GUIDANCE NOTES

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CHINA CLASSIFICATION SOCIETY

GUIDELINES FOR INSPECTION OF HULL WELDS

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CHAPTER 1 GENERAL

Section 1 GENERAL

1.1.1 Objectives

1.1.1.1 Welding is an essential link in the chain of modern shipbuilding and ship repairs. The Guidelines have been developed to ensure an appropriate control of technological factors involved throughout the process of hull welding.

1.1.1.2 The Guidelines constitute a supplement to PART THREE of CCS Rules for Materials and Welding, in which practical recommendations are available for actual operations of parties concerned with hull welding.

1.1.1.3 The requirements in the Guidelines are recommendatory, except those which are the same as the requirements in CCS Rules for Materials and Welding. 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 manufacture of welding consumables, qualification tests of welders, design and approval of welding procedures, hull assembly and welding, non-destructive testing of welds and other inspections in respect to shipbuilding and ship repairs.

1.1.2.2 The Guidelines apply mainly to welding of hull structures made of steel and aluminum alloys complying with the requirements of CCS Rules for Materials and Welding, covering also welding of marine machinery or equipment of other 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 (SMAW), submerged arc welding (SAW), gas metal arc welding (GMAW), gas tungsten arc welding (GTAW) and electro gas welding (EGW).

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.

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. Associated testing equipment is to be recalibrated at least once a year 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 manufacture, 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 and rejected for at least one year (half-year for flux-cored wires) if stored in a dry warehouse.

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) when in use, low-hydrogen electrodes are to be kept in thermostated containers for preferably not more than 4 hours;
(2) electrodes or fluxes are not to be kept in baking ovens having a temperature of 100℃ to 150℃ for more than 7 days; otherwise they are to be re-baked. Low-hydrogen electrodes are preferably not to be re-baked more than twice. Acid electrodes may be dealt with according to the requirements recommended by the manufacturer;
(3) certain electrodes in vacuum packages may be directly used without baking. However, they are to be unpackaged immediately before use. If exposed too long in air, they are to be re-baked according to the conditions recommended by the manufacturer;
(4) when unpackaged, the wires for gas shielded arc welding are to be used up in 2 days. If they are to be left in a wire feeder overnight, suitable measures are to be taken to reduce their contact with moisture in the air.

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.

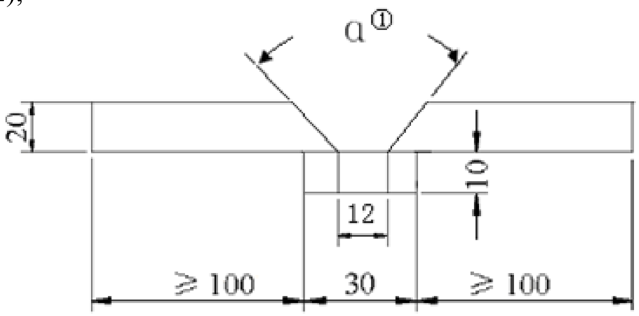
2.2.1.2 Unless contractually specified, the testing and acceptance requirements for welding consumables used for copper and copper alloys, temporary backing materials for one-side welding and braze welding consumables are to be consistent with this Section.

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 parent 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);

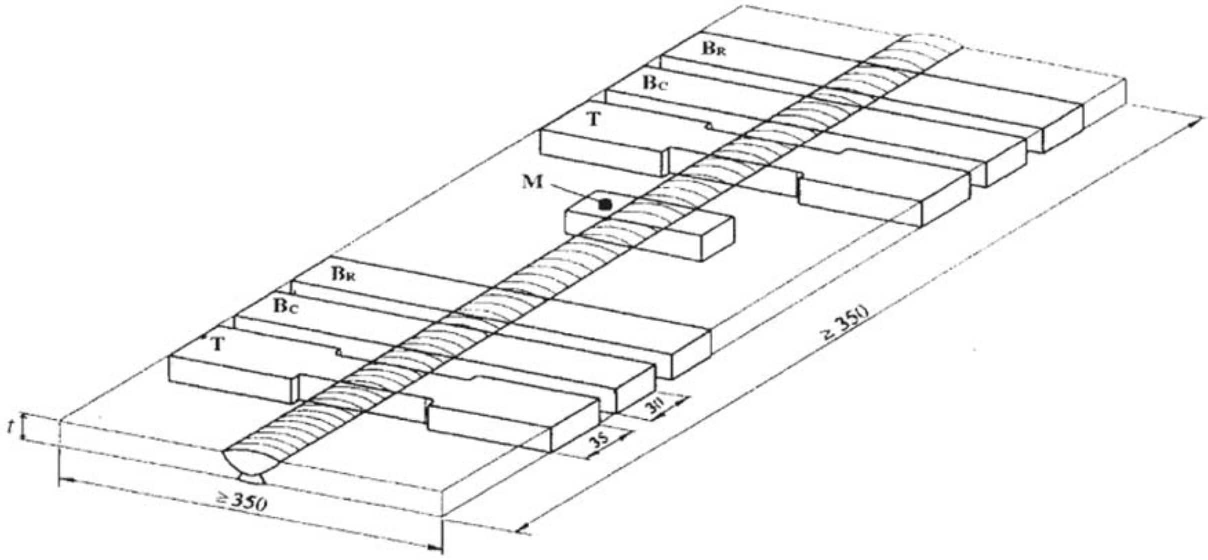


Note: ① 60° for Cu-Ni-Fe alloy, 60° ~ 90° for other copper alloys

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 parent material 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, 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 ~ 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 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 parent materials.

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 parent material 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 less than (mm)	4t~~③~~②				③	③
	Angle of bend α	180°					
	Test requirement	Tested specimen is not to reveal any crack or other flaw 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 properties 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 porosity test, volume density test, fire resistance test and flexural strength test, according to recognized standards. Specific acceptance criteria are given in Table 2.2.3.2.

Main technical properties of ceramic weld backings **Table 2.2.3.2**

Porosity (%)	Volume density (g/cm^3)	Flexural strength (N/cm^2)	Fire resistance (℃)
< 0.4	> 1.75	> 50	> 1300

2.2.3.3 Performance tests of aluminum foil tapes include peeling strength test and holding power test, which are to be carried out according to recognized standards. Specific acceptance criteria are as follows
(1) the peeling strength is to be not less than 8 N/25 mm;
(2) the holding power is to be 1 h/25 mm × 25 mm ·1 kg at ambient temperature without any displacement.

2.2.3.4 The requirements for the test of welding properties 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 parent steel 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).

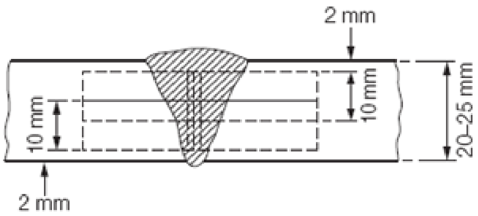


Figure 2.2.3.5(3) Sampling of impact specimens

2.2.3.6 The required test results of welding properties are as follows:
(1) back runs are smooth, free of 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 parent 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.

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 marine structural steels, stainless steels, aluminum alloys and copper alloys.

2.3.1.2 The welding consumables selected are to be the products approved by CCS.

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

2.3.2 Marine structural steels

2.3.2.1 The welding consumables selected for marine structural steels are to match the grade of the parent steel.

2.3.2.2 The welding consumables for normal strength and higher strength marine steels are to be selected according to the requirements of Section 4, Chapter 1, PART TWO of CCS Rules for Classification of Sea-Going Steel Ships.

2.3.2.3 The applicable grades of welding consumables for high strength quenched and tempered steels are given in Table 2.3.2.3.

Applicable grades of welding consumables for high strength quenched and tempered Steels

Table 2.3.2.3

Grade of welding	High strength quenched and tempered steels for welded structures																	
	A420 D420	E420	F420	A460 D460	E460	F460	A500 D500	E500	F500	A550 D550	E550	F550	A620 D620	E620	F620	A690 D690	E690	F690
3Y42	×																	
4Y42	×	×																
5Y42	×	×	×															
3Y46	O			×														
4Y46	O	O		×	×													
5Y46	O	O	O	×	×	×												
3Y50	O			O			×											
4Y50	O	O		O	O		×	×										
5Y50	O	O	O	O	O	O	×	×	×									
3Y55				O			O			×								
4Y55				O	O		O	O		×	×							
5Y55				O	O	O	O	O	O	×	×	×						
3Y62							O			O			×					
4Y62							O	O		O	O		×	×				
5Y62							O	O	O	O	O	O	×	×	×			
3Y69										O			O			×		
4Y69										O	O		O	O		×	×	
5Y69										O	O	O	O	O	O	×	×	×

Notes: "×" for applicable steel grade
"O" for permissible steel grade
Blank for non-applicable steel grade

2.3.2.4 The following principles are to be followed for the joining of steels of different grades:
(1) for the joining of steels of different strength levels, welding consumables suitable for the lower strength are generally acceptable except at discontinuities or other points of stress concentration;
(2) for the joining of steels of the same strength levels but of different toughness grades, welding consumables suitable for the lower toughness grade are generally acceptable except for the structural

members with complicated forces or severe construction conditions.

2.3.2.5 Low-hydrogen welding consumables are to be used for the welding of the following steels or structures:
(1) higher strength steels or steels with carbon equivalent exceeding 0.41%;
(2) structural members and structures specified in Section 4, Chapter 1, PART TWO of CCS Rules for Classification of Sea-Going Steel Ships.

2.3.3 Austenitic and duplex stainless steels

2.3.3.1 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 parent metals, ensuring that the corrosion resistance and mechanical properties of the weld metal are basically equivalent to those of parent metals and that the required cracking resistance is achieved.

2.3.3.2 Welding consumables having the same or similar alloy contents as the parent 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 parent metal.

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

2.3.3.4 Welding consumables having contents of Cr, Ni etc. higher than the parent 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 parent metal of the lower grade.

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

2.3.4 Aluminum alloys

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

2.3.4.2 Welding consumables, the chemical composition of which is similar to that of the parent 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).

2.3.4.3 In general, welding consumables the chemical composition of which is different from the parent 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).

2.3.5 Copper alloys

2.3.5.1 A good deoxidizing capacity is to be taken into account in selecting welding consumables for copper alloys, ensuring tightness and mechanical properties of welded joints to achieve well shaped welds. In general, welding consumables, the chemical composition of which is similar to that of the parent metal and into which deoxidizing elements are added, are to be selected.

2.3.5.2 The selection of welding consumables for the repair welding of copper propellers may be referred to 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		Parent metal 2②										
		~~304L~~ S30403	~~304LN~~ S30453	~~316L~~ S31603	~~316LN~~ S31653	~~317L~~ S31703	~~317LN~~ S31753	~~347~~ S34778	~~32205~~ S22053 S22253	~~32550~~ S25554	~~32750~~ S25073	Low carbon or low alloy steels
Parent metal 1②	~~304L~~ S30403	308L	308L	308L	308L	308L	308L	308L	308L	308L	308L	309~~L~~
	~~304LN~~ S30453		308L	308L	308L	308L	308L	308L	308L	308L	308L	309~~L~~
	~~316L~~ S31603			316L	316L	316L	316L	316L	316L	316L	316L	309~~L~~
	~~316LN~~ S31653				317L	317L	317L	316L	316L	316L	316L	309~~L~~
	~~317L~~ S31703					317L	317L	316L	317L	317L	317L	309~~L~~
	~~317LN~~ S31753						317L	316L	2209	317L	317L	309~~L~~
	~~347~~ S34778							347	308L	308L	308L	309~~L~~
	~~32205~~ S22053 S22253								2209	2209	2209	309~~L~~ 2209
	~~32550~~ S25554									2553	2553	309~~L~~
	~~32750~~ S25073										~~2553~~ 2594	309~~L~~

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 Parent metals are listed according to ~~AISI standard grades~~ 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		Parent metal 2		
		5754, 5454, 5086	5083, 5383, 5456	6061, 6005A, 6082
Parent metal 1	5754, 5454, 5086	5356, 5556, 5183	5356, 5556, 5183	5356, 5556, 5183
	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

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 and gas tungsten arc welding of steels, aluminium alloys, copper alloys and titanium alloys for structures of ships and offshore installations.

3.1.1.2 In general, the qualification tests for automatic submerged-arc 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 by CCS.

3.1.2.2 A welder will be qualified to take the test for his operational skill only after he has successfully passed the basic knowledge test. The content of the basic knowledge test is to correspond to the welding processes to be used in the test for the operational skill and mainly include the basic knowledge of common parent materials, welding consumables, welding equipment, welding procedures, welding defects and how to prevent such defects as well as safety knowledge of welding.

3.1.2.3 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), edge preparation and size (groove angle, root face, root gap) of test plates, they may be determined according to the actual condition of production. In general, the principles for selecting joint types of test plates are as follows:
(1) where the production welding is to be performed from both sides or at one side with backing, the joint type of test plates may be welding by both sides or one-side welding with backing;
(2) where the production welding includes the one-side welding without backing and with back formation, the joint type of test plates is to be one-side welding without backing.

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 <u>for steel and aluminum alloy</u> 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 parent materials 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.

3.1.5 Qualification Certificate of Welder

3.1.5.1 Upon a satisfactory qualification test, 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 Manufacturers are to control the period of validity and the application of the Qualification Certificate of Welder.

3.1.5.3 The Qualification Certificate of Welder is to include at least the following:
(1) personal information of the welder (name, date of birth and photo);
(2) application of the certificate, type and specification of test assembly;
(3) expiry date;
(4) observation record by the manufacturer for 6 months;
(5) record of CCS-approved extension of the period of validity.

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 parent 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 or 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 approval①
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.

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 SPECIAL REQUIREMENTS FOR QUALIFICATION TESTS OF AUTOMATIC SUBMERGED ARC WELDING OPERATORS

3.3.1 Application

3.3.1.1 This Section applies to the qualification tests for automatic submerged arc welding operators of steels (including austenitic or duplex stainless steels).

