when the distance between indications is less than 2mm and at least three indications are aligned. b) Linear indications form an alignment when the distance between two indications is smaller than the length of the longest indication.

Allowable number and size of surface indications in a reference area **Table 7A.4.8**

Test assembly	Inspection zone	Max. number of indications	Type of indication①	Max. number for each type	Max. size (mm)
Crankshaft forgings	I	0	Linear Nonlinear Aligned	0 0 0	– – –
	II	3	Linear Nonlinear Aligned	0 3 0	– 3.0 –
	III	3	Linear Nonlinear Aligned	0 3 0	– 5.0 –
Steel forgings excluding crankshaft	I	3	Linear Nonlinear Aligned	0② 3 0②	– 3.0 –

forgings	II	10	Linear Nonlinear Aligned	3② 7 3②	3.0 5.0 3.0

Notes: ① Steel forgings excluding crankshaft forgings include austenitic stainless steel and ferritic-austenitic (duplex) stainless steel forgings.

② Linear or aligned indications are not permitted on bolts, which receive a direct fluctuating load, e.g. main bearing bolts, connecting rod bolts, crosshead bearing bolts.

7A.4.9 Indications that exceed the requirements of Table 7A.4.8 should be classed as defects and repaired subject to the agreement of CCS. Generally it may be permissible to remove shallow indications by light grinding to a maximum depth of 1.5 mm, but grinding is not permitted in way of finished machined threads. All repairs should comply with relevant requirements of Chapter 5, PART ONE of CCS Rules for Materials and Welding. Complete removal of the defect should be proved by magnetic particle testing or penetrant testing, as appropriate.

7A.4.10 This Appendix does not include surface inspection of forged slewing rings and other forged component types, and in such cases appropriate national/international standards may be applied, to determine the appropriate testing regime and defect acceptance criteria. This Appendix may be applied to surface inspection of austenitic stainless steel and ferritic-austenitic (duplex) stainless steel forgings, however, other acceptance criteria may be applied, upon agreement with CCS. Where other national or international standards are applied, the quality levels are to be not lower than the requirements of this Appendix, to provide reasonable equivalence.

7A.5 Non-destructive internal inspections

7A.5.1 Non-destructive test for internal inspections of steel forgings are usually to be carried out by ultrasonic testing using the contact method with straight beam technique. The surfaces of forgings to be examined should be such that adequate coupling can be established between the probe and the forging and that excessive wear of the probe should be avoided.

7A.5.2 The ultrasonic testing generally applies to the following steel forgings:
(1) All crankshafts ;
(2) Propeller shafts, intermediate shafts, thrust shafts and rudder stocks with minimum diameter not less than 200 mm;
(3) Cylinder heads, connecting rods, piston rods, crosshead, coupling bolts and studs as per the engine type and size requirements in PART THREE of CCS Rules for Materials and Welding.

7A.5.3 The internal inspections of the relevant areas of typical essential marine forgings are to be in accordance with Figures 7A.5.3(1) to 7A.5.3(4). If deemed necessary by the attending Surveyor, he may require the test area be extended or the test zone upgraded.

7A.5.4 The internal ultrasonic testing of forgings may be carried out in accordance with Section 5 of this Chapter. Generally, the methods of setting test sensitivity and testing evaluation utilise the DAC (distance amplitude correction), DGS (distance-gain size) or bottom wave calculation methods. The applied methodology should use 2 to 5 MHz straight beam (or normal) probes and/or angle beam probes. For near surface testing (up to a depth of 25 mm) twin crystal 0° probe is should used, plus a 0° probe (usually single crystal beyond a depth of 25 mm) for the remaining volume. Fillet radii should be examined using 45°, 60° or 70° probes, primarily to determine the presence of any cracks within the radiused areas, and as an additional scan to confirm any indications that may have been detected with 0° probe(s) within this area. Reference blocks are to be manufactured from similar material, with similar surface condition to that being inspected. Where necessary, allowances should be made for attenuation losses by performing a transfer correction and adjusting the DAC curve as required. The applied transfer correction is to become the new reference sensitivity, to which indications are evaluated against, according to the acceptance criteria of this Appendix. When the DAC curve technique is used, the indications with an echo height exceeding the indication of DAC-4dB are to be recorded and evaluated.

7A.5.5 The internal evaluation of forgings and their acceptance criteria are to comply with Table 7A.5.5, which does not apply to austenitic stainless steel or ferritic-austenitic (duplex) stainless steel forgings. ASTM A745 / A745M-20 or EN 10228-4:2016 may be used. Other national or international standards may be used, as agreed with CCS and acceptance criteria are to be agreed with CCS.

Acceptance criteria for internal ultrasonic testing of forgings **Table 7A.5.5**

Type of forging	Inspection zone	Allowable disc shape indication according to DGS ①	DAC reference level, based on 3.0mm FBH③④	Allowable length of indication	Allowable distance between two indications⑥
Crankshaft	I	d ≤ 1 mm②	3.0mm DAC - 19dB ②	–⑤	–
	II	d ≤ 2.0 mm	3.0mm DAC - 7 dB	≤ 10 mm	≥ 20 mm
	III	d ≤ 4.0 mm	3.0mm DAC + 5 dB	≤ 15 mm	≥ 20 mm
Propeller shaft Intermediate shaft Thrust shaft Rudder stock	II	Outer: d ≤ 2.0 mm Inner: d ≤ 4.0 mm	Outer DAC - 7 dB Inner DAC + 5 dB	≤ 10 mm ≤ 15 mm	≥ 20 mm ≥ 20 mm
	III	Outer: d ≤ 3.0 mm Inner: d ≤ 6.0 mm	Outer DAC + 0 dB Inner DAC + 12 dB	≤ 10 mm ≤ 15 mm	≥ 20 mm ≥ 20 mm
Connecting rod Piston rod Crosshead	II	d ≤ 2.0 mm	DAC - 7 dB	≤ 10 mm	≥ 20 mm
	III	d ≤ 4.0 mm	DAC + 5 dB	≤ 10 mm	≥ 20 mm

Notes: ① Outer part means the part beyond one third of the shaft radius from the centre, the inner part means the remaining core area.

② For zone I testing, probe selection is to take into account the limits of probe beam-path length and depth of beam penetration and is normally to be carried out with a minimum probe frequency of 4MHz.

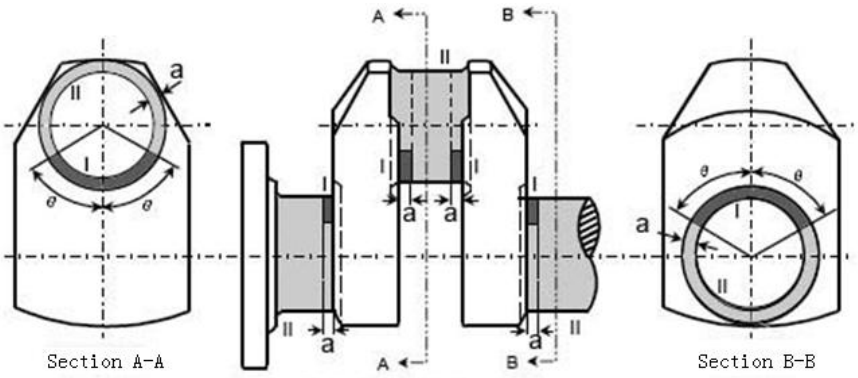
③ The requirement of a 3mm FBH is to standardise the DAC reference blocks for clarity and consistency. The dB value for the FBH/DAC setting is equivalent to the disc shaped reflector stated in the Table, corresponding to the applicable zone.

④ Other size FBHs may be used for the DAC method (and the dB value adjusted accordingly to provide equivalence with the stated FBH/disc shaped reflector). Where other size FBHs are used, the ultrasonic procedure is to state the equivalence using an appropriate calculation formula.

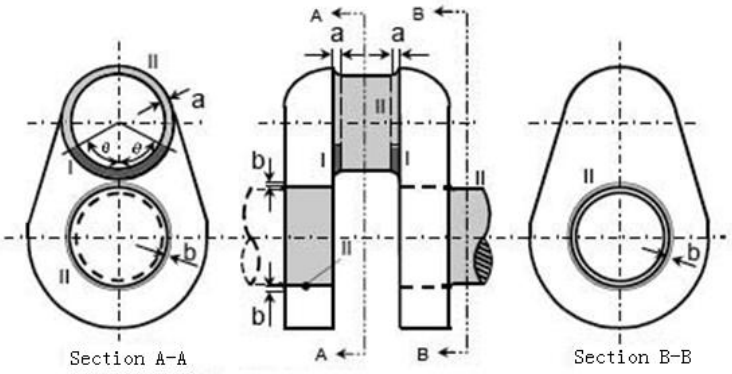
⑤ For zone I, indications with an echo height greater than a 1.0mm disc shaped reflector or the DAC reference level are not acceptable. Indications with an echo height of less than a 1.0mm disc shaped reflector or the DAC reference level are acceptable if they are deemed as point reflectors and have no measurable length.