3.3.1.2 The qualification tests for automatic submerged arc welding operators are to be carried out in accordance with the requirements of ISO 14732 standards. When the operators are qualified by the method based on test assemblies, it is recommended to follow the requirements of this Section.

3.3.2 Type and size of test assemblies

3.3.2.1 The type of test assemblies is butt joint with steel backing, and specific groove angles and root gaps may be determined by the manufacturer.

3.3.2.2 The test assembly is to consist of 2 plates and 1 backing plate. The test plates are to be 14 to 20 mm in thickness, 500 mm in length and not less than 150 mm in width; the backing plate is to be 10 mm in thickness and not less than 50 mm in width.

3.3.2.3 Both ends of the test assembly are to be provided with temporary run-on and run-off tabs.

3.3.3 Inspection items

3.3.3.1 After completion of welding, the surface of welds is to be inspected visually and no obvious defect is allowed.

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

3.3.4 Precautions for qualification tests

3.3.4.1 The assembly of the test plates, adjustment of welding parameters and groove cleaning etc. are to be performed by the operator himself.

3.3.4.2 The selection of welding parameters may be determined according to WPS. However, there is no requirement for preheating, post-weld heating and interpass temperature.

3.3.4.3 No grinding or any other repair is allowed during welding and on the surface layer.

3.3.4.4 Each layer is to be completed continually, without any intermediate joint.

3.3.5 Coverage of welding operator qualification

3.3.5.1 Upon successful completion of the test according to the plate thicknesses specified in 3.3.2.2, no plate thickness limit will be imposed for the application of the qualification.

3.3.5.2 The successful completion of a qualification test for any steel grade covers all steel grades.

3.3.5.3 The successful completion of a qualification test for butt weld with steel backing covers butt weld by both sides, fillet weld and butt weld of pipes having a diameter over 600 mm.

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 is 180°, and the diameter of former is not to be greater than those specified in Table 3.4.3.4.

Diameter of formerfor 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)	8t	10t	14t	16t

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 4.2.5.1, 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 macroexamination are to satisfy the relevant requirements in 4.2.5, 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 as follows:

Group	Type of titanium and titanium alloys	Typical examples in CCS Rules
51	Pure titanium	TA9, TA9-1
52	α alloys	TA2, TA3, TA10, TA18
53	α - β alloys	TA7, TA31, TC4, TC4ELI
54	β alloys	-

3.4.5.2 Except for 3.4.5.1, the coverage of other variables (e.g. thicknesses of parent 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.

Appendix 3A

Comparison of Indications of Welding Positions under Various Standards

Welding position		ISO 6947	ASME/AWS	CCS rules/guidelines
Butt welds of plates	Flat	PA	1G	F
	Horizontal	PC	2G	H
	Vertical-downward	PG	3G downhill	–
	Vertical-upward	PF	3G uphill	V
	Overhead	~~PO~~PD	4G	O
Butt welds of pipes	Horizontally rolling pipes	PA	1G	1G
	Vertically fixed pipes	PC	2G	2G
	Horizontally fixed pipes	PJ (downward) PH (upward)	5G downhill 5G uphill	– 5G
	Pipes fixed at 45° inclination	J-L045 (downward) H-L045 (upward)	6G downhill 6G uphill	– 6G
	Pipes fixed at 45° inclination with restriction ring	–	6GR uphill	6GR
Fillet welds of plates	Flat	PA	1F	FF
	Horizontal	PB	2F	FH
	Vertical-downward	PG	3F downhill	FVd
	Vertical-upward	PF	3F uphill	FVu
	Overhead	~~PO~~PD	4F	FO
Pipe-to-plate fillet welding	Flat for horizontally rolling pipes	PA	1FR	–
	Flat for vertically fixed pipes	PB	2F, 2FR	2FG
	Overhead for vertically fixed pipes	~~PO~~PD	4F	4FG
	Horizontally fixed pipes	PJ (downward) PH (upward)	5F downhill 5F uphill	– 5FG
	Pipes fixed at 45° inclination	J-L045 (downward) H-L045 (upward)	6F downhill 6F uphill	– 6FG

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.

4.1.3 Welding procedure documents

4.1.3.1 The following welding procedure documents are to be submitted: Preliminary Welding Procedure Specification (pWPS), Welding Procedure 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 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 The following are to be added in the laser beam welding procedure document:

(1) Laser generator:
- ① type (e.g. CO_2 or YAG);
- 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, class 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;
— rate, direction, position and angle of wire feeding;
③ gas parameters:
— gas type and grade;
— 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.

4.1.3.5 The following are 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 inclination angle of stir head;
② speed of stir head;
③ travel speed;
④ upsetting force exerted by stir head to workpiece.

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 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 parent 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.
(2) Where the grade is the same, chromium molybdenum steels, nickel steels and duplex stainless steels cover materials in the same group or material groups having less alloy content.
(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

Cr-Mo 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
Nickel steel	1	Ni≤3.0%	0.5Ni, 1.5Ni
	2	3.0%<Ni≤8.0%	3.5Ni, 5Ni
	3	8.0%<Ni≤10.0%	9Ni
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	0Cr16Ni5Mo②
	2	Martensitic stainless steel	1Cr12NiMo②, 0Cr13Ni4Mo②
Austenitic stainless steel	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 Currently no corresponding grade of material or designation code in GB, so IACS grades of material or designation codes are used.

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 ~~of fillets at~~ in the same ~~corresponding~~ welding conditions.
(2) The welding of butt joints covers the fillet welding in corresponding welding conditions ~~non-full-penetration welding of fillets (including fillet welding and partial penetration fillet welding)~~ for steels having a required minimum yield strength less than 355 N/mm^2.
~~(3) The fillet welding covers the partial penetration fillet welding at corresponding welding conditions.~~

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

Table 4.1.5.6 is newly added as follows:

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 H V O H+V	F H V O F, H, V, O		FF FF, FH FVu FO FF, FH, FVu, FO	
Butt welding of pipes④	1G 2G 5G 2G+5G 6G	F H F, V, O F, H, V, O F, H, V, O	1G 2G 1G, 5G 1G, 2G, 5G, 6G 1G, 2G, 5G, 6G	FF FF, FH FF, FVu, FO FF, FH, FVu, FO FF, FH, FVu, FO	 2FG 4FG, 5FG 2FG, 4FG, 5FG, 6FG 2FG, 4FG, 5FG, 6FG
Fillet welds of plates	FF FH FVd FVu FO FH+FVu			FF FF, FH FVd FVu FO FF, FH, FVu, FO	
Pipe-to-plate fillet welding	2FG 4FG 5FG 2FG+5FG 6FG			FF, FH FO FF, FVu, FO FF, FH, FVu, FO FF, FH, FVu, FO	2FG 4FG 5FG 2FG, 4FG, 5FG, 6FG 2FG, 4FG, 5FG, 6FG

Notes: ① See Appendix 3 of the Guidelines 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.

⑤ The welding procedure approval test is to be carried out separately for the vertical-downward welding.

4.1.5.~~6~~7 The coverage of laser welding is mainly different from that of other welding processes as follows:
(1) the range of material thicknesses is 0.8t ~ t;
(2) different joint types (butt, fillet, lap joints) can not cover each other;
(3) different welding positions can not cover each other;
(4) the number of weld layers is to be the same as that in the approval test;
(5) in respect to welding parameters, the rate of laser power to the product of plate thickness and travel speed is to be controlled within 90% to 120% of that obtained at the approval test;
(6) changes of the surface condition (e.g. with or without shop primer) can not cover each other.

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 and 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 and duplex 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 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 diameter of former and the angle of bend are given in Table 4.2.2.3(2);

Required diameter of former and angle of bend for bend test Table 4.2.2.3(2)

Test material		Diameter of former	Angle of bend
Austenitic stainless steel		4t	180°
Duplex stainless steel	~~31803~~S22253 ~~32205~~S22053	4t	180°
	~~32550~~S22254 ~~32750~~S25073	6t	180°

Note: *t* is thickness of the specimen.

(3) one set of impact specimens at the centre of the weld where impact specimens of 5 mm and above can be taken from the thickness of the test assembly ~~exceeds 6 mm~~ (additionally 1 set at the fusion line and 1 set at 2 mm from the fusion line in the heat-affected zone if used in deep cold condition); This requirement does not apply to ships carrying liquefied natural gas in bulk.
(4) one macrographic section;
(5) one set of test specimens for intercrystalline corrosion test. (The austenitic stainless steels used in

non-corrosive medium conditions can be exempted.)

4.2.2.4 In addition to the items in 4.2.2.3(1) to (4), the following test items are to be added for the duplex stainless steel:
(1) one set of impact specimens respectively at the fusion line and at 2 mm from the fusion line in the heat-affected zone where impact specimens of 5 mm and above can be taken from the thickness of the test assembly ~~exceeds 6 mm~~;
(2) pitting test of welds (except connection to other stainless steels or carbon steels);
(3) ~~micro-examination and~~ measurement of ferrite content of the weld and heat affected zone of the final bead and rooted bead respectively;

(4) one hardness test;

(5) micro-examination of welds and heat affected zones.

4.2.2.5 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 of joints is not to be lower than the minimum value specified for parent metals. The tensile strength of joints consisting of two parent metals of different grades is to comply with the requirement for the minimum tensile strength of the parent metal having lower strength.
(3) After bending, there is to be no crack or any other open defect exceeding 3 mm in any direction on the outer surface.
(4) In general, the impact test temperature is to be -20℃(if the austenitic stainless steel is used in deep cold condition, the test temperature is to be -196℃)and the impact energy is to be not less than 27J.
(5) The macrographic section 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 austenitic stainless steel welds is to satisfy the requirements of Section 7, Chapter 2, PART ONE of CCS Rules for Materials and Welding.
(7) The pitting test of duplex stainless steel welds is to satisfy the requirements of Section 9, Chapter 2, PART ONE of CCS Rules for Materials and Welding.
(8) The ferrite content of duplex stainless steel welds is to be within ~~35% to 65%.~~30% to 70%;
(9) The hardness test result of duplex stainless steels is not to exceed HV420;
(10) No precipitate of intercrystalline carbide and intermetallic compound is to be found in the micro -examination of duplex stainless steels.

4.2.3 Methods of welding procedure approval test for fillet welding of austenitic and 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 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 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 material (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 material 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 material, in mm;
t_2 – nominal thickness of clad material, in mm;
R_1 – specified minimum tensile strength of base material, 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 defect 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 materials.
(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 parent 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:

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

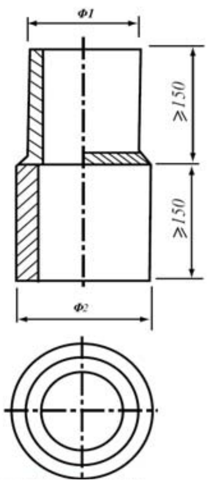
where: d – maximum diameter of former, in mm;
t – thickness of bend test specimens (including side-bend specimens), in mm;
A_5 – specified minimum elongation required by parent metals (a lesser value to be taken for a weld consisting of different materials), in %.

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

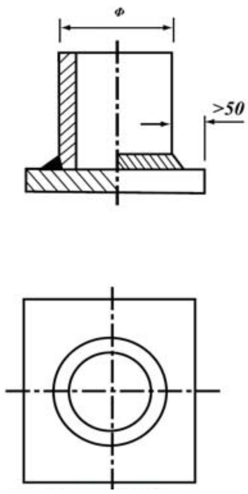
4.3.2.4 Required test results are as follows:
(1) The results of visual examination and non-destructive testing are to comply with recognized standards.
(2) The tensile strength of joints is not to be lower than the minimum value specified for parent metals. The tensile strength of butt joints consisting of two materials is not to be lower than the minimum tensile strength specified for the parent metal having lower strength.
(3) After bending, there is to be no crack or any other open defect 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

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 parent metals of copper alloy pipes is specified in Table 4.3.4.1.

Coverage of approval forparent 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.

Rangeofwall thickness of copper alloypipesTable4.3.4.2

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

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 diameter of former is not to be greater than those given in Table 3.4.3.4 in Chapter 3 of the Guidelines;
(3) when the test assembly is more than 6 mm in thickness, three sets of impact specimens are to be taken (respectively at the centre of the weld, at the fusion line and in the heat-affected zone 2 mm from the fusion line);
(4) one specimen for macro examination;
(5) one longitudinal tensile test specimen of weld metal.

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 parent 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 parent metals.
(5) The results of macro examination are to comply with recognized standards.
(6) The results of tensile test of weld metal are not to be lower than the minimum value specified for or considered in the design of parent metals.

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 parent 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 parent metals, pipe diameters, welding processes, joint types, welding positions, welding conditions, etc.) of approval of welding procedures of titanium alloys satisfy relevant requirements in 3.1.4, Chapter 3, PART THREE of CCS Rules for Materials and Welding.

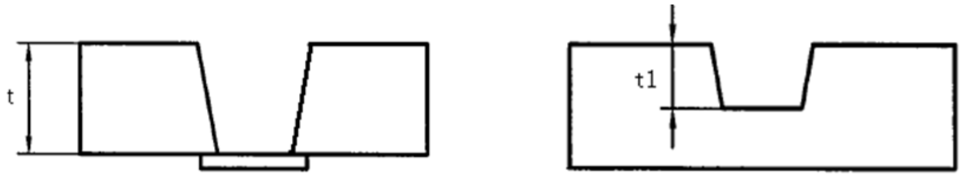
Section 5 APPROVAL OF SPECIAL WELDING PROCEDURES

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, repair welding of copper alloy propellers, 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 dimensions of test assemblies are to be same as in 4.2.2.1.



(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 parent metal included in the thickness of a specimen having a catching groove is to be removed;
(2) if required for the parent 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 4.2.3.3(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 parent 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 parent metal. If the test specimen is cut from the parent metal outside the fusion line, its tensile strength is allowed to be not less than 95% of the minimum value specified for the parent metal.
(3) The temperature and energy of Charpy V-notch impact test are to comply with the requirements for the parent metal.
(4) The results of bend test and macrographic examination are to comply with the requirements of 4.2.1.5(3) and 4.2.1.5(5) respectively.
(5) Required hardness test results: Where the specified minimum yield strength of the parent 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 parent 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 parent 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
$15 \leq t \leq 30$	3mm ~2t
t>30	$\geq$0.5t

(2) For the coverage of materials of base metals, welding consumables, welding conditions, refer to relevant provisions of Section 1, Chapter 3, PART THREE of CCS Rules for Materials and Welding.

4.5.3 Repair welding of copper alloy propellers

4.5.3.1 The test assembly is to be butt welded by both sides at the down-hand position, and the plate thickness is to be not less than 30 mm. The test assembly is to be not less than 250 mm in length and not less than 280 mm in width.

4.5.3.2 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.

4.5.3.3 After completion of welding, test assemblies are to be 100% inspected visually,tested by dye penetration and by radiographic testing. If post-weld heat treatment is required, the non-destructive testing is to be carried out thereafter.

4.5.3.4 Test items are specified as follows:
(1) two transverse tensile test specimens;
(2) three macrographic sections.

4.5.3.5 Required test results are as follows:
(1) the results of the visual examination are to comply with recognized standards;
(2) no crack is allowed, as shown by the dye penetrant testing;
(3) the radiographic examination is to comply with recognized standards;
(4) no cracks and no pores greater than 3 mm are allowed, as shown by the macrographic examination;
(5) the tensile strength requirement is given in Table 4.5.3.5(5).

Tensile strength of repair weld joints of copper alloy propellers Table 4.5.3.5(5)

Alloy type	Minimum tensile strength(N/mm^2)
Cu1	370
Cu2	410
Cu3	500
Cu4	550

4.5.3.6 The coverage of approval of welding procedures are as follows:
(1) Repair welding of copper alloy propellers is subjected to the procedure approval test with plate thickness specified in this Section. This requirement is applicable to the repair welding of copper alloy propellers of all thicknesses.
(2) Copper alloy propellers of different materials are subjected to procedure approval tests separately.
(3) For the coverage of welding conditions, relevant provisions of Section 1, Chapter 3, PART THREE of CCS Rules for Materials and Welding may be referred to.

4.5.4 Copper alloy pipe brazing

4.5.4.1 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.

4.5.4.2 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.

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

4.5.4.4 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 parent 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.

4.5.4.5 The coverage of approval of welding procedures is as follows:
(1) for the coverage of parent 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.

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

4.5.5.1 The dimensions of test assemblies and joint types are shown in Figure 4.5.5.1 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.

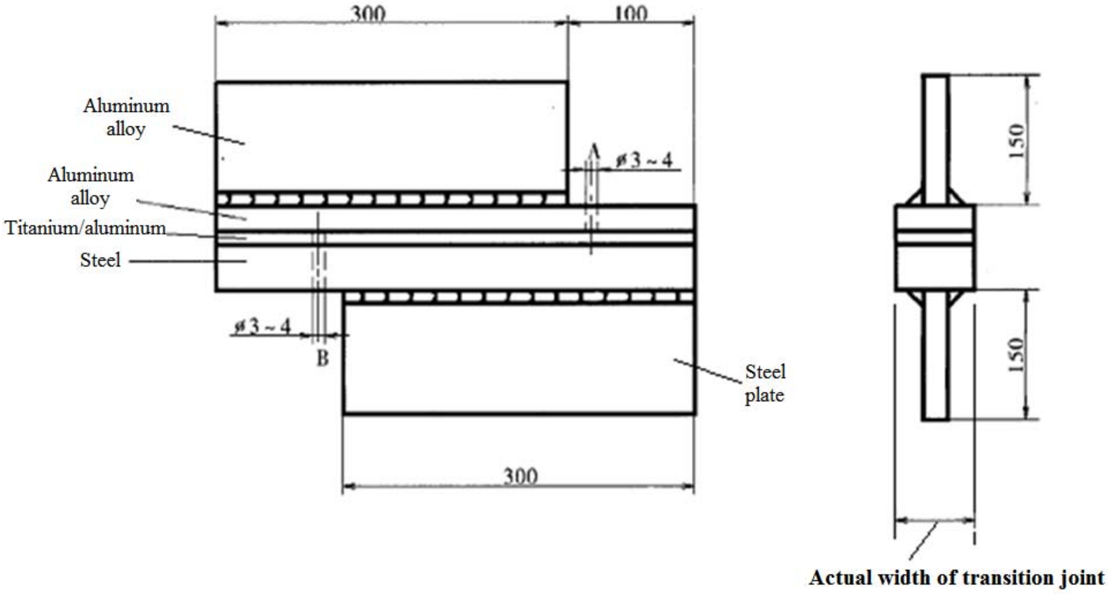


Figure 4.5.5.1 Dimensions of test assembly and joint types

4.5.5.2 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.

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

4.5.5.4 Test items are specified as follows:
(1) two cross tensile test joints, the dimensions of which are shown in Figure 4.5.5.4(1);

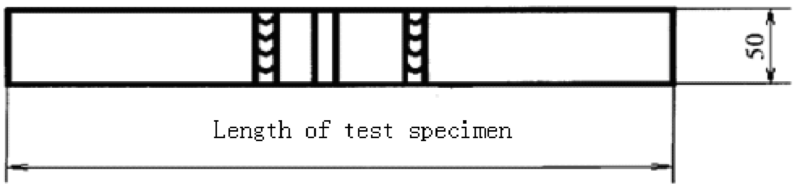


Figure 4.5.5.4(1) Cross tensile test joint

(2) one test specimen of macrographic sections.

4.5.5.5 Required test results are as follows:
(1) the results of visual examination and dye penetrant testing are to comply with recognized standards;
(2) the tensile strength for tensile test is to be not less than the minimum value specified for hull structural components (aluminium plates);
(3) the macrographic section is to show good profile and complete fusion, without peeling and other defects at the clad interface of transitional joints.

4.5.5.6 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.
(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.

Appendix 4A

Preliminary Welding Procedure Specification (pWPS)

Job no.________________

Essential parameters

Name and number of welding procedure			
Manufacture's name and address			
Welding process:		Single pass ☐	One side ☐
Joint type:		Multi-pass ☐	Both sides ☐
Welding position:		Multi-process ☐	Back gouging ☐
Parent metal grade/delivery condition:		Model of welding equipment:	
Thickness of base metal:	Shop primer:	Outside diameter of pipe:	Gas type:
Test joint details (sketch with dimensions)		Bead sequence details(sketch)	

Welding parameters

Run	Process	Size of filler material (mm)	Type and polarity of current	Current (A)	Voltage (V)	Travel speed* (cm/min)	Heat input* [kJ/cm]	Gas flow rate (1/min)

* If required

Direct current straight polarity: DCEN; Direct current reversed polarity: DCEP

Preliminary Welding Procedure Specification (pWPS) (continued)

Filler material (type/size/grade):						
Backing:						Welding site conditions:
Preheating temperature		Interpass temperature				Post-weld heat treatment:
Min.	℃	Min.	℃	Max.	℃	
Preheating method:						
Other information*:						

* E.g. weaving (max. width of run), method of interpass cleaning, characteristics of pulse current

Test items

1. **Non-destructive testing**						
Visual ☐	Radiography ☐		Ultrasonic ☐		Magnetic particle ☐	Liquid penetrant ☐
2. **Destructive testing**						
1) **Tensile tests**		Transverse ☐			Longitudinal ☐	
2) **Bend tests**		Face ☐		Root ☐		Side ☐
3) **Impact tests**						Test temperature: ℃
Root of weld	Center of weld ☐	Fusion line ☐	2 mm from fusion line ☐			
Face of weld	Center of weld ☐	Fusion line ☐	2 mm from fusion line ☐	5 mm from fusion line ☐	___mm from fusion line ☐	
4) Macro examination ☐		5) Hardness test ☐		6) Fillet weld fracture test ☐		
3. **Additional test(s)**	Chemical analysis of weld ☐			Chemical analysis of base metal ☐		
	Metallograph of the joint (× times) ☐					
	Pitting test ☐			Intercrystalline corrosion test ☐		

Signature:

Manufacturer ______________________ **Date** ____________________

Preliminary Welding Procedure Specification (pWPS) (continued)

The following are to be completed by the Surveyor:

The above pWPS has been reviewed and implementation of WPT in accordance with this pWPS is approved ……………….. ☐

The above pWPS has been reviewed and comments are as follows: (Please reply and contact the attending Surveyor as soon as possible) ………………………………………………………………

Signature:

CCS Surveyor ______________________________ **Date** ______________________________

Notes:
☒ ———— Applicable ⊟ ———— Inapplicable

The following abbreviations may be used in this form:
Welding process:
Shield metal arc welding: SMAW Submerged-arc welding: SAW Gas metal arc welding: GMAW,
Gas tungsten arc welding: GTAW Fluxed-cored arc welding: FCAW Electro-gas welding: EGW

Welding position:
Flat: F Vertical (up): V (up) Vertical (down): V (down) Horizontal: H Overhead: O

Type and polarity of current:
Alternating current: AC Direct current straight polarity: DCEN Direct current reversed polarity: DCEP
Pulse current: Pulsed

Appendix 4B

Welding Procedure Qualification Record (WPQR)

Job no. ________________

Name and number of welding procedure	
Manufacture's name and address	
Material and welding procedure:	Date of welding procedure test:

Welding process:	Single pass ☐	One side ☐	Test joint details (sketch with dimensions)
Joint type:	Multi pass ☐	Both sides ☐	
Welding position:	Multi process ☐	Back gouging ☐	
Parent metal (grade/thickness/delivery condition):			
Filler material (type/size/grade):			Bead sequence details (sketch)
Backing:	Shielding gas (type/purity):		
Outside diameter of pipe:	Flux:		

Preheating and post-weld heat treatment					
Preheating temperature		Interpass temperature			
Min.	℃	Min.	℃	Max.	℃
Post-weld heat treatment:					

Other information[1]:

Welding details

Run	Process	Size of filler material (mm)	Type of current /polarity	Current [A]	Voltage [V]	Travel speed[2] [cm/min]	Heat input[2] [kJ/cm]	Gas flow rate (l/min)
Welder's name					Ambient Temperature ℃		Relative humidity %	

Welding Procedure Qualification Record (WPQR) (continued)

Test items and results

1. Non-destructive testing

Visual	☐	Radiography	☐	Ultrasonic	☐	Magnetic particle	☐	Liquid penetrant	☐

2. Destructive testing

Tensile tests

Test assembly	Tensile strength (N/mm^2)	Yield stremgtj (N/mm^2)	Elongation %	Reduction of area %	Location of rupture	Test temperature ℃
Transverse 1						
Transverse 2						
Longitudinal						

<table>
<tr><td colspan="3">Bend tests</td><td>Fillet weld fracture</td></tr>
<tr><td>Test assembly</td><td>Diameter of former/angle of bending</td><td>Result</td><td>1.</td></tr>
<tr><td>Face/root/side</td><td></td><td></td><td>2.</td></tr>
<tr><td>Face/root/side</td><td></td><td></td><td>3.</td></tr>
<tr><td>Face/root/side</td><td></td><td></td><td rowspan="3">Macro examination</td></tr>
<tr><td>Face/root/side</td><td></td><td></td></tr>
<tr><td>Longitudinal</td><td></td><td></td></tr>
</table>

<table>
<tr><td colspan="6">Impact tests</td><td colspan="4">Test temperature ℃</td></tr>
<tr><td rowspan="5">Requirement:
Size:

Type:</td><td>Notch location</td><td>Values (J)
1 2 3</td><td>Average (J)</td><td>Remarks</td><td>Notch location</td><td>Values (J)
1 2 3</td><td>Average (J)</td><td>Remarks</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Retest</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

<table>
<tr><td colspan="3">Hardness test</td></tr>
<tr><td colspan="2">Type and load:</td><td>Location of hardness measurements (sketch)</td></tr>
<tr><td>Area</td><td>Hardness range</td><td rowspan="4"></td></tr>
<tr><td>Parent material</td><td></td></tr>
<tr><td>Heat-affected zone</td><td></td></tr>
<tr><td>Weld</td><td></td></tr>
</table>

Welding Procedure Qualification Record (WPQR) (continued)

Additional test(s) and result(s) (according to 3.2.4.3 of CCS Rules for Materials and Welding):

Notes:
1. E.g. weaving (max. width of run), method of interpass cleaning;
2 If required.

☒ ———— Applicable ⊟ ———— Inapplicable

The following abbreviations may be used in this form:
Welding process:
Shield metal arc welding: SMAW Submerged-arc welding: SAW Gas metal arc welding: GMAW,
Gas tungsten arc welding: GTAW Fluxed-cored arc welding: FCAW Electro-gas welding: EGW

Welding position:
Flat: F Vertical (up): V (up) Vertical (down): V (down) Horizontal: H Overhead: O

Type and polarity of current:
Alternating current: AC Direct current straight polarity: DCEN Direct current reversed polarity: DCEP
Pulse current: Pulsed

THIS is to certify that the test process and results were found to be in compliance with the relevant requirements of CCS Rules for Materials and Welding (2006) and amendments thereto.

Signature:

Manufacturer ______________________________ Date ______________________________

CCS Surveyor ______________________________ Date ______________________________

Appendix

In order to ensure the quality of welding procedure approval tests and make them traceable, photocopies of the documents listed below are to be submitted (items in the list may be deleted or new one(s) added as necessary).