⑥ In case of accumulations of two or more isolated indications which are subject to registration, the minimum distance between two neighbouring indications is to be at least the length of the larger indication. This also applies to the distance in axial directions as well as to the distance in depth. Isolated indications with less distances are to be determined as one single indication.

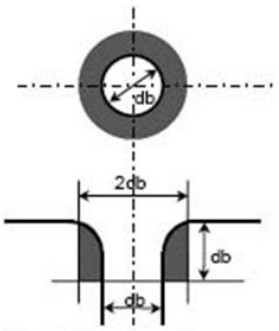
7A.5.6 This Appendix does not include internal inspection of forged slewing rings and other forged component types, and in such cases appropriate national/international standards may be applied, to determine the appropriate testing regime and defect acceptance criteria. Where other national or international standards are applied, the quality levels are to be not lower than the requirements of this Appendix, to provide reasonable equivalence.



(a) Solid crankshaft



(b) Semi-built-up crankshsft



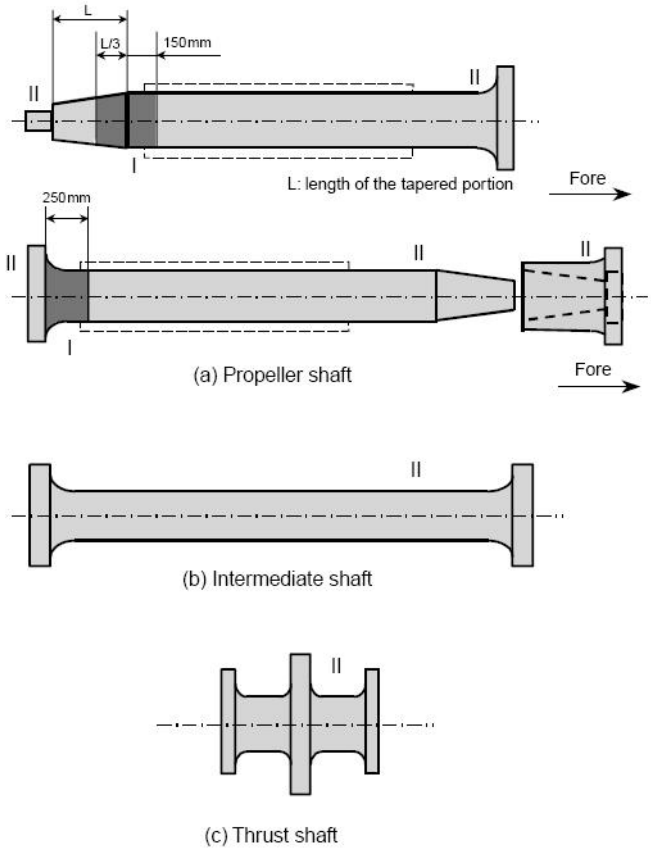
db: oil hole bore diameter

Notes: 1. Where the crankpin or journal has oil holes, the circumferential surfaces of the oil holes are to be treated as Zone I.

2. In the above figures:
   θ = 60°,
   a = 1.5 r,
   b = 0.05 d (circumferential surfaces of shrinkage fit),
   where r is fillet radius and d is journal diameter.

3. Identification of the zones:
   Dark color for zone I,
   Light color for zone II,
   Colorless for zone III.

Figure 7A.4.3(1) Zones for magnetic particle/penetrant testing on crankshafts



Note: For propeller shafts, intermediate shafts and thrust shafts, all areas with stress raisers such as radial holes, slots and keyways are to be treated as Zone I.

Figure 7A.4.3(2) Zones for magnetic particle/penetrant testing on shafts

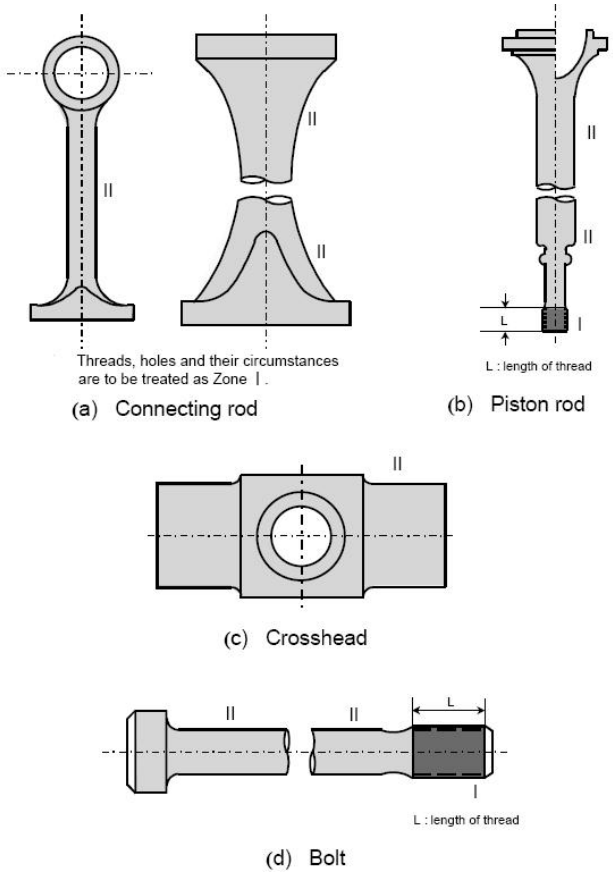


Figure 7A.4.3(3) Zones for magnetic particle/penetrant testing on machinery components

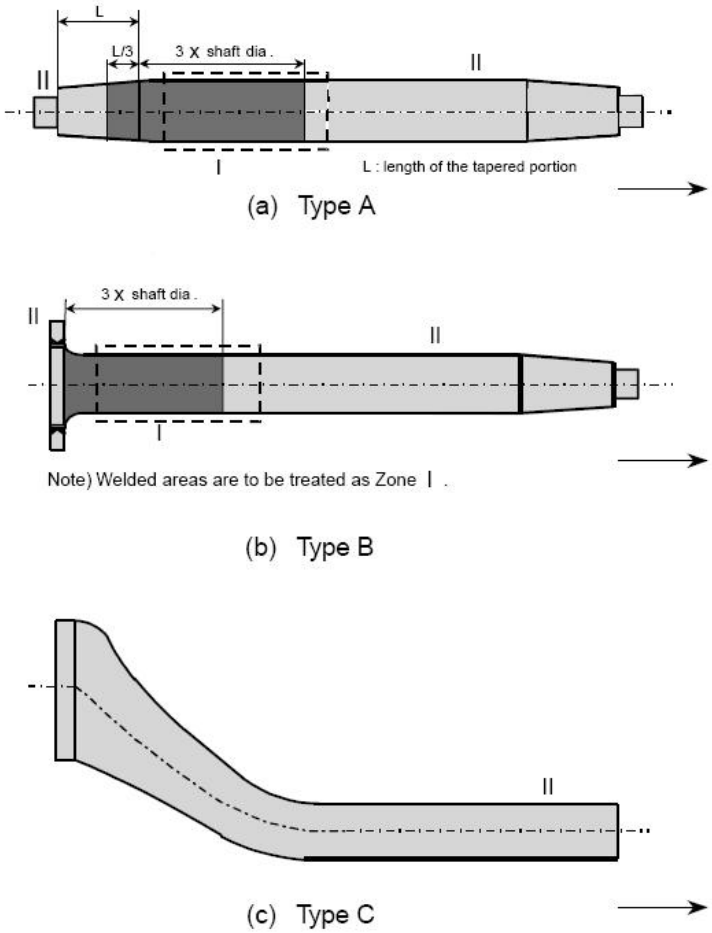
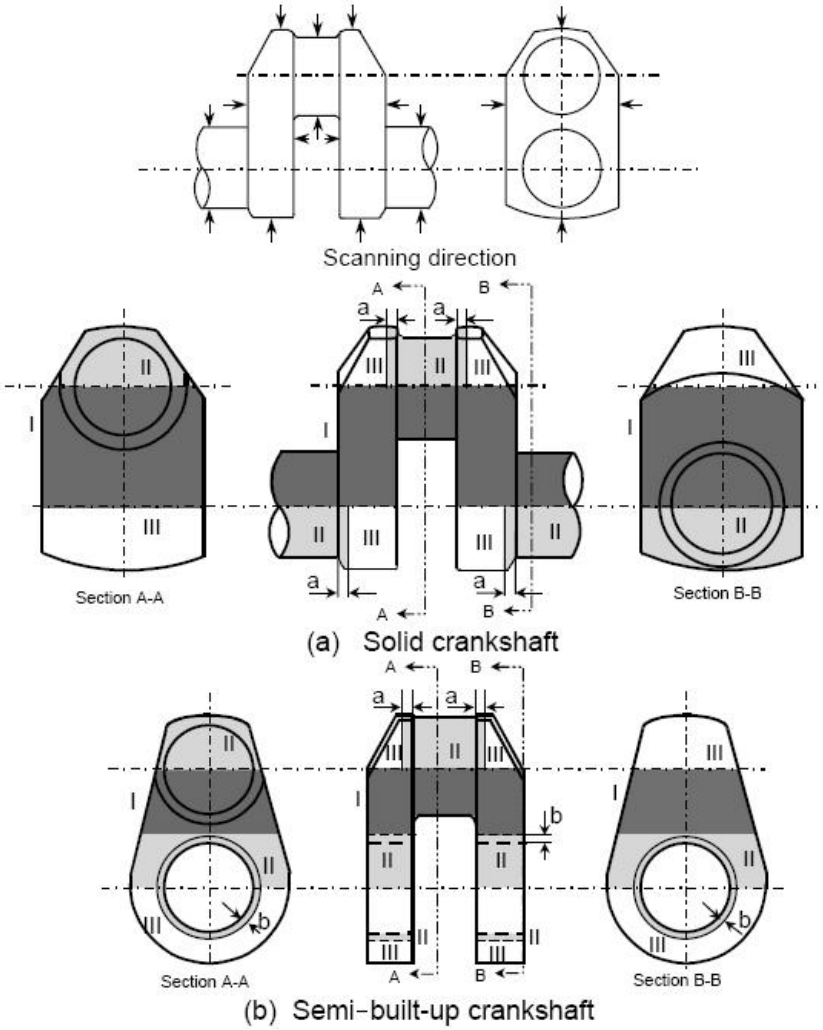
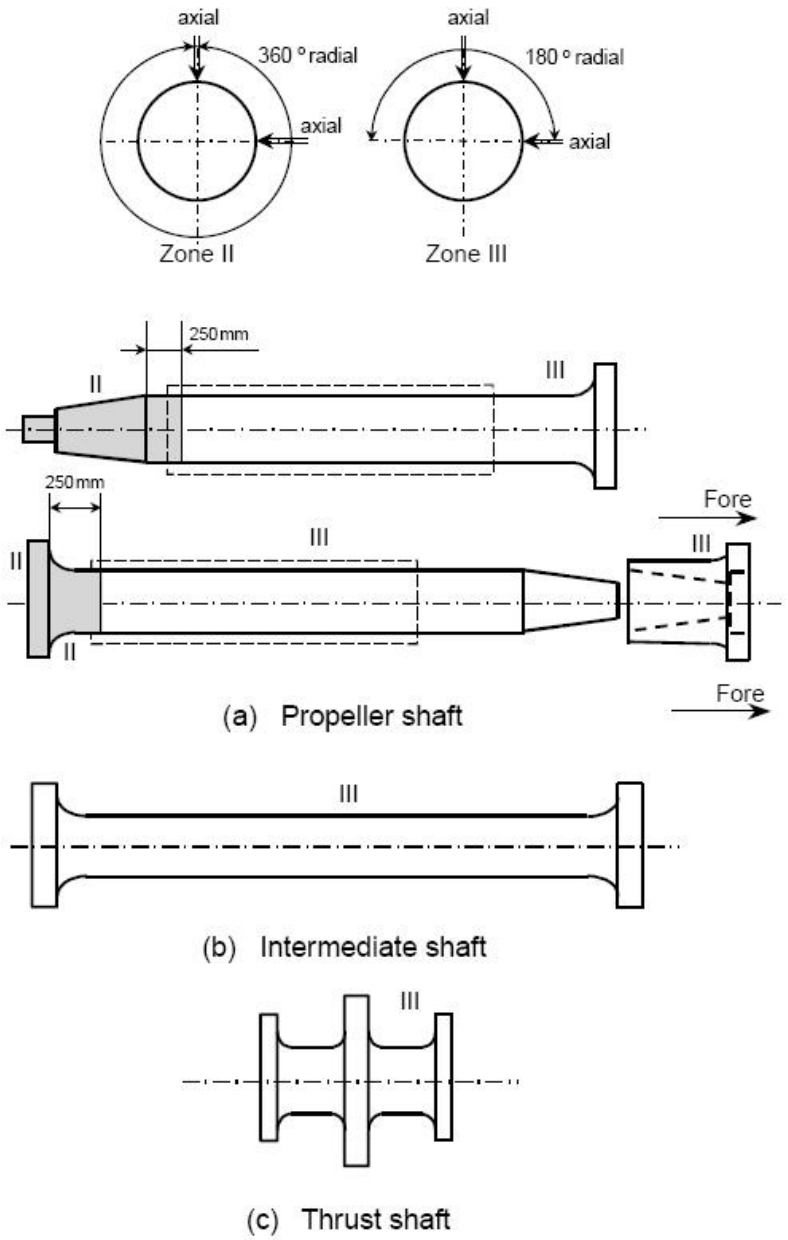


Figure 7A.4.3(4) Zones for magnetic particle/penetrant testing on rudder stocks



Notes: 1. In the above figures:
a = 0.1d or 25 mm, whichever is greater;
b = 0.05 d or 25 mm, whichever is greater (circumstances of shrinkage fit);
where d is pin or journal diameter.
2. Core areas of crankpins and/or journals within a radius of 0.25d between the webs may generally be treated as Zone II.
3. Identification of the zones:
Dark color for zone I,
Light color for zone II,
Colorless for zone III.

Figure 7A.5.3(1) Zones for ultrasonic testing on crankshafts



Notes: 1. For hollow shafts, 360 radial scanning applies to Zone III.
2. Circumferences of the bolt holes in the flanges are to be treated as Zone II.