List of Documents

No.	Document title		Remarks
1	**Certification of parent material**	☐	
2	**Certification of filler material**	☐	
3	**NDT reports**	☐	
4	**Test reports (tensile test, bend test, impact test, hardness test, etc.)**	☐	
5	**Macro examination reports (photos and result)**	☐	
6	**Photos of weld surface**	☐	
7	**Photos of mechanical test assemblies**	☐	
8	**Qualification Certificates of Welder issued by CCS (if any)**	☐	
9			
10			

Appendix 4C

Welding Procedure Specification (WPS)

Job no. ________________

Name and number of welding procedure			
Manufacture's name and address			
Range of applicable plates (pipes)			
Welding process:		Single pass ☐	One side ☐
Joint type:		Multi pass ☐	Both sides ☐
Welding position:		Multi process ☐	Back gouging ☐
Parent metal (grade/delivery condition):		Model and main parameters of welding equipment:	
Thickness:	Shop primer:	Outside diameter of pipe:	Gas type:
Test joint details (sketch with dimensions)		Bead sequence details (sketch)	

Welding parameters

Run	Process	Size of filler material (mm)	Type and polarity of current	Current (A)	Voltage (V)	Travel speed* (cm/min)	Heat input* [kJ/cm]	Gas flow rate (1/min)

* If required

Welding Procedure Specification (WPS) (continued)

<table>
<tr><td colspan="6">Filler material (type/size/grade):</td><td></td></tr>
<tr><td colspan="6">Backing:</td><td>Welding site conditions:</td></tr>
<tr><td colspan="2">Preheating temperature (℃)</td><td colspan="4">Interpass temperature (℃)</td><td rowspan="3">Post-weld heat treatment</td></tr>
<tr><td>Min.</td><td></td><td>Min.</td><td></td><td>Max.</td><td></td></tr>
<tr><td colspan="6">Preheating method:</td></tr>
<tr><td colspan="7">Other information*:</td></tr>
</table>

* e.g. weaving (max. width of run), method of interpass cleaning, characteristics of pulse current

Notes:
The following abbreviations may be used in this form:
Welding process:
Shield metal arc welding: SMAW　　Submerged-arc welding: SAW　　Gas metal arc welding: GMAW,
Gas tungsten arc welding: GTAW　　Fluxed-cored arc welding: FCAW　　Electro-gas welding: EGW

Welding position:
Flat: F　　Vertical (upward): V (up)　　Vertical (downward): V (down)　　Horizontal: H　　Overhead: O

Type and polarity of current:
Alternating current: AC　　Direct current straight polarity: DCEN　　Direct current reversed polarity: DCEP
Pulse current: Pulsed

☒ ———— Applicable　　⊟ ———— Inapplicable

Signature:

Manufacturer ______________________ Date ______________________

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) Plans and supporting documents;
(2) Examination and testing plans;
(3) NDE plans;
(4) Welding consumable details;
(5) Welding procedure specifications;
(6) Welding plan or details;
(7) Qualification certificates of welders;
(8) Qualification certificates of NDE operators.

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.

5.1.3 Butt, lap and plug welds

5.1.3.1 Where thick plates are butt welded to thin plates, an abrupt change of their sectional areas is to be avoided. The edge of the thick plate is to be tapered or beveled to form a proportionately appropriate weld joint. The width of taper is not to be less than 4 times the difference between thicknesses. If such difference is less than 4 mm, the profile of the weld may be uniformly sloped within the width of the weld.

5.1.3.2 In general, plates which are subjected to high tensile stress or compressive load are not connected by lap welds. Where overlaps are adopted, the width (b) of the overlap is to be not less than 3 times the thickness of the thinner plate, but need not exceed 4 times, see Figure 5.1.3.2. Joints are to be arranged to facilitate welding so as to achieve good welds. The faying surfaces of lap joints are to be in close contact and both edges of the overlap are to have continuous fillet welds.

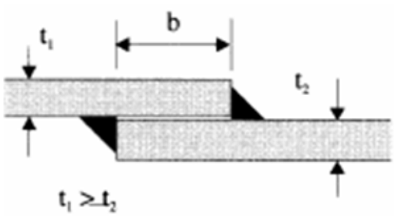


Figure 5.1.3.2 Lap size

5.1.3.3 For the connection of plating to internal vertical or horizontal webs, where access for fillet welding is not practicable, a flat bar is to be attached by plug welds between the plating and the webs. In general, plug weld holes are to have a minimum length of 75 mm and a minimum width of twice the plating thickness, with well rounded ends. The distance between holes is not to exceed 150 mm, the weld factor is to be 0.44, and the requirements for leg length in 1.4.4, PART TWO of CCS Rules for Classification of Sea-Going Steel Ships (hereinafter referred to as "the Rules") are to be met.

5.1.4 Fillet welds

5.1.4.1 Fillet welds of hull structures are to be made on both sides. The types and application of fillet welds for structural connections are to be as shown in Table 1.4.4.1, PART TWO of the Rules. Where such connection is subjected to high stress, deep penetration welds or full penetration fillet welds may be applied.

If full penetration fillet welds are required, the attached plate may be required to be beveled.

5.1.4.2 The weld factor is to be in accordance with Table 1.4.4.2, PART TWO of the Rules.

The fillet welds of CSR ships are to be in accordance with the requirements in the Common Structural Rules of Bulk Carriers.

5.1.4.3 Where a deep penetration welding process is applied according to an approved welding procedure, the fillet leg length required for deep penetration welds may be reduced by 15% of that obtained by calculations as specified in 5.1.4.2.

5.1.4.4 The hull structural areas requiring double continuous fillet welding are specified in Table 1.4.1.8, PART TWO of the Rules.

5.1.4.5 The welding of main structures and the welding of primary and secondary structural members are given in Tables 1.4.4.8 to 1.4.4.12, PART TWO of the Rules.

Section 2 HULL CONSTRUCTION

5.2.1 Process of hull assembly and erection

5.2.1.1 There are approximately the following four steps in the process of hull assembly and erection at a shipyard:
(1) various pieces are fitted and welded to form structural parts or components of the hull;
(2) structural members, parts and components of the hull are fitted and welded to form hull blocks;
(3) flat and curved blocks, parts and components are integrated to form large blocks or general blocks;
(4) blocks, large blocks (or general blocks) together with a small number of parts are assembled into a ship within dock or on slipway.

5.2.2 Hull construction accuracy and control

5.2.2.1 Hull construction accuracy means a technique of zero-allowance assembly, mainly including:
(1) permissible deviation from sizes of lofting, plate cutting and laying off;
(2) permissible tolerance of surface smoothness of gas-cut kerfs;
(3) size of structural members: Permissible side non-straightness of cut size, permissible tolerances of edge beveling and root face, shape and size;
(4) permissible size tolerances of flanged flat plate, profiled panels (circular cylinders), shaped steels and shaped steel members, curved plates, plate edge planning and cutting;
(5) permissible tolerances of parts assembly;
(6) permissible tolerances of flat blocks assembly;
(7) permissible tolerances of blocks assembly, general blocks assembly and post-weld dimensions;
(8) permissible tolerances of assembly dimensions in dock (or on slipway);
(9) weld shape: Permissible deviation from weld dimension, undercut depth and leg length.

5.2.2.2 Much importance is to be attached to the accuracy-ensuring measures for all processes of pre-weld lofting, cutting, processing and assembling, in order to reduce size errors of hull parts from one construction stage to another, thereby guaranteeing correct sizes and shapes of hull parts and improving the assembly accuracy of blocks, general blocks and the accuracy of assembly in dock.

5.2.2.3 During construction, technology and management are to be combined to enhance the monitoring of hull construction accuracy.

5.2.3 Quality standards for shipbuilding

5.2.3.1 The shipbuilding quality is usually to meet IACS Rec. 47 or international and national standards approved by CCS.

Section 3 WELD ARRANGEMENT AND TYPICAL STRUCTURAL JOINTS OF HULL

5.3.1 General requirements

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

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

5.3.1.3 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.

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

5.3.2 Weld arrangement for main areas

5.3.2.1 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.

5.3.2.2 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.

5.3.2.3 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.

5.3.2.4 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.

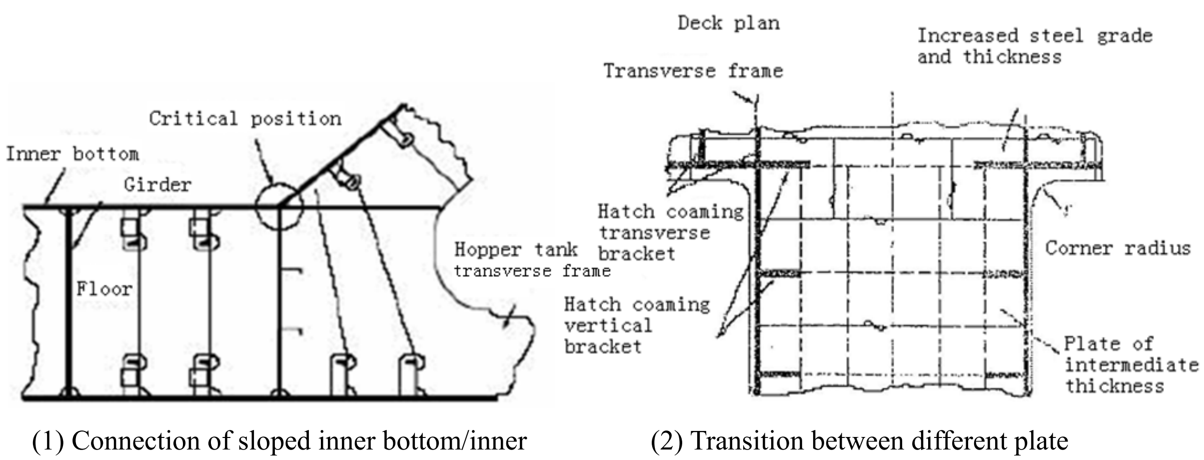
5.3.2.5 When arranging end joints of shell plating, construction techniques applied for hull blocks and full use of plate length are to be taken into account. The end joints of external strakes are to be arranged within the same cross section so far as possible, and end welds amidships may be longer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

5.3.2.6 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.

5.3.3 Typical structural joints

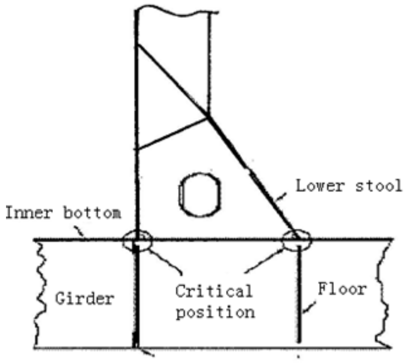
5.3.3.1 For the design of hull structural joints within high stress areas or at critical positions, attention is to be given to the effective transmission of forces of structural members, avoiding excessive stress concentration. During construction, good alignment of structural members and their assembling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

Typical joints of hull structures are shown in Figure 5.3.3.1 (which shows only schematic diagrams and is a not mandatory requirement).

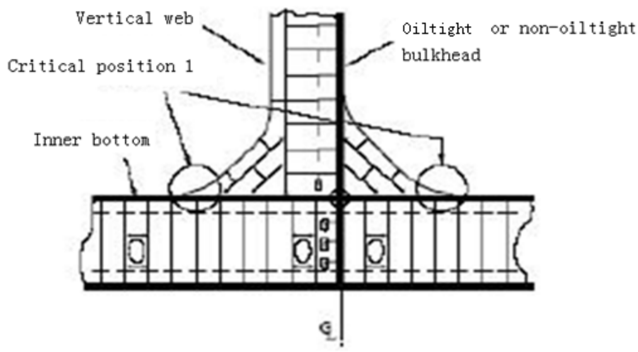


(1) Connection of sloped inner bottom/inner bottom/hopper tank girder

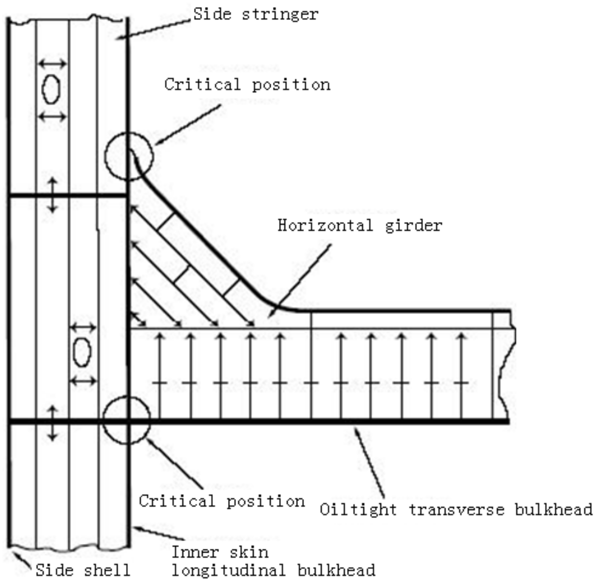
(2) Transition between different plate thicknesses of hatch corners and both sides



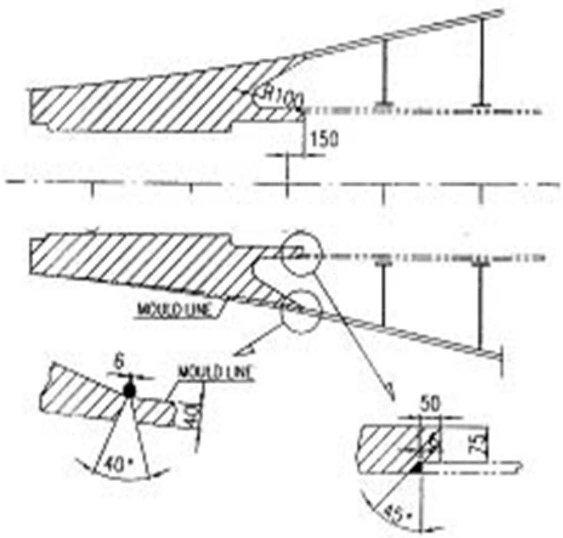
(3) Connection of corrugated bulkhead lower stool to double bottom