Figure 7A.5.3(2) Zones for ultrasonic testing on shafts

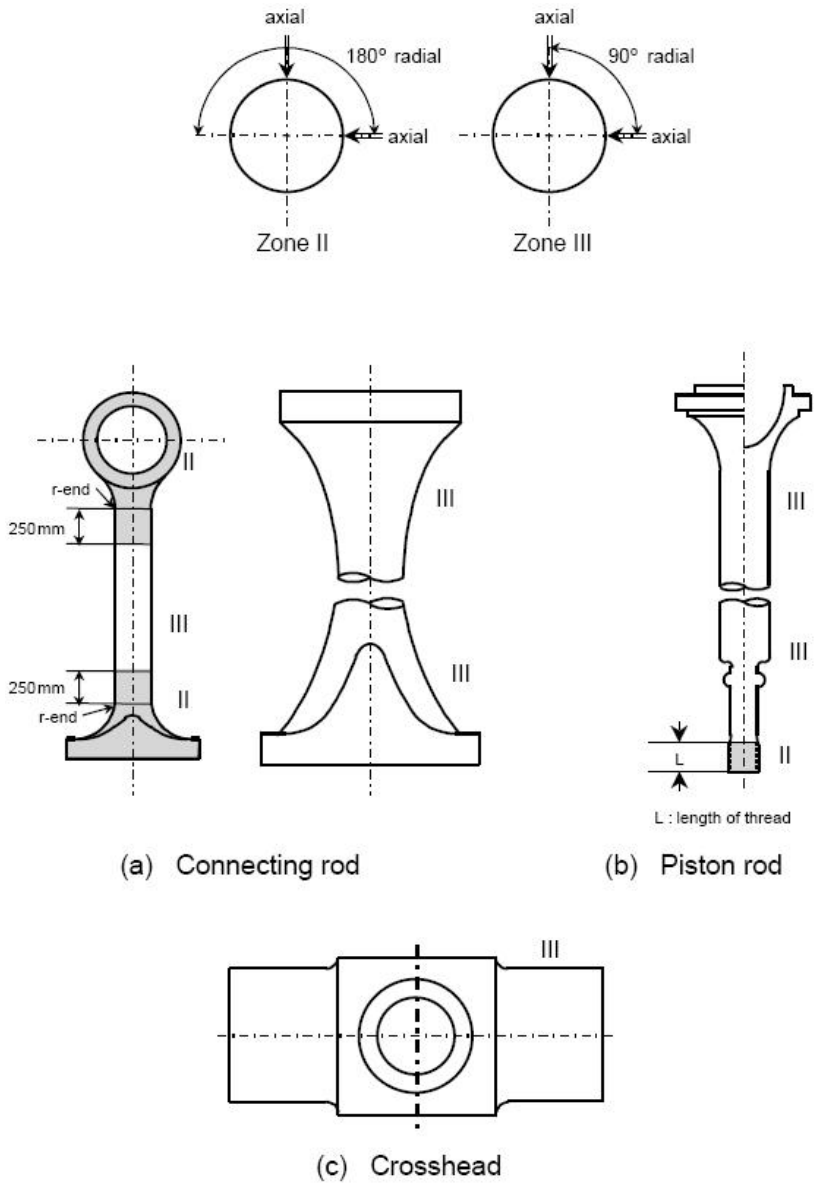


Figure 7A.5.3(3) Zones for ultrasonic testing on machinery components

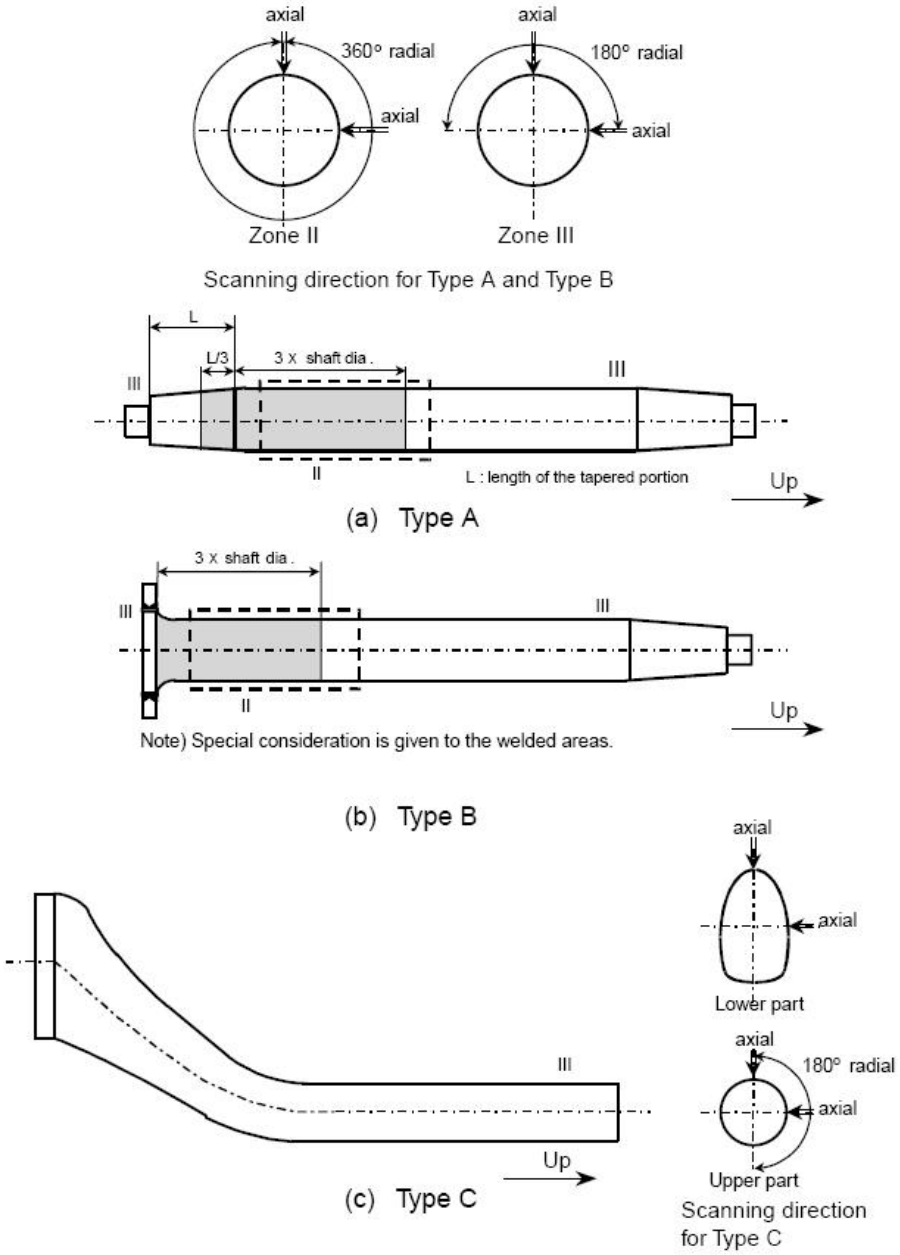


Figure 7A.5.3(4) Zones for ultrasonic testing on rudder stocks

Appendix 7B Non-Destructive Testing of Hull Steel Castings

7B.1 Application

7B.1.1 This Appendix applies to the non-destructive testing of hull steel castings covered by CCS Rules for Materials and Welding.

7B.1.2 For steel castings other than those specified in this Appendix, the requirements in this Appendix may apply correspondingly considering their materials, types, shapes, service conditions and stress conditions at delivery.

7B.1.3 This Appendix covers mainly the inspection of marine steel castings. Unless otherwise specified in this Appendix, non-destructive testing techniques used in specific tests are to comply with the relevant requirements of this Chapter. For specific forms of steel castings not covered in this Appendix, appropriate NDT plans and acceptance criteria are to be formulated according to applicable recognized standards.

7B.2 General requirements

7B.2.1 Steel castings are generally to be examined in the final delivery condition. Where intermediate non-destructive tests have been performed in manufacturing of steel castings, the manufacturer is to furnish a test report upon the request of the Surveyor.

7B.2.2 For small castings produced in batches, random check may be allowed in accordance with the relevant requirements of Section 1, Chapter 6, PART ONE of CCS Rules for Materials and Welding.

7B.2.3 Where a certain defect indication is found, the inspection may be extended or additional NDT method(s) used for a more detailed evaluation of surface irregularities upon the request of the Surveyor.

7B.2.4 The visual and non-destructive surface inspections are usually to be carried out in the presence of the Surveyor.

7B.2.5 Where advanced ultrasonic testing methods are applied, (e.g. PAUT or TOFD), the technical requirements may refer to Appendix 2, PART THREE in CCS Rules for Materials and Welding. The acceptance criteria is to be in accordance with the requirements of this Appendix.

7B.3 Preparation for inspections and visual examination

7B.3.1 Steel castings are to be subjected to a 100% visual examination of all accessible surfaces by the manufacturer.

7B.3.2 Prior to inspection, steel castings are to be cleaned to remove all sand fusions, scales, oil, rust, grease and other impurities and contaminants that will affect the inspection. For surface inspection NDT methods, the surface quality is to be a minimum value of $Ra \leq 6.3$ μm. When magnetic particle testing is used, the surface can be coated with contrast paint. Ultrasonic testing is to be carried out after the castings have been ground, machined or shot blasted to a suitable condition, with a minimum value surface quality of $Ra \leqslant 12.5$ μm. The surfaces of castings are to be such that adequate coupling can be established between the probe and the casting and that excessive wear of the probe is avoided.

7B.3.3 The visual examination may be carried out in accordance with the relevant requirements of Section 3 of this Chapter or the other recognized standards.

7B.3.4 All castings are to be free of cracks, crack-like indications, hot tears, cold shuts or other injurious indications. The thickness of the remains of sprues or risers is to be within the casting dimensional tolerance.

7B.4 Non-destructive surface inspections

7B.4.1 Non-destructive surface inspections of steel castings are usually to be carried out by magnetic particle testing or liquid penetrant testing. The magnetic particle testing is usually recommended with the exception of austenitic stainless steels or other special cases. AC magnetisation method is normally to be used. Where DC magnetisation method is used, the reason is to be clearly stated and with the consent of CCS.

7B.4.2 The surface inspections of the relevant areas of typical essential marine castings are to be in accordance with Figures 7B.4.2(1) to 7B.4.2(6). The manufacturer is to carry out testing in accordance with atesting plan approved by CCS. The plan is to specify the extent of the test, the test technique, the quality

level or, if necessary, level for different locations of the castings. Criteria for the examination of other castings not listed in this paragraph are to be subject to agreement.

7B.4.3 In addition to the areas specified in 7B.4.2, surface inspections are usually to be carried out in the following locations:
(1) at all accessible fillets and changes of section;
(2) in way of fabrication weld preparation, for a band width of 30 mm;
(3) in way of chaplets;
(4) in way of weld repairs;
(5) at positions where surplus metal has been removed by flame cutting, scarifying or arc-air gouging.

7B.4.4 For magnetic particle testing, attention is to be paid to the contact between the casting and the clamping devices of fixed particle detector in order to avoid local overheating or burning damage on its surface. Magnetic particle testing by contact method are not permitted on finished machined items. Note that the use of solid copper at the prod tips is to be avoided due to the risk of copper penetration contamination into the casting. The pole of the magnets is to have close contact with the component.

7B.4.5 Non-destructive surface inspections may be carried out in accordance with Section 6 or 7 of this Chapter or the other national or international standards.

7B.4.6 The surface evaluation of marine castings and their acceptance are to be carried out as follows:
(1) The surface is usually to be divided into reference areas of 225 cm^2, and the area for evaluation is to be taken in the most unfavorable location relative to the indication being evaluated.
(2) For welded and repaired castings, the weld surface is to be divided into reference band lengths of 150 mm. The band length is to be taken in the most unfavorable location relative to the indications being evaluated.
(3) Cracks and hot tears are not acceptable. The allowable number and size of indications in the reference band length and/or area are not to exceed those given in Table 7B4.6.

The categories are shown as followings:

1) Linear indication: an indication with a largest dimension three or more times its smallest dimension;

2) Non-linear indication: an indication with a largest dimension less than three times its smallest dimension;

3) Aligned indication: a unique indication and its length is equal to the overall length of the alignment, including: a) non-linear indications form an alignment when the distance between indications is less than 2mm and at least three indications are aligned; b) Linear indications form an alignment when the distance between two indications is smaller than the length of the longest indication.

Acceptance criteria for surface testing of castings **Table 7B4.6**

Inspection zone	Max. number of indications	Type of indication①	Max. number for each type	Max. dimension of single indication mm②
Fabrication weld preparation and weld repairs	4	Linear Non-linear Aligned	4① 4① 4①	3 5 3
Locations other than welds	20	Linear Non-linear Aligned	6 10 6	5 7 5

Notes:
① 30 mm minimum (measured in any direction) between relevant indications.
② In weld repairs, the maximum dimension is 2 mm.

7B.5 Inspections of internal defects of castings

7B.5.1 Non-destructive inspections of internal defects of castings are usually to be carried out by ultrasonic testing using the contact method with straight beam or angle beam technique. The test procedure, instrument and condition are to be in compliance with the relevant recognized standards.

7B.5.2 Unless otherwise specified in the contract/drawings, ultrasonic testing is to be carried out in the following zones indicated in Figures 7B.4.2(1) to 7B.4.2(6) for internal inspections of typical essential marine castings:
(1) in way of all accessible fillets and at pronounced changes of section;
(2) in way of fabrication weld preparations for a distance of 50 mm from the edge;
(3) in way of weld repairs where the original defect was detected by ultrasonic testing;

(4) in way of sprue or riser positions;
(5) in way of machined areas, particularly those subject to further machining such as bolt hole positions;
(6) in the case of castings such as rudder horns, which may have a large surface area still untested after the above inspections have been applied, an additional ultrasonic inspection of the untested areas is to be made along continuous perpendicular grid lines on nominal 225 mm centres, scanning from one surface only.

7B.5.3 Ultrasonic scans are to be made using a straight beam probe of 1 to 4 MHz (usually 2 MHz) frequency or angle probe, where required. Whenever possible, scanning is to be performed from both surfaces of the casting and from surfaces perpendicular to each other.

7B.5.4 The back wall echo obtained on parallel sections is to be used to monitor variations in probe coupling and material attenuation. Any reduction in the amplitude of the back wall echo due to material properties is to be corrected. Attenuation in excess of 30 dB/m could be indicative of an unsatisfactory heat treatment, and may render the effectiveness of the testing as unsuitable and this is to be noted in the test report. In such cases of excessive attenuation, investigation is to be carried out and suitable mitigation measures are to be taken to continue the effective ultrasonic testing, where possible.

7B.5.5 Steel castings are usually to be scanned as follows:

(1) machined surfaces, especially those in the vicinity of riser locations and in the bores of stern boss castings, is to be subject to a near-surface (approximately 25 mm) scan using a twin crystal straight beam probe;
(2) machined surfaces of particular importance (e.g. bolt holes, surface close to possible areas of shrinkage) are to be additionally scanned, straight probe is usually to be used beyond a depth of 25mm;
(3) also, it is advisable to examine the machined bores of castings using circumferential scans with 70° probes in order that axial radial planar flaws such as hot tears can be detected;
(4) fillet radii are to be examined using angle probes scanning from the surface/direction likely to give the best reflection, primarily to determine the presence of any cracks within the radiused areas, and as an additional scan to confirm any indications that may have been detected with straight probe within this area.

7B.5.6 The reference sensitivity for the straight beam probes of ultrasonic testing is to be established against a 6 mm reflector. The testing sensitivity can be calibrated either against 6 mm diameter flat bottom hole(s) in a reference block(s) which its material similar to that of the test piece and the thickness is corresponding to that of the casting is to be applied or by using the DGS (distance-gain-size) method, or by using the DAC (distance-amplitude-correction) method. The reference sensitivity of of angle probes is to be established against an appropriate 6mm reflector (e.g. reference reflectors angled perpendicular to the sound beam) for the DAC method, or equivalent using the DGS method. The DGS diagrams issued by a probe manufacturer identify the difference in dB between the amplitude of a back wall echo and that expected from a 6mm diameter disk reflector. By adding this difference to the sensitively level initially set by adjusting a back wall echo to a reference height e.g. 80%, the amended reference level will be representative of a 6mm diameter disk reflector. Similar calculations can be used for evaluation purposes to establish the difference in dB between a back wall reflector and disk reflectors of other diameters (such as 12mm or 15mm).

7B.5.7 Having made any necessary corrections for differences in attenuation or surface condition between the reference block and the casting, any indications received during scanning that exceed the 6mm reference level is to be marked for additional scans with angle probes in order that the extent and location of the discontinuity can be plotted.

7B5.8 In some cases, due to the shape, nature, complexity of casting, or defect type or orientation, radiographic testing may be carried out with the consent of CCS.

7B.6 Evaluation of internal defects

7B.6.1 Acceptance criteria for internal ultrasonic testing of steel castings are divided into the following two levels according to their significance:

Level UT1 is applicable to: fabrication weld preparations for a distance of 50 mm;
50 mm depth from the final machined surface including bolt holes;
fillet radii to a depth of 50 mm and within a distance of 50 mm from the radius end;
castings subject to cyclic bending stresses e.g. rudder horn, rudder castings and rudder stocks – the outer one third of thickness in the zones nominated for internal examination shown in Figures 7b.4.2(1) to (6);

discontinuities within the examined zones interpreted to be cracks or hot tears.

Level UT2 is applicable to: other locations nominated for ultrasonic testing in Figures 7B. 4.2(1) to (6) or the inspection plan;

positions outside locations nominated for level UT1 examination where feeders and gates have been removed;

castings subject to cyclic bending stresses – at the central one third of thickness in the zones nominated shown in Figure7b.4.2(1) to (6).

7B.6.2 For quality level UT 1, any discontinuity producing a signal amplitude in excess of the 6.0 mm DAC curve is unacceptable. For quality level UT2, the sensitivity may be based on actual size of flat bottom hole (of 12mm and 15 mm) or based on equivalent 6mm of flat bottom hole and the sensitivity adjusted to obtain equivalent amplitudes, For use of flat bottom hole of 6mm for setting sensitivity, adjustment of signal amplitudes (measured in dB above 6mm DAC) can be determined for 12mm and 15mm flat bottom hole reflectors: to be DAC + 12dB and DAC + 16dB (plus any compensation for transfer and attenuation losses), see Figure 7B.6.2.

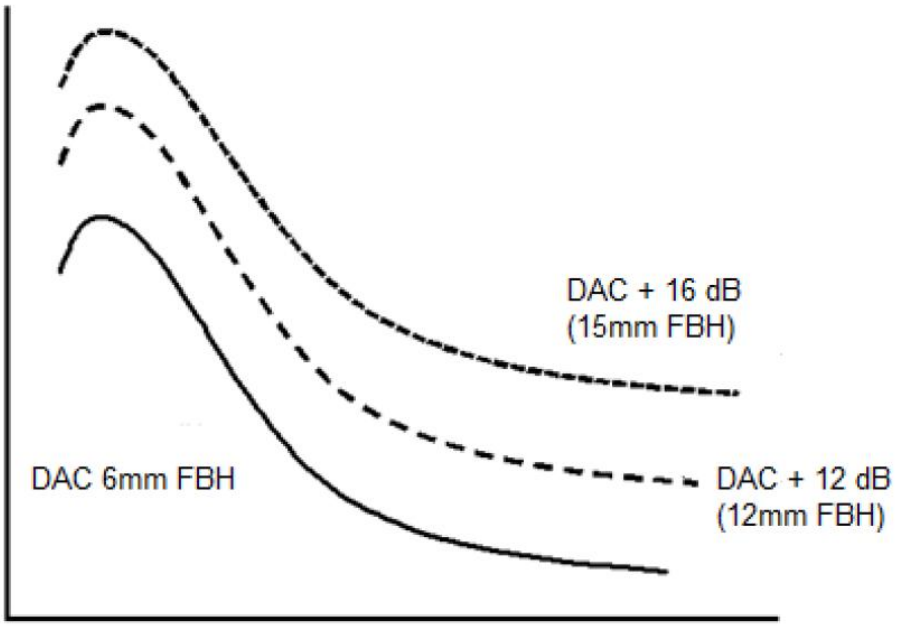


Figure 7B.6.2 DAC curve produced from 6mm flat bottom hole reflector and DAC curves adjusted to represent equivalent 12.0mm and 15.0 mm

7B.6.3 The acceptance criteria for ultrasonic testing of different zones are to be in accordance with Table 7B.6.3.