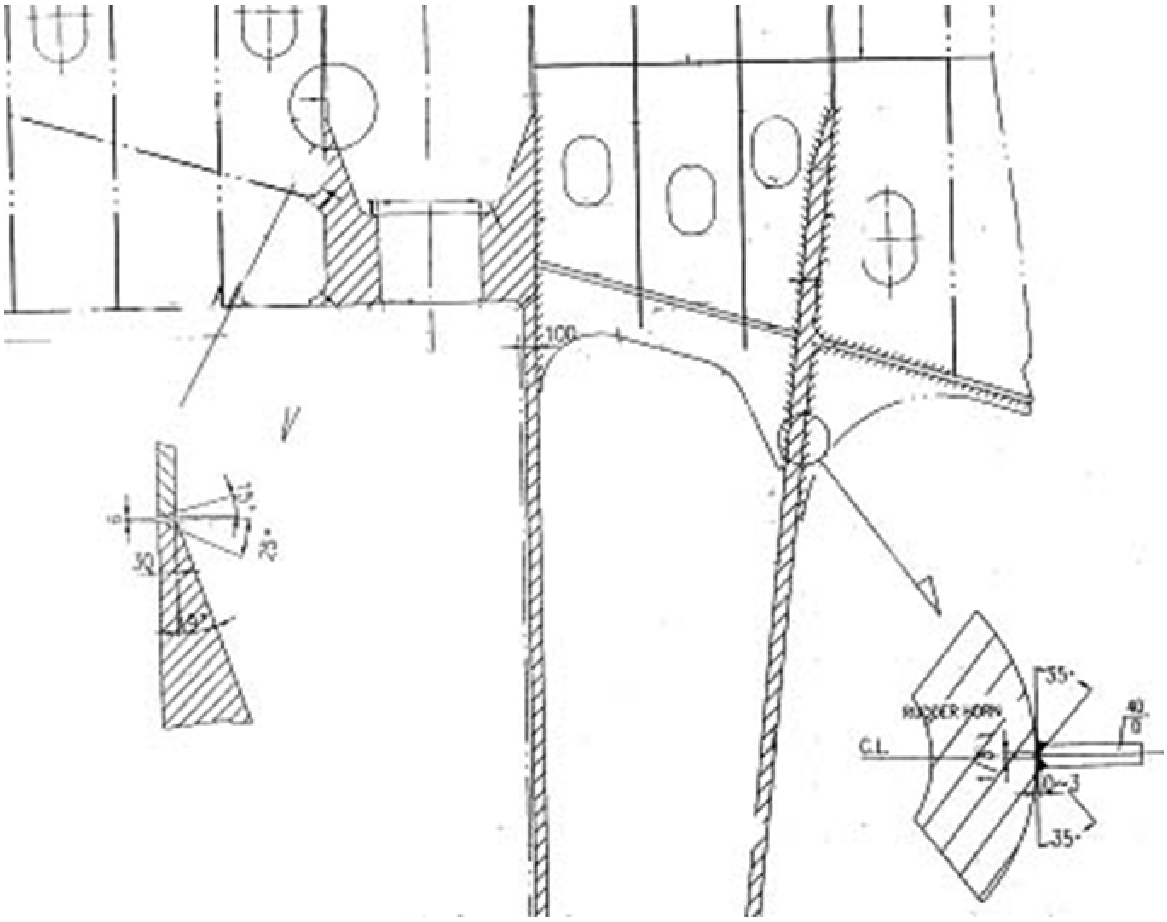
(4) Connection of end bracket toe end of centerline bulkhead vertical web to double bottom floor



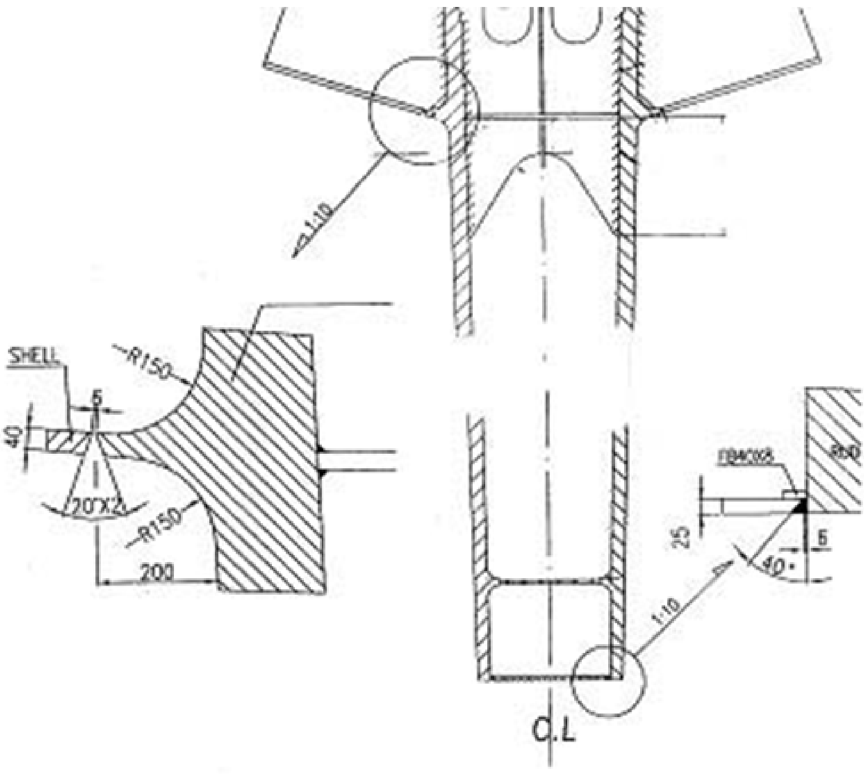
(5) Connection of end bracket toe end of horizontal girder to side stringer



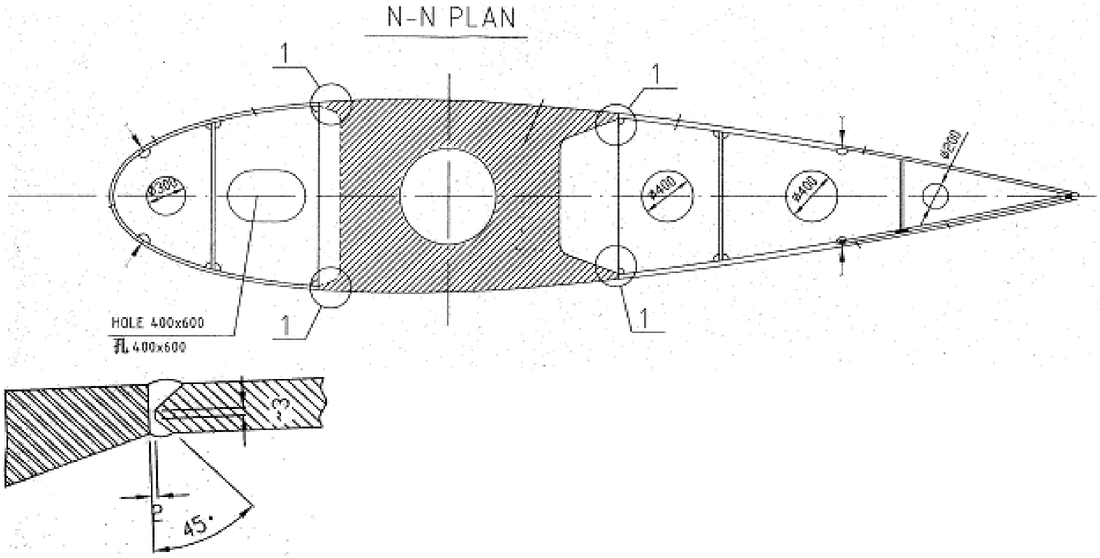
(6) Connection of cast rear shaft hub of stern tube to shell plating



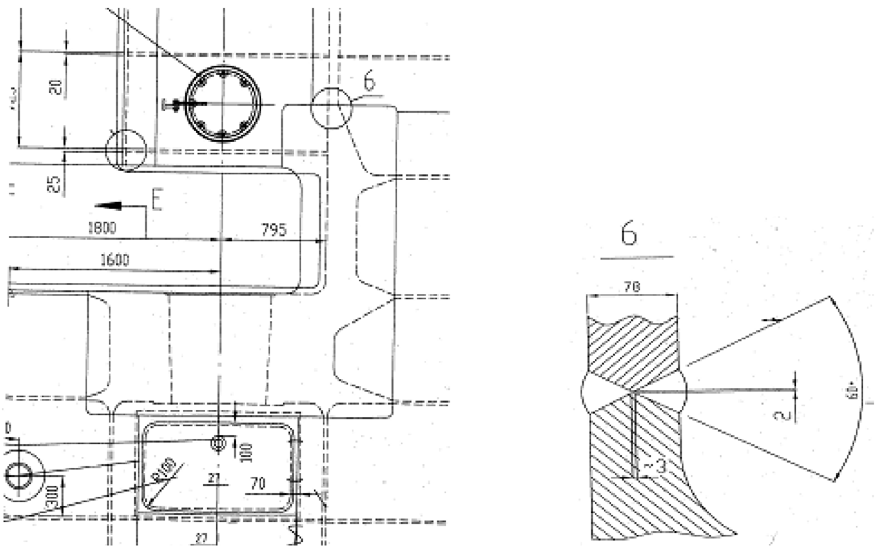
(7) Connection of cast steel rudder horn to stiffening bracket and internals



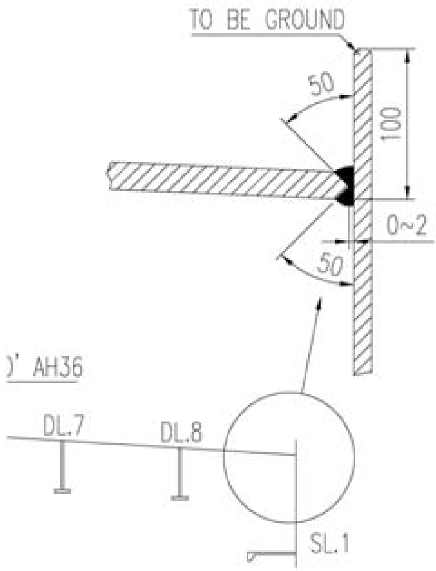
(8) Connection of cast steel rudder horn to hull envelope and lower closing plate



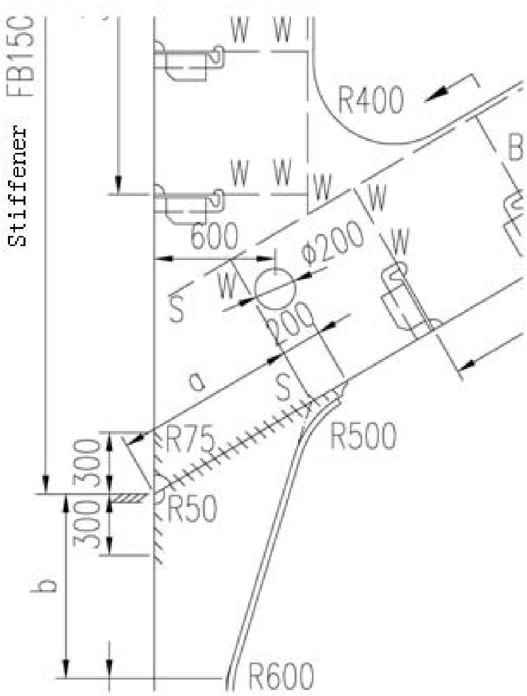
(9) Connection of rudder stock housing associated with rudder blade to upper closing plate



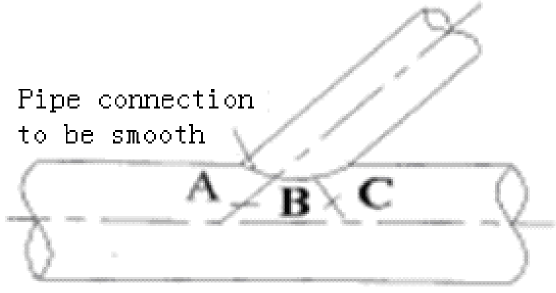
(10) Connection of rudder blade pintle to vertical web plates



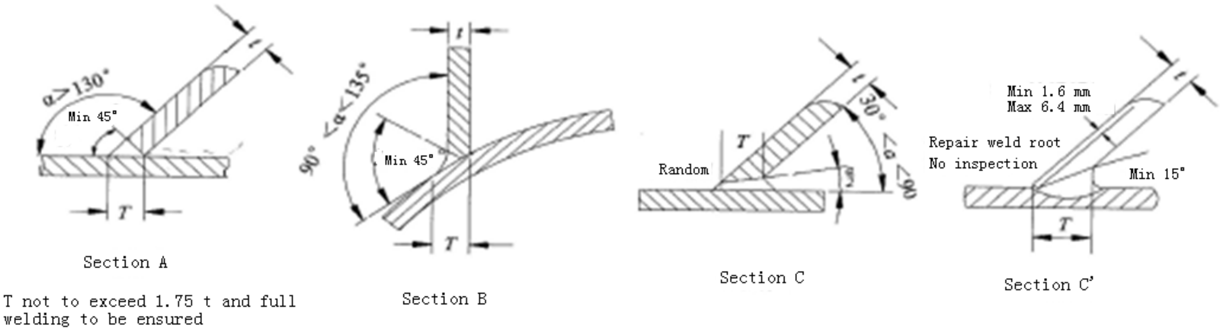
(11) Connection of top strake to main deck plating



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

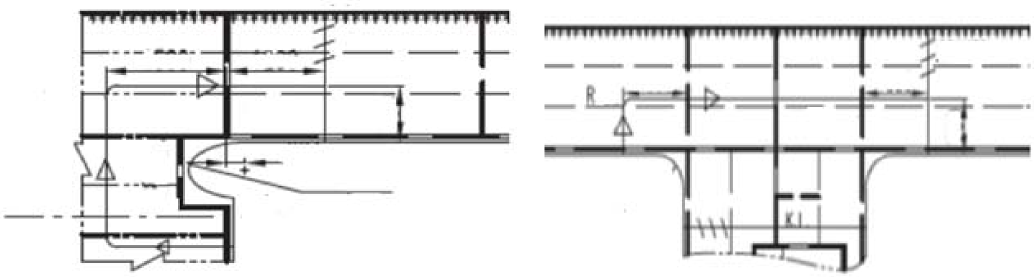


Typical connection
where angle α is formed by crosstie and chord at any point of their intersection with external surface of the connection