Acceptance criteria for ultrasonic testing of steel castings **Table 7B.6.3**

Inspection zone	Allowable disc shape according to DGS or allowable flat bottom hole shape according to DAC (mm)①	Max. number of indications to be registered②	Allowable length of linear indications (mm) ③④
UT1	> 6	0	0
UT2	12 ~ 15 > 15	5 0	50 0

Notes: ① The corresponding DAC level to each of the FBH reflectors is at 100% DAC.

② Grouped in an area measuring 300 × 300 mm.

③Measured on the scanning surface.

④ The measured indication is regarded as the longest dimension, as measured in the scanning process.

7B.6.4 The ultrasonic acceptance criteria for other casting areas not nominated in the figures annexed to this Appendix will be subject to special consideration based on the anticipated stress levels and the type, size and position of the discontinuity.

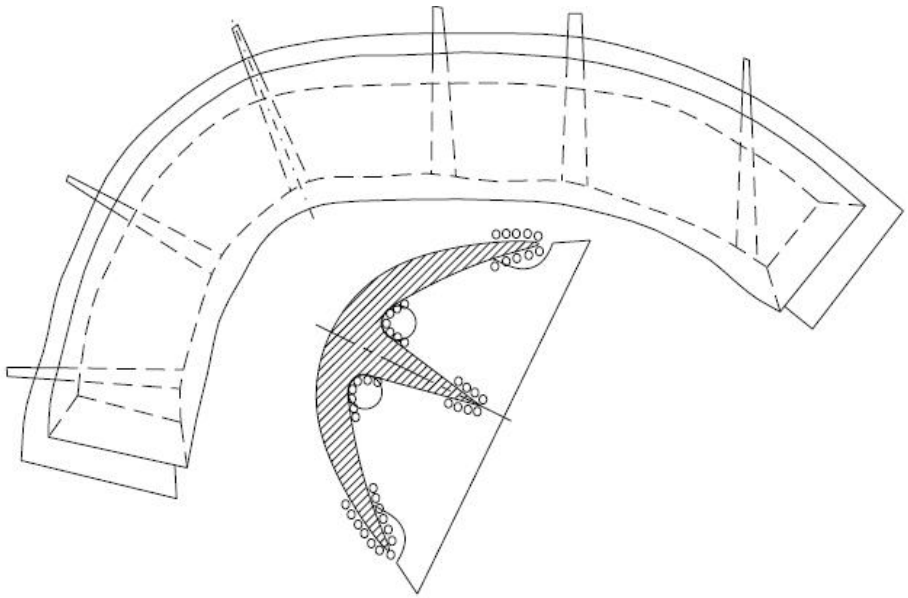
7B.6.5 National or international standards agreed by CCS may be adopted for radiographic testing method and quality level. The radiographic testing method may refer to the requirements of GB/T 5677 or ISO 4993, and the requirements of acceptable testing standards and acceptance levels for steel castings are not

to be lower than the levels or higher levels of recognized standards listed in Table 7B.6.5.

Acceptable testing standards and acceptance levels for steel castings Table 7B.6.5

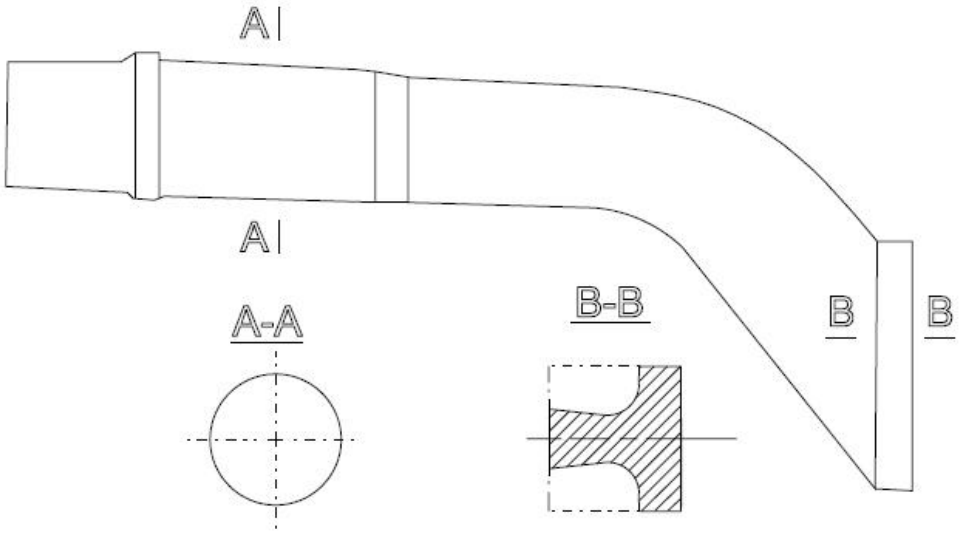
Standard No.	Level
JB 5000.14	2*/3
ASTM E446 – 15	2*/3
ASTM E186 – 15	2*/3
ASTM E280 – 15	2*/3

Note: * used to the castings subject to higher stress and dynamic load.



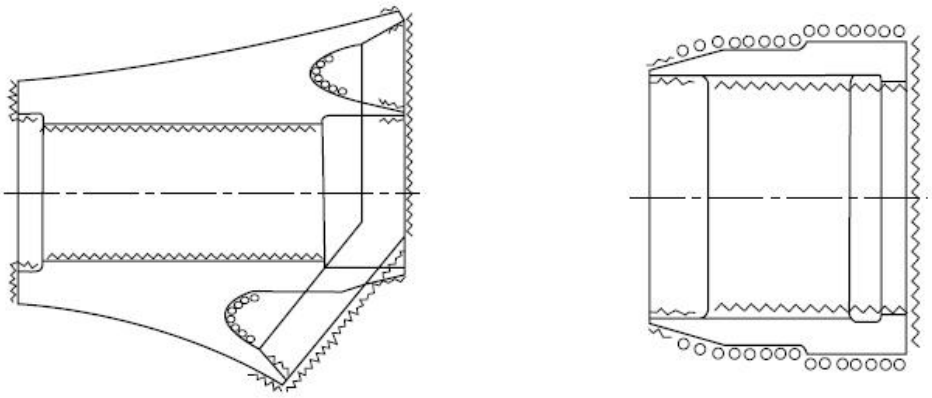
Notes: 1. All surfaces are to be visually examined.
2. Locations indicated with "O" are to be subjected to magnetic particle and ultrasonic testing.

Figure 7B4.2(1) Inspection zones of stern frame



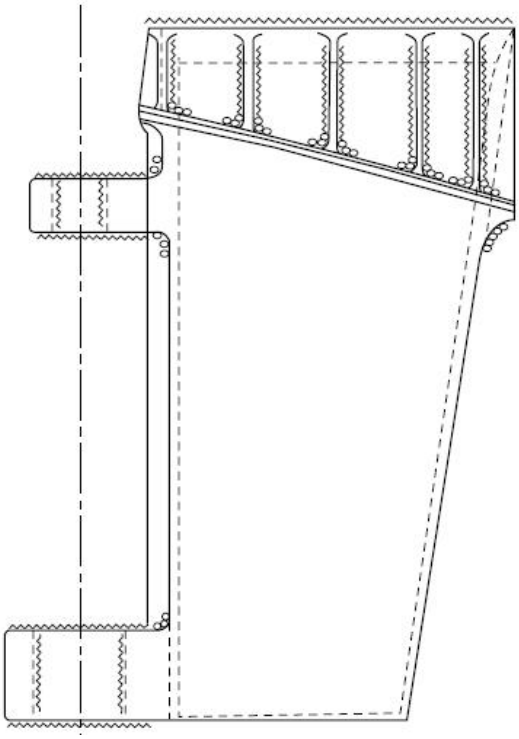
All supporting surfaces are to be subjected to visual examination, magnetic particle and ultrasonic testing.

Figure 7B4.2(2) Inspection zones of rudder stock



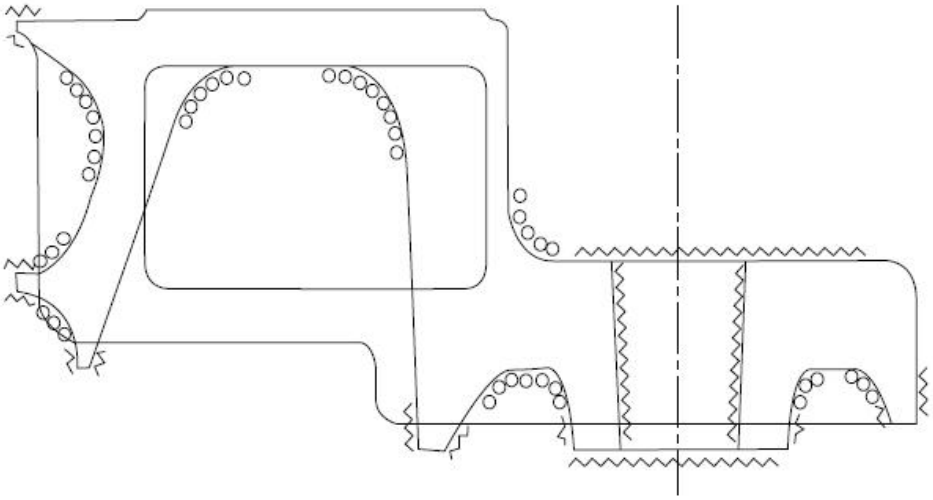
Notes: 1. All surfaces are to be visually examined.
2. Locations indicated with “O” are to be subjected to magnetic particle and ultrasonic testing.
3. Locations indicated with “∧∧” are to be subjected to ultrasonic testing.
4. The detailed extents of examinations are to be in accordance with the requirements of 7b.5.2 of this Appendix.

Figure 7B4.2(3) Inspection zones of stern boss



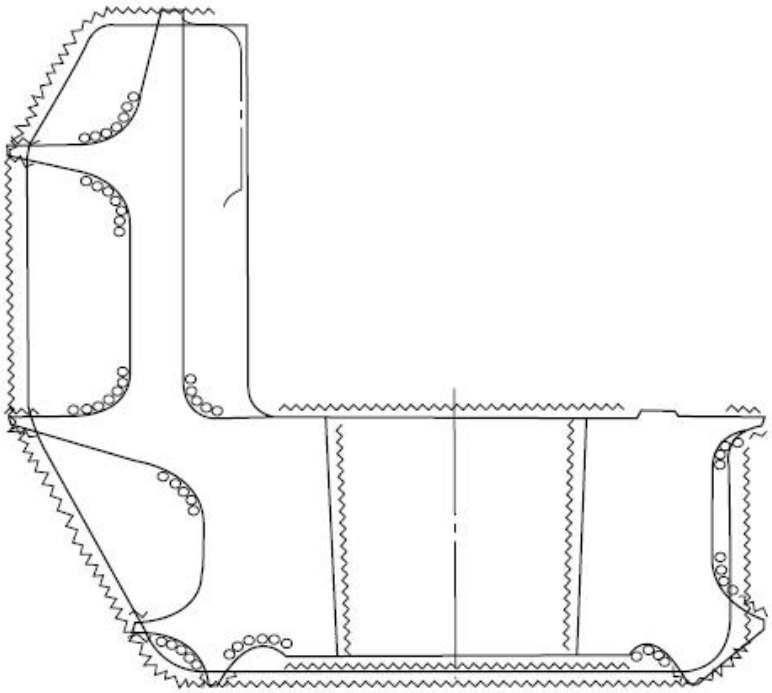
Notes: 1. All surfaces are to be visually examined.
2. Locations indicated with “O O” are to be subjected to magnetic particle and ultrasonic testing.
3. Locations indicated with “∧∧” are to be subjected to ultrasonic testing.
4. The detailed extents of examinations are to be in accordance with the requirements of 7b.5.2 of this Appendix.

Figure 7B4.2(4) Inspection zones of rudder hangings



Notes: 1. All surfaces are to be visually examined.
2. Locations indicated with “O” are to be subjected to magnetic particle and ultrasonic testing.
3. Locations indicated with “∧∧” are to be subjected to ultrasonic testing.
4. The detailed extents of examinations are to be in accordance with the requirements of 7b.5.2 of this Appendix.

Figure 7B4.2(5) Inspection zones of rudder (upper part)



Notes: 1. All surfaces are to be visually examined.
2. Locations indicated with “O” are to be subjected to magnetic particle and ultrasonic testing.
3. Locations indicated with “∧∧” are to be subjected to ultrasonic testing.
4. The detailed extents of examinations are to be in accordance with the requirements of 7b.5.2 of this Appendix.

Figure 7B4.2(6) Inspection zones of rudder (lower part)

Appendix 7C　Forms of non-destructive testing reports

射线检测报告

Radiographic Test Report

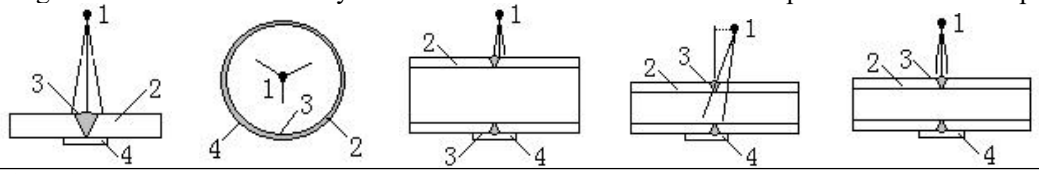
报告编号 Report No.：

委托单位 Client			工程名称/编号 Project name/No.		
构件名称 Component name			检测部位 Test location		
钢材等级/材质 Steel grade /material			产品类型 Type of production	□铸件 □锻件 □焊接件 □母材 Casting Forging Welding Base metal	
焊接方法 Welding process			接头形式 Type of joints		
射线机型号/射线源类型 Type of equipment/ Type of radiation source		辐射源宽度 Width of radiation source		射线检测数(曝光量)Number of radiographs (exposures)	
管电压 Tube Voltage		管电流 Tube Current		曝光方法和时间 Exposure technique and time	
焦点尺寸 Focus spot size		像质计灵敏度 Sensitivity of IQI		像质计类型和位置 Type and position of IQI	
胶片类型/名称 Type of film/designation		每个胶片夹/盒子中的胶片数 Number of film in each film holder/cassette		增感屏类型/厚度 Intensifying type/thickness	
检测时机 Timing of test		几何不清晰度 Geometric un-sharpness		黑度范围 Density range	
检测标准和技术等级 Testing standards & level of test technique		验收标准和级别 Acceptance criteria & levels		检测比例/数量 Spot-test rate/ Total quantity	
焦距 Focus-to-film distance	射线源到焊缝的距离： Distance from radiation source to weld 射线源侧焊缝到胶片距离： Distance from source side of the weld to radiographic film 射线穿过焊缝的角度(与垂直方向夹角)： Angle of radiation beam through the weld(from normal)				
其他报告事项 Other items					

检测布置图 Sketch：（说明 1-射线源 Radiation source，2-构件 Component，3-像质计 IQI，4-胶片 Film）

□单壁透照　□中心法透照　□双壁透照　□椭圆成像　□小径管垂直成像　□其他

Single well　Source centrally located　Double-well　Elliptic　Perpendicular　Other



检测结论：

Statement of test results

评定人员(级别) Evaluator (level)	(　)	评　定　日　期 Evaluation date		检验人员(级别) Inspector(level)	(　)	检测日期 Test date	

注：1、其他报告事项，指检测限制条件、观察条件、温度等事项（如有时）

2、检测位置示意图另附

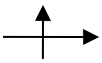
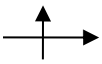
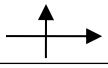
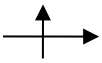
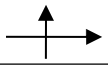
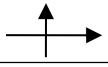
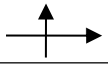
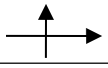
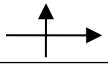
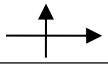
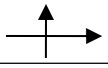
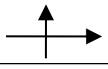
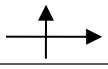
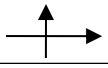
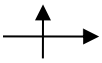
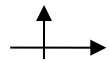
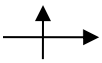
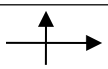
Note: 1.Other items refer to any test limitations, viewing conditions and temperature etc. (if any)

2. The sketch of test positions is attached.

射线检测报告

Radiographic Test Report

报告编号 Report No.：

序号 NO	构件或焊缝底片编号 Part or weld film No	母材检测厚度/规格 Thickness/size (mm)	检测长度 Length (mm)	像质指数 IQI Index	显示类型和尺寸 Type & size of indications	显示位置 Location of indications	评级 Level	合格/不合格 Acc. / Rej.	备注 Remark
									
									
									
									
									
									
									
									
									
									
									
									
									
									
									
									
									
									
									

注：1 显示类型代号 Type of indications : A-无显示 No indications S-夹渣 Slag P-气孔 Porosity C-裂纹 Crack
Note U-咬边 Undercut L-未熔合 Lack of fusion I-未焊透 Incomplete penetration
2 “备注”栏 Remark：Rn(R1-返修一次，Repair Once R2-返修两次，Repair twice) 另外视客户需要填写，Client required