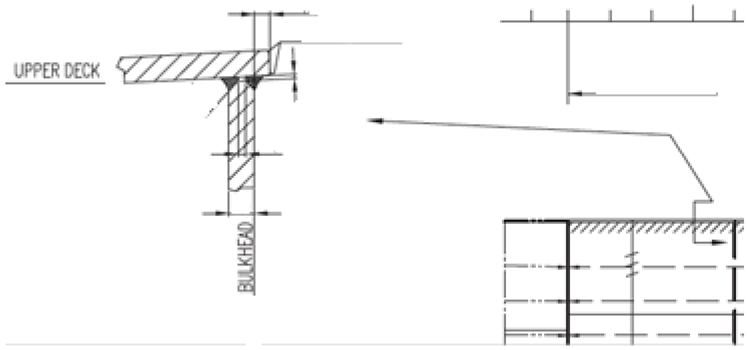


where size "T" does not include the concave formed to ensure smooth transition from weld surface to base metal

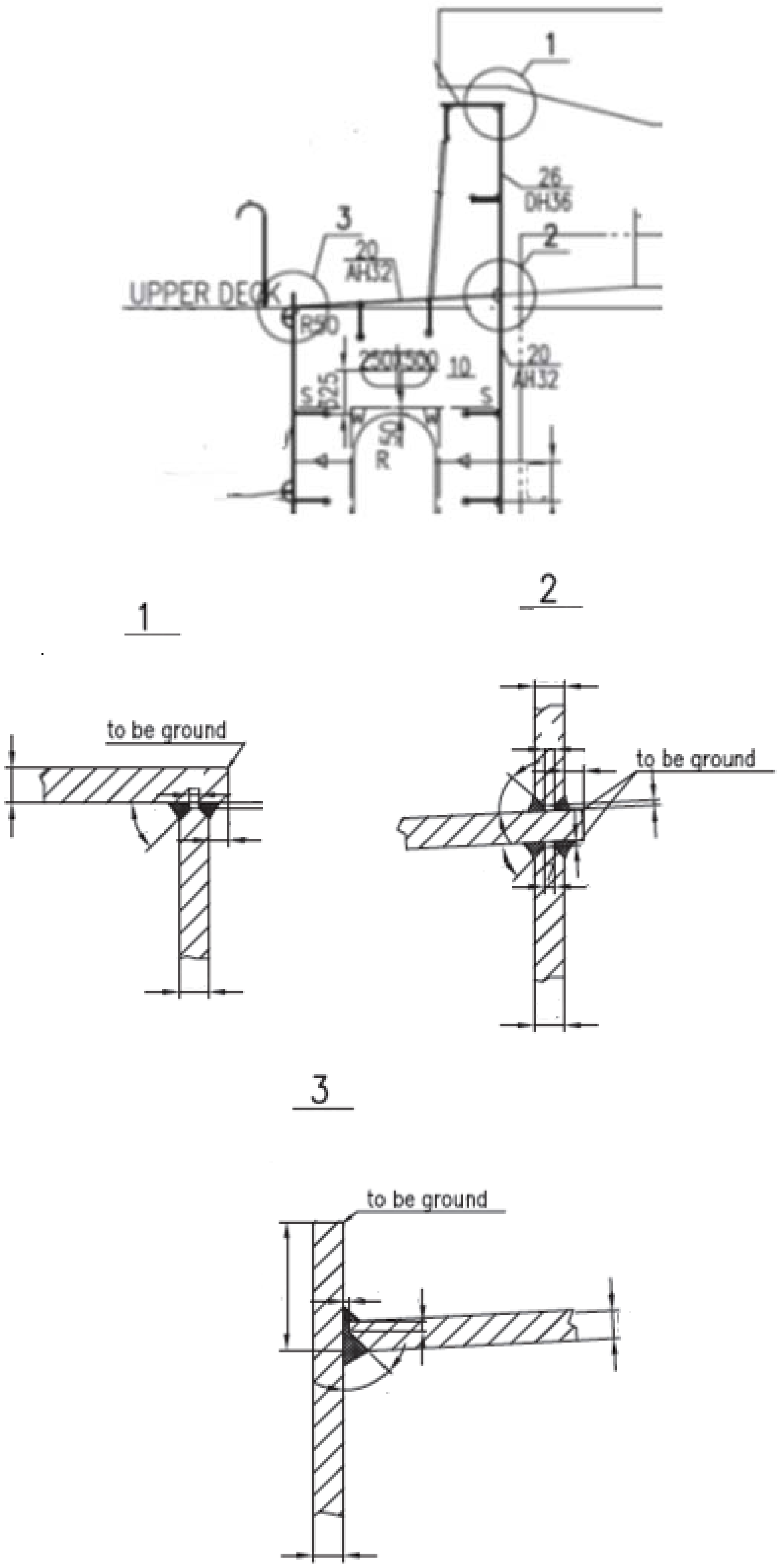
(13) Connection of pipes of structures of fixed offshore installations



(14) Upper deck Hatch



(15) Main deck and longitudinal bulkhead



(16) Transverse midship section

Figure 5.3.3.1 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 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

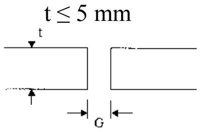
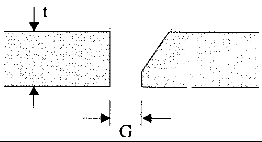
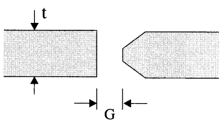
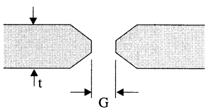
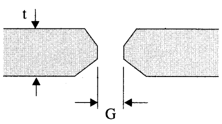
6.1.3.1 Welding personnel engaged in shipbuilding are to hold a "Qualification Certificate of Welder" issued or accepted by CCS, and to be engaged in welding operations appropriate to their respective certificates.

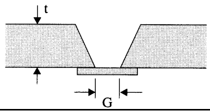
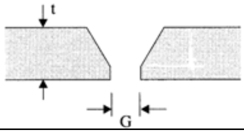
6.1.3.2 Personnel engaged in assembly and visual examinations in shipbuilding are to be those employees of the manufacturer who have rich experience and have been internally trained in their respective specialties.

6.1.4 Pre-weld preparations

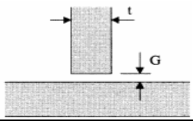
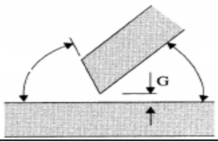
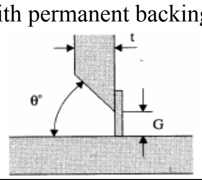
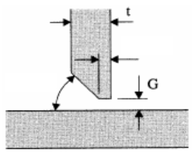
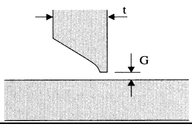
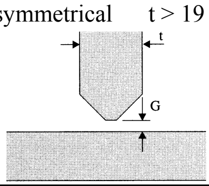
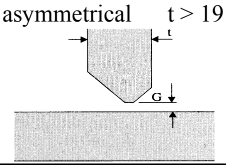
6.1.4.1 Welding consumables, edge sizes and assembly accuracy are to comply with approved welding procedures and relevant criteria.
The details of weld joints may be referred to Tables 6.1.4.1(1) to 6.1.4.1(5). The weld joints do not apply to the special types of ships (e.g. gas tankers) and structures fabricated from stainless steel or other, special types or grades of steel.
Welding consumables are to be selected and used according to the requirements of CCS Rules for Materials and Welding.

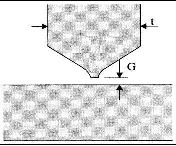
Typical butt weld plate edge preparation
(manual welding and semi-automatic welding) **Table 6.1.4.1(1)**

Detail	Standard	Limit	Remark
Square butt $t \le 5$ mm 	$G \le 3$ mm	$G = 5$ mm	see Note 1
Single bevel butt $t > 5$ mm 	$G \le 3$ mm	$G = 5$ mm	see Note 1
Double bevel butt $t > 19$ mm 	$G \le 3$ mm	$G = 5$ mm	see Note 1
Double vee butt, uniform bevels 	$G \le 3$ mm	$G = 5$ mm	see Note 1
Double vee butt, non-uniform bevel 	$G \le 3$ mm	$G = 5$ mm	see Note 1

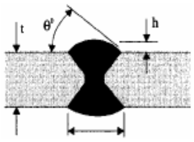
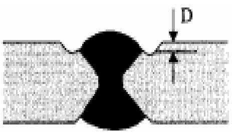
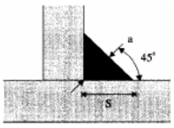
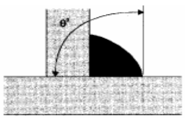
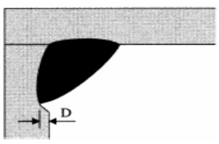
Single vee butt, one side welding with backing strip (temporary or permanent) 	G = 3 - 9 mm	G =16 mm	see Note 1
Single vee butt 	G ≤ 3 mm	G = 5 mm	see Note 1
Note 1: Different plate edge preparation may be accepted or approved by CCS in accordance with CCS Rules for Materials and Welding or other recognized standard. For welding procedures other than manual welding and semi-automatic welding, see national or international standards recognized by CCS.			

Typical fillet weld plate edge preparation
(manual welding and semi-automatic welding) Table 6.1.4.1(2)

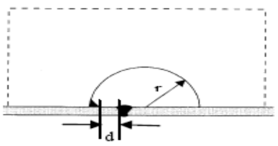
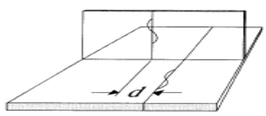
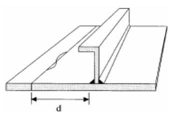
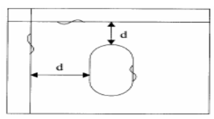
Detail	Standard	Limit	Remark
Tee fillet 	G ≤ 2 mm	G = 3 mm	see Note 1
Inclined fillet 	G ≤ 2 mm	G = 3 mm	see Note 1
Single bevel tee with permanent backing 	G ≤ 4 – 6 mm θ° = 30° – 45°	G = 16 mm	Not commonly used for strength members see Note 1
Single bevel tee 	G ≤ 3 mm		see Note 1
Single ‘J’ bevel tee 	G = 2.5 – 4 mm		see Note 1
Double bevel tee symmetrical t > 19 mm 	G ≤ 3 mm		see Note 1
Double bevel tee asymmetrical t > 19 mm 	G ≤ 3 mm		see Note 1
Double ‘J’ bevel tee symmetrical	G = 2.5 – 4 mm		see Note 1

			
Note 1: Different plate edge preparation may be accepted or approved by CCS in accordance with CCS Rules for Materials and Welding or other recognized standard. For welding procedures other than manual welding and semi-automatic welding, see national or international standards recognized by CCS.			

Butt and fillet weld profile
(manual welding and semi-automatic welding) **Table 6.1.4.1(3)**

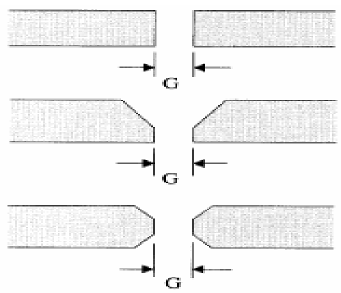
Detail	Standard	Limit	Remark
Butt weld toe angle 	$\theta \le 60°$ $h \le 6$ mm	$\theta \le 90°$	
Butt weld undercut 		D≤ 0.5 mm for strength member D≤ 0.8 mm for other	
Fillet weld leg length  s = leg length a = throat depth		$s \ge 0.9s_d$ $a \ge 0.9a_d$ over short weld lengths	s_d = design s a_d = design a
Fillet weld toe angle 		$\theta \le 90°$	In areas of stress concentration and fatigue, CCS may require a lesser angle
Fillet weld undercut 		D≤ 0.8 mm	

Distance between welds **Table 6.1.4.1(4)**

Detail	Standard	Limit	Remark
Scallops over weld seams 		for strength members d ≥ 5 mm for other d ≥ 0 mm	The “d” is to be measured from the toe of the fillet weld to the toe of the butt weld
Distance between two butt welds 		d ≥ 0 mm	The “d” is to be measured as distance between butt welds of intersecting planes
Distance between butt weld and Fillet weld 		for strength members d ≥ 10 mm for other d ≥ 0 mm	The “d” is to be measured from the toe of the fillet weld to the toe of the butt weld
Distance between butt welds 	For cut-outs d ≥ 30 mm		
	For margin plates d ≥ 300 mm	150 mm	

Typical butt weld plate edge preparation (submerged arc automatic welding)

Table 6.1.4.1(5)

Detail	Standard	Limit	Remark
	0 ≤ G ≤ 0.8 mm	G = 2 mm	see Note 1
Note 1: Different plate edge preparation may be accepted or approved by CCS in accordance with CCS Rules for Materials and Welding or other recognized standard. For welding procedures other than automatic welding, see national or international standards recognized by CCS.			

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.

6.1.4.5 The preheating and interpass temperatures are to be determined by welding procedure approval tests, taking into account the steel grade and carbon equivalent of the materials used, thickness of weldment, welding site conditions, welding process and procedure, and degree of joint restraint, provided that the following requirements are complied with:

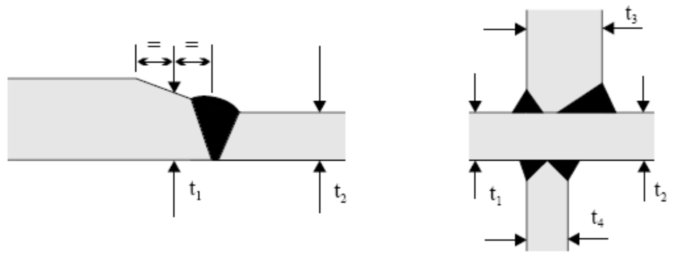
(1) Where the preheating temperature is determined according to the chemical composition of the materials and the thickness of the structural members to be welded, the temperature values in Table 6.1.4.5(1) may be taken.

Recommended minimum preheating temperatures **Table 6.1.4.5(1)**

Carbon equivalent[①]	T≤50 mm[②]	50 mm＜T≤70 mm[②]	T＞70 mm[②]
C_{eq}≤0.39	----	----	50℃
C_{eq}≤0.41	----	----	75℃
C_{eq}≤0.43	----	50℃	100℃
C_{eq}≤0.45	50℃	100℃	125℃
C_{eq}≤0.47	100℃	125℃	150℃
C_{eq}≤0.50	125℃	150℃	175℃

Notes: ① Ceq=C+Mn/6+(Ni+Cu)/15+(Cr+Mo+V)/5 %

② $T = t_1+t_2+t_3+t_4$, shown as follows:



(2) Where there is no preheating requirement in the approved welding procedure specification and the ambient temperature is low, the preheating temperature of steel plates to be welded is usually to comply with Table 6.1.4.5(2).

Preheating for welding hull steels at low temperature **Table 6.1.4.5(2)**

Item	Standard		Limit	Remark
	Base metal temperature needed preheating	Minimum preheating temperature		
Normal strength steel (A, B, D, E)	＜-5℃	20℃[①]		
TMCP higher strength steel (AH32 ~ EH32, AH36 ~ EH36)	＜0℃			
Common higher strength steel (AH32 ~ EH32, AH36 ~ EH36)	＜0℃			

Note: ① This level of preheat is to be applied unless the approved welding procedure specifies a higher level.

(3) The interpass temperature is in general required to be not lower than the preheating temperature of steel plates and the maximum temperature is not to exceed 250℃.

6.1.5 Welding remedial

6.1.5.1 During the construction of ships, the weld plate edge preparation is different from the design value due to factors such as assembly, accuracy control and welding. Consequently, remedial is to be carried out before or after welding to comply with the design requirements. For detailed requirements, see Appendix 6A.

Section 2 WELDING OF HULL STRUCTURAL MEMBERS

6.2.1 General requirements

6.2.1.1 The welding procedure approval test is required when a new material or a new welding procedure is to be applied, 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 Welding equipment

6.2.2.1 Welding equipment and devices are to be suitable for their intended purposes and kept in an effective working condition. Satisfactory storage facilities are to be provided for welding consumables used in production near the welding site. If necessary, CCS will examine the shipbuilding equipment.

6.2.3 Principles for determination of welding sequence

6.2.3.1 The welding sequence is to be selected properly 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 The welding sequence is to be reasonably arranged to reduce welding stress and prevent deformation. Weld joints are to be arranged to facilitate downhand welding so far as possible.
(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 parent metal as well as the weld seam is to be avoided, otherwise grinding is to be employed.

Section 3 WELDING OF STAINLESS STEEL~~S~~ 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 ~~are allowed to be~~ 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 ~~only upon satisfactory technical appraisal by CCS~~.

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 parent 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 parent metal, capable of preventing general corrosion, gap corrosion, pitting corrosion and stress corrosion.

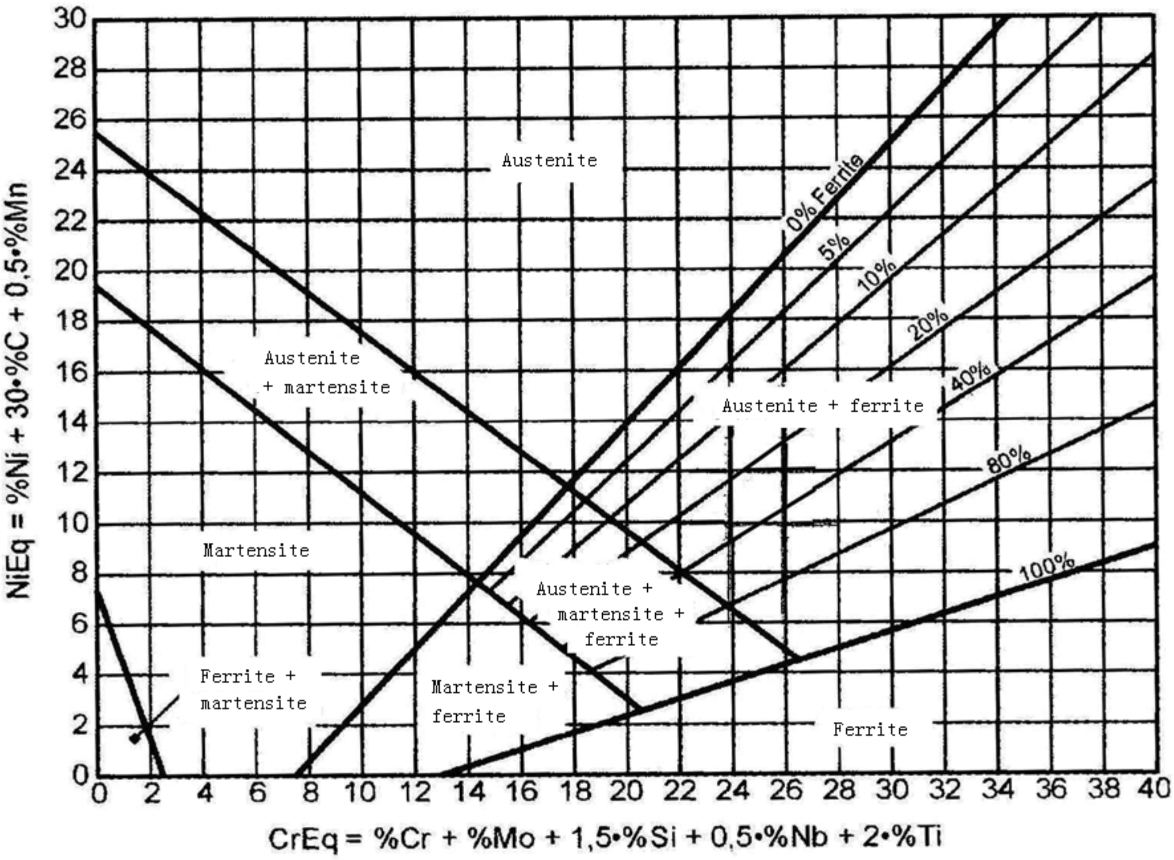


Figure 6.3.1.5 Diagram of stainless steel

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. ~~t~~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 ~~straight butt,~~ 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 mm 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~~11~~ 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 6B 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.~~3~~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.~~3~~6.

Edge preparation of stainless steel butt joints made by GTAW Table 6.3.4.~~3~~6

Thickness of weldment 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

6.3.4.47 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 ~~60~~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 6.3.4.47.

Edge preparation of stainless steel butt joints made by shielded metal arc welding Table 6.3.4.47

Thickness of weldment 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.~~5~~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.~~5~~8.

Edge preparation of stainless steel butt joints made by double submerged arc welding
Table 6.3.4.~~5~~8

Thickness of weldment mm	Edge preparation	Edge size		Remarks
		Gap a (mm)	Root face p (mm)	
6	I-shaped	< 0.5	–	
8	I-shaped	< 0.5	–	
10	Double side V-shaped 60°	< 0.8	4	
13	Double side 90° V-shaped	< 0.8	6	
15	Double side 90° V-shaped	<0.8	7	
20	Double side 90° V-shaped	<1.0	10	
25	Double side 90° V-shaped	<1.0	10	

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 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 60°-70°	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 parent 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. ~~Other non-destructive testing methods may also be specified by the Surveyor or in contract documents.~~

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

6.4.1.3 Welders are allowed to be engaged in the welding of marine aluminum alloys only upon satisfactory technical appraisal by CCS.

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.

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. Mechanically cleaned parts are to be welded within 4 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

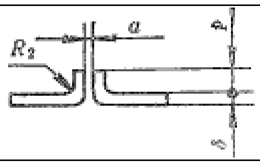
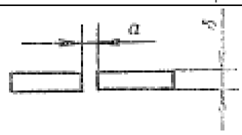
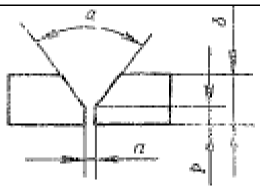
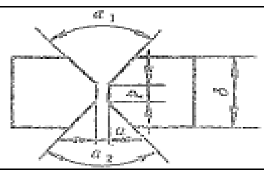
6.4.4.1 The plates of hull and superstructures may be joined by gas tungsten arc welding and gas metal arc welding. For the fillet welds of hull plating and framing, gas metal arc welding is applied to weld aluminum alloy structures.

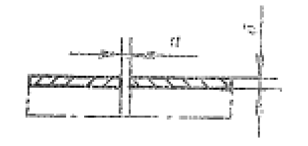
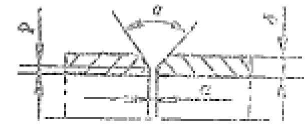
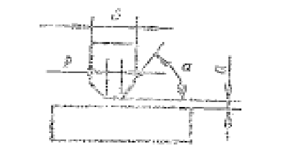
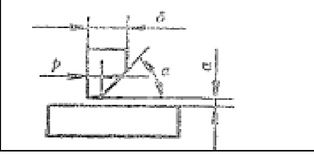
6.4.4.2 Aluminum alloys are to be welded and repaired in accordance with the requirements of Section 5, Chapter 5, PART THREE of CCS Rules for Materials and Welding.

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

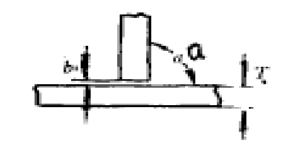
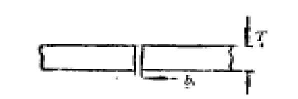
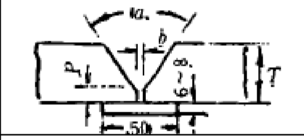
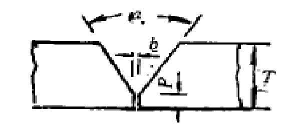
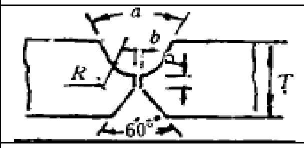
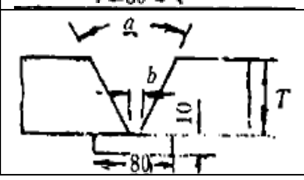
Thickness of weldment	Edge preparation	Edge size			Remarks
		Gap a (mm)	Root face p (mm)	Angle (θ)°	
1 ~ 2		< 1	2 ~ 3		Without filler wires or rods
1 ~ 3 3 ~ 5		0 ~ 0.5 1 ~ 2			Welding by both sides, back gouging
3 ~ 5 6 ~ 10 12 ~ 20		0 ~ 1 1 ~ 3 1.5 ~ 3	1 ~ 1.5 1 ~ 2.5 2 ~ 3	70 ± 5 70 ± 5 70 ± 5	Welding by both sides, back gouging
14 ~ 25		1.5 ~ 3	2 ~ 3	80 ± 5 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	Total of 1 ~ 3 layers
8 ~ 25		1 ~ 2	1 ~ 2	50 ± 5	2 or more layers on each side

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	Edge preparation	Edge size			Remarks
		Gap a (mm)	Root face p (mm)	Angle (θ)°	
1.5 ~ 3		0		90	Semi-automatic welding
3 ~ 8		0 ~ 1			
4 ~ 8		0 ~ 1			Semi-automatic welding
8 ~ 15		3 ~ 6	2 ~ 3	40	Semi-automatic welding with backing
6.4 ~ 16		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 REPAIR WELDING OF COPPER ALLOY PROPELLERS

6.5.1 General requirements

6.5.1.1 This Section applies to the repair welding of blades and hubs of copper alloy propellers complying with the requirements of Section 4, Chapter 8, PART THREE of CCS Rules for Materials and Welding.

6.5.1.2 This Section also applies to the repair welding for casting defects and insufficient sizes found during the manufacturing process of integral and built-up cast copper alloy propellers of civilian ships and during their service.

6.5.1.3 The chemical composition and mechanical properties of copper alloys used in manufacturing propellers are to comply with the requirements of Section 1, Chapter 9, PART ONE of CCS Rules for Materials and Welding.

6.5.2 Division of repair welding zones and scope of defects for which repair welding is allowed

6.5.2.1 For the repair welding of propellers, defects are divided into three different zones according to their positions, sizes and their levels of hazard to the service of propellers. Such zones are in accordance with the requirements of Section 4, Chapter 8, PART THREE of CCS Rules for Materials and Welding.

6.5.2.2 In principle, the detection of defects and the repair of defects in each zone are to follow the requirements of Section 4, Chapter 8, PART THREE of CCS Rules for Materials and Welding. For propellers having the defects listed in the following Table and requiring repair welding, a document stating the scope of repair welding details and a welding procedure specification are to be submitted in advance by the manufacturer to CCS for approval. The repair welding zones of propellers and their areas are to be as specified in Table 6.5.2.2.

Repair welding zones and areas of propellers **Table 6.5.2.2**

<table>
<tr><th rowspan="2">Position of defect</th><th rowspan="2">Repair allowed or not</th><th colspan="5">Maximum size of a single defect for which repair welding is allowed
Area s × depth h
(mm^2×mm)</th><th rowspan="2">Total area for which repair is allowed</th></tr>
<tr><th>D ≤ 1.0 m</th><th>1.0 m < D ≤ 1.5 m</th><th>1.5 m < D ≤ 2.5 m</th><th>2.5 m < D ≤ 4.0 m</th><th>D > 4.0 m</th></tr>
<tr><td>Zone A</td><td>Repair generally not allowed</td><td colspan="6">Repair welding may be carried out only upon implementation of certain procedures, subject to discreet acceptance by CCS. If accepted, effective heat treatment for stress relief and inspection are to be carried out after completion of welding. The repairs which CCS may discreetly accept refer to single defects the area and depth of which are not greater than 70% of maximum size of a single defect allowed in zone B on pressure face, and the total area of which is not greater than 3% of surface area of zone A, subject to agreement reached by parties concerned</td></tr>
<tr><td>Zone B on pressure face (B1 + B2)</td><td rowspan="5">Repair allowed</td><td>500 × 6</td><td>1400 × 7</td><td>2500 × 10</td><td>5000 × 15</td><td>7500 × 15</td><td rowspan="3">Total repair welding area on each face in each subzone is to be not greater than 5% of surface area of the subzone. Where total repair welding area on a blade face is to be not greater than 5% of the face, however, total repair welding area in zone C on pressure face or in zone B4 and zone C on suction side may be 7% of respective areas of these zones</td></tr>
<tr><td>Zone B on suction side from fillet to 0.4R (subzone B3)</td><td>700 × 8</td><td>1500 × 8</td><td>2500 × 10</td><td>5000 × 15</td><td>7500 × 20</td></tr>
<tr><td>Zone C, zone B on suction side from 0.4R to 0.7R (subzone B4)</td><td>700 × 8</td><td>1500 × 8</td><td>4000 × 10</td><td>7500 × 15</td><td>20000 × 25</td></tr>
<tr><td>Internal and external hub surfaces</td><td rowspan="2">700 × 8</td><td rowspan="2">1000 × 8</td><td rowspan="2">2000 × 10</td><td rowspan="2">4000 × 15</td><td rowspan="2">10000 × 25</td><td rowspan="2">Total repair welding area on internal and external hub surfaces is to be not greater than 5% of respective areas of these surfaces.
Total repair welding area on large and small hub end faces is to be not greater</td></tr>
<tr><td>Large and small hub end faces</td></tr>
</table>

							than 10% of respective areas of these end faces

Notes: (1) The portion of zone B within 0.4 R on pressure face is called subzone B1, the portion of zone B on pressure face beyond subzone B1 is called subzone B2;
(2) Propeller sizes given in the Table are net sizes in propeller drawings, and D is propeller diameter;
(3) The size of a defect is the size after removal of the defect;
(4) The maximum length of a single defect for which repair welding is allowed is to be not greater than twice the square root of the area of the defect.

6.5.3 Repair welding procedure

6.5.3.1 Repair welding is to be carried out in calm weather. If weather conditions are severe, it is to be carried out at a sheltered location.

6.5.3.2 The repair welding consumables are to be approved by CCS as qualified ones.

6.5.3.3 The shielded metal arc welding with coated electrodes or the electro gas welding are generally to be applied for propeller repairs. The gas tungsten arc welding is to be used with care.

6.5.3.4 The repair welding is preferably to be carried out at the down-hand position and where this is not practicable, the gas metal arc welding is to be carried out. If necessary, suitable preheating is to be done prior to welding and kept till completion of welding.

6.5.3.5 Upon completion of each run during the repair welding, all slag inclusions, undercuts and other defects are to be removed before the metal deposition of the next run.

6.5.3.6 After completion of the repair welding, welds are to be ground smooth for visual examination and dye penetrant test. If the propeller or its blades are to be heat treated for stress relief, they are to be visually examined before the heat treatment and are still to be subjected to the visual examination and dye penetrant test after such heat treatment. The radiographic examination is to comply with ~~the requirements of the Guidelines for non-destructive tests of propellers~~ recognized standards. The repair welding of any area within the zone A specified by CCS is to be evaluated.

6.5.4 Heat treatment

6.5.4.1 In general, straightened or weld repaired propellers are to be stress relieved. Furnace annealing is recommended for the repair welding in zones A and B or the repair welding of large areas in other zones. In addition, local stress relief may be applied (e,g. local annealing and hammering).

6.5.4.2 Suitable temperature control equipment is to be provided for stress-relief heat treatment in a furnace. Where local stress is to be relieved, various positions of the thickest blade are to be monitored by sufficient thermocouples. The Surveyor is to confirm that the technical means of heat treatment provided for local stress relief and the monitored technical data are effective.

6.5.4.3 In addition to the above requirements, other requirements for repair welding, straightening and heat treatment as specified in Section 4, Chapter 8, PART THREE and Section 1, Chapter 9, PART ONE of CCS Rules for Materials and Welding are to be complied with.

6.5.5 Welders

6.5.5.1 Welders are allowed to be engaged in the repair welding of propellers only upon satisfactory technical appraisal by CCS. However, those welders who have not been engaged in such welding for more than one year are to be satisfactorily re-appraised before they can be re-engaged in such welding.

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.

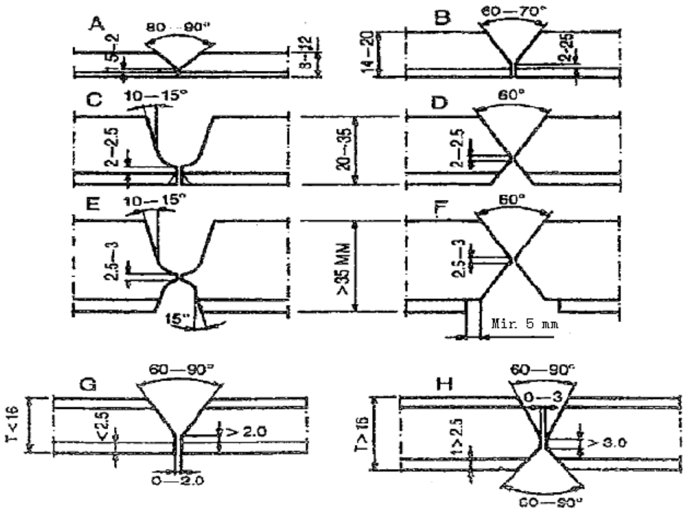


Figure 6.6.3.1 Usual edge preparation

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 parent 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:

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

where: B – volumetric percentage of parent 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

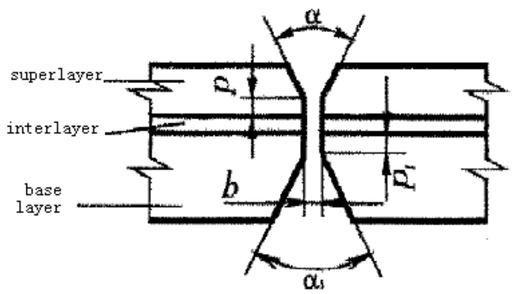
6.7.1.1 This Section applies to the welding between aluminium-steel transition joints (hereinafter referred to as transition joints) in compliance with the requirements of Section 5, Chapter 8, PART ONE of CCS Rules for Materials and Welding as well as welding of transition joints to structural members.

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

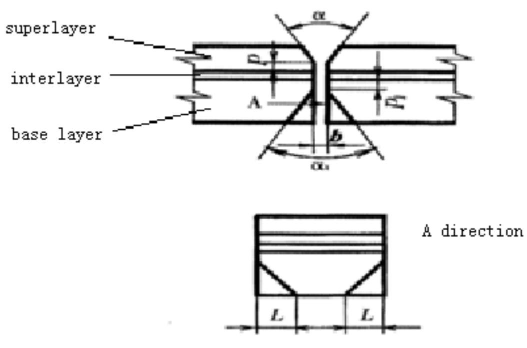
6.7.1.3 The welders engaged in the welding of transition joints are to be trained and certified for steel and aluminium alloy welding qualification respectively.

6.7.2 Welding joint types between transition joints

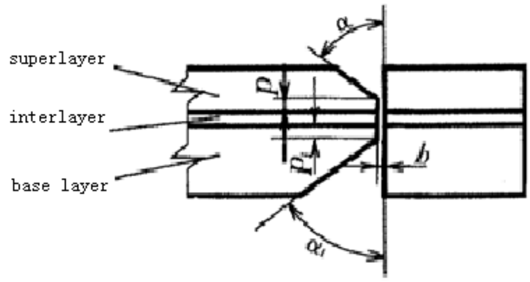
6.7.2.1 Welding joint types between transition joints are butt joints and fillet joints. The specific edge preparations are as follows:
(1) turnable free butt joint, see Figure 6.7.2.1(1);
(2) non-turnable restrained butt joint, see Figure 6.7.2.1(2);
(3) Tee joint, surfaces of transition joints on the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



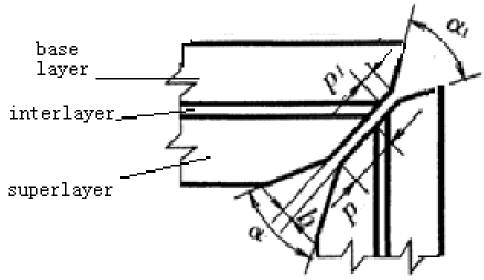
(1) Turnable free butt joint



(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.

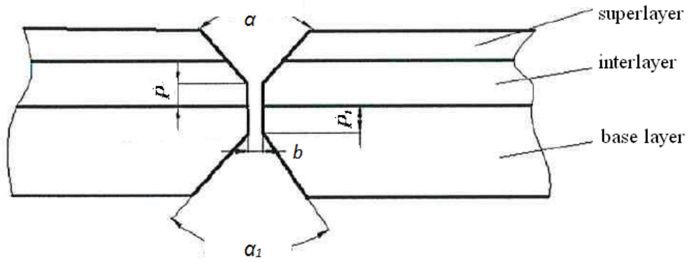


Figure 6.7.2.2 Edge preparation for welding between special transition joints

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).

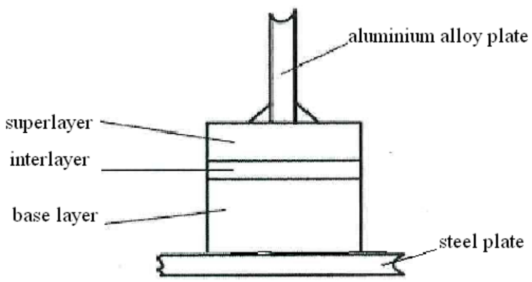


Figure 6.7.2.3(1) Welded to hull structure directly

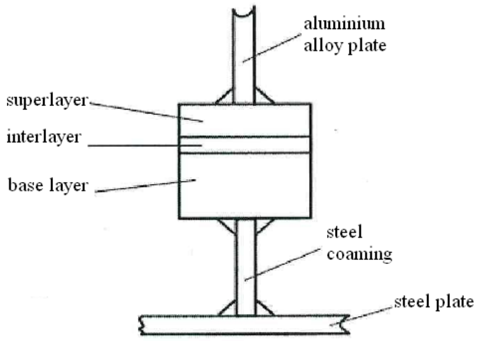


Figure 6.7.2.3(2) Welding using steel coaming

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 coverage of which complies with relevant provisions of Section 1, Chapter 3, PART THREE of CCS Rules for Materials and Welding.

6.7.3.2 For welding of transition joints to structural members, welding procedure approval tests are to be carried out in accordance with the requirements of 4.5.5, 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℃).
(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.

Section 8 WELDING OF STAINLESS STEEL PIPES

6.8.1 General provisions

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

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

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

6.8.1.4 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.

6.8.2 Preparations before welding

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

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

6.8.2.3 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.

6.8.2.4 Before welding, the grooves and an area within the scope of at least 50 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.

6.8.3 Tack welding

6.8.3.1 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.

6.8.3.2 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.

6.8.4 Welding of stainless steel pipes

6.8.4.1 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 CO_2 welding with flux-cored wires and root run with argon-shielded tungsten arc welding and shielded metal arc welding (SMAW) by capping run.

6.8.4.2 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.

6.8.4.3 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.

6.8.4.4 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 σ phase.

6.8.4.5 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.

6.8.4.6 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.

6.8.5 Cleaning of stainless steel welds and post-weld treatment

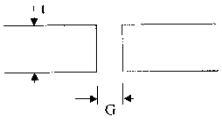
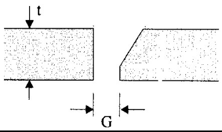
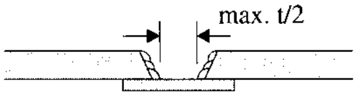
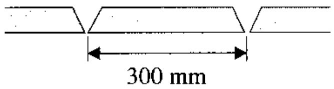
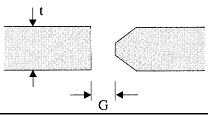
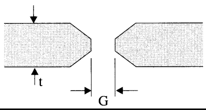
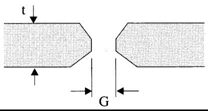
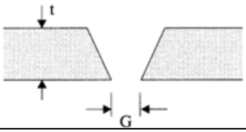
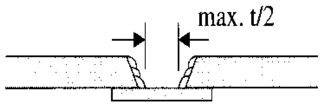
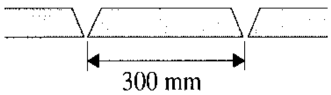
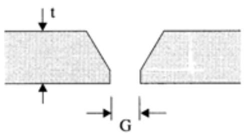
6.8.5.1 Welds and base metals in adjacent areas are to be cleaned by stainless steel brush or other appropriate methods.

6.8.5.2 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.

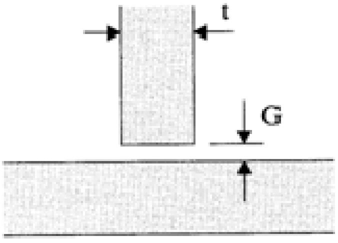
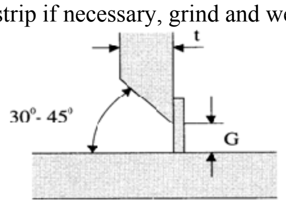
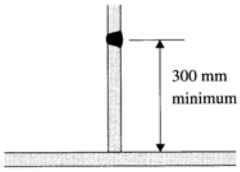
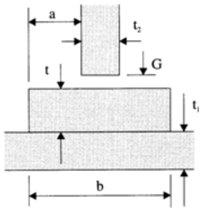
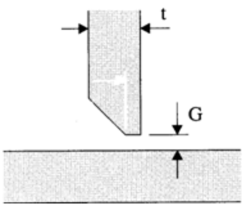
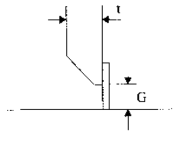
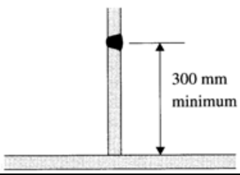
6.8.5.3 Acid dip or passivating is to be carried out for welded stainless steel pipes so as to achieve sound corrosion resistance in surface areas.

Appendix 6A

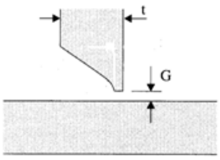
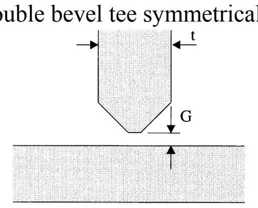