超声波检测报告

Ultrasonic Test Report

报告编号 Report No.：

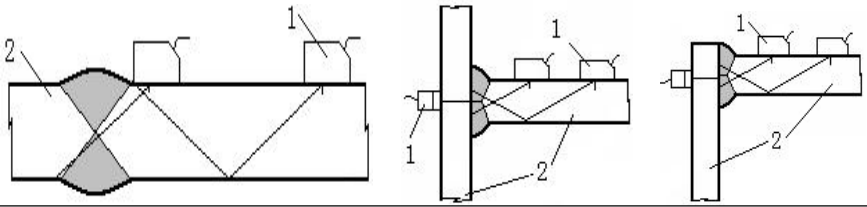
委托单位 Client			工程名称/编号 Project name/No.		
构件名称 Component name			检测部位 Test location		
钢材等级/材质 Steel grade /Material			产品类型 Type of production	□铸件 □锻件 □焊接件 □母材 Casting Forging Welding Base metal	
焊接方法 Welding process			接头形式 Type of joints		
检测时机 Timing of test		表面状况 Surface status		检测部位温度 Temperature of test location	℃
超声波设备制造商 Instrument maker of ultrasonic equipment		耦合剂品牌及类型 Type & brand of couplant		检测灵敏度 Sensitivity	
超声波设备型号和序列号，Model & series number. of ultrasonic equipment		标准/对比试块 Sta. /Cal. block		传输修正 Transfer correction	dB
检测标准和技术等级 Testing standards & level of test technique		验收标准和级别 Acceptance levels		检测比例/数量 Spot-test rate/ total quantity	

探头 Probes	制造商 Instrument maker	序列号 Serial number	频率 Frequency	晶片尺寸 Crystal size	实测折射角度 Actual angle of refraction	校准灵敏度 Sensitivity levels calibrated
			MHz			
			MHz			
			MHz			

其他报告事项 Other items	

超声检测布置图 Sketch：（图示说明：1-探头 Probes，2-构件 Component）

□平对接 Butt joint　□T 型角接 T joint　□C 型角接 C joint　□其他 Others



检测结论：
Statement of test results

评定人员(级别) Evaluator (level)	( )	评定日期 Evaluation date		检验人员(级别) Inspector(level)	( )	检测日期 Test date	

注：1、其他报告事项，指检测限制条件、观察条件、温度等事项（如有时）
2、检测位置示意图另附

Note: 1.Other items refer to any test limitations, viewing conditions and temperature etc. (if any)
2. The sketch of test positions is attached.

超声波检测报告

Ultrasonic Test Report

报告编号 Report No.：

序号 NO.	构件或焊缝编号 Part or weld No.	母材检测厚度/规格 Thickness/size (mm)	检测长度 Length (mm)	超标回波高度 Reflections interpreted as failing to meet	显示当量 Indications equivalent (dB)	L mm	X mm	Y mm	H mm	评级 Class	合格/不合格 Acc./Rej.	备注 Remark

注：1 X：距基准点距离 Distance to the base point　　Y：显示距焊缝中心距离 Distance from the indications to the center of the weld

Note　H：显示深度距离 Depth of indications　　L：显示长度 Length of indications

2 “备注”栏 Remark：Rn(R1-返修一次，Repair Once　R2-返修两次，Repair twice)　　另外视客户需要填写，Client Required

磁粉检测报告

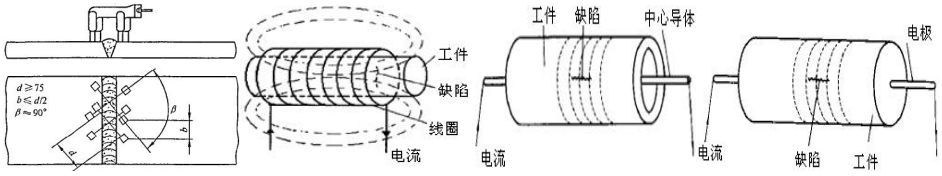
Magnetic Particle Test Report

报告编号 Report No.:

委托单位 Client			工程名称/编号 Project name/No.		
构件名称 Component name			检测部位 Test location		
钢材等级/材质 Steel grade /material			产品类型 Type of production	☐铸件 ☐锻件 ☐焊接件 ☐母材 Casting Forging Welding Base metal	
焊接方法/接头形式 Welding process / joints			母材厚度/规格 Thickness /Specification		
检测时机 Timing of test		表面状况 Surface status		检测部位温度 Temperature of test location	
仪器型号和编号 Unit type / Reg. No.		检测介质 Detection media		反差增强剂 White contrast	
检测方法 Test technique	☐连续 Continuous ☐荧光 Fluorescent ☐干法 Dry ☐剩磁 Residual ☐非荧光 Un-fluorescent ☐湿法 Wet				
磁化类型 Type of magnetization		磁场强度 Magnetic field strength		灵敏度试片 Sensitivity Indicator	
磁化时间 Magnetization time		退磁 Demagnetization		观察条件 Vision Condition	
检测标准和技术等级 Testing standards & level of test technique		验收标准和级别 Acceptance levels		检测比例/数量 Spot-test rate/ total quantity	
其他报告事项 Other items					

磁粉检测布置图 Sketch：

☐磁轭法 Yoke ☐线圈法 Coil ☐中心导体法 Central conductor axial ☐轴向通电法 Current flow ☐其他 Others



检测结论：

Statement of test results

评定人员(级别) Evaluator (level)	( )	评定日期 Evaluation date		检验人员(级别) Inspector(level)	( )	检测日期 Test date	

注：1、其他报告事项，指检测限制条件、温度等事项（如有时）；

2、检测位置示意图另附

Note: 1.Other items refer to any test limitations and temperature etc. (if any)

2. The sketch of test positions is attached.

磁粉检测报告

Magnetic Particle Test Report

报告编号 Report No.:

序号 No.	构件或焊缝编号 Part or weld No.	检测长度（mm） Inspected length	显示编号 Indications No.	X（mm）	显示类型 Type of indications:	显示尺寸 Size of indications（mm）	评级 Class	合格/不合格 Acc. / Rej.	备注 Remark

注：1 显示类型代号 Type of indications : A-无显示 No indications S-夹渣 Slag P-气孔 Porosity C-裂纹 Crack
Note U-咬边 Undercut L-未熔合 Lack of fusion I-未焊透 Incomplete penetration X-距基准点距离 Distance to the base point
2 “备注”栏 Remark：Rn(R1-返修一次，Repair Once R2-返修两次，Repair twice) 另外视客户需要填写，Customer Required

渗透检测报告

Penetration Test Report

报告编号 Report No.:

委托单位 Client			工程名称/编号 Project name/No.		
构件名称 Component name			检测部位 Test location		
钢材等级/材质 steel grade /Material			产品类型	☐铸件 ☐锻件 ☐焊接件 ☐母材 Casting Forging Welding Base metal	
焊接方法/接头形式 Welding process/joints			母材厚度/规格 Thickness /specification		
检测时机 Timing of test		表面状况 Surface status		检测部位温度 Temperature of test location	
检测方法 Test technique	☐着色 colour-contrast ☐荧光 fluorescent ☐水洗型 Water washable ☐溶剂去除型 Solvent removable ☐后乳化型 Post emulsifiable				
清洗剂 Cleaning Agent		渗透剂 Penetrant		显像剂 Developer	
对比试块 Calibration block		灵敏度 Sensitivity		渗透时间 Penetrate time	min
乳化时间 Emulsification time	min	显像时间 Developer time	min	观察条件 Viewing condition	lx
检测标准和技术等级 Testing standards & level of test technique		验收标准和级别 Acceptance levels		检测比例/数量 Spot-test rate/ total quantity	
其他报告事项 Other items					

检测位置示意图(可另附)
The sketch of test positions (may be attached)

检测结论：
Statement of test results

评定人员(级别) Evaluator (level)	( )	评定日期 Evaluation date		检验人员(级别) Inspector(level)	( )	检测日期 Test date	

注：1、其他报告事项，指检测限制条件等事项（如有时）。
Note: 1.Other items refer to any test limitations and etc. (if any)

渗透检测报告

Penetration Test Report

报告编号 Report No.:

序号 No.	构件或焊缝编号 Part or weld No.	检测长度 Inspected length (mm)	显示编号 Indication No.	X (mm)	显示类型 Type of indications	显示尺寸 Size of Indication (mm)	评级 Class	合格 不合格 Acc. / Rej.	备注 Remark

注：1 显示类型代号 Type of indications : A-无显示 No indications S-夹渣 Slag P-气孔 Porosity C-裂纹 Crack
Note U-咬边 Undercut L-未熔合 Lack of fusion I-未焊透 Incomplete penetration X-距基准点距离 Distance to the base point
2 “备注”栏 Remark：Rn(R1-返修一次，Repair Once R2-返修两次，Repair twice)
另外视客户需要填写，Customer required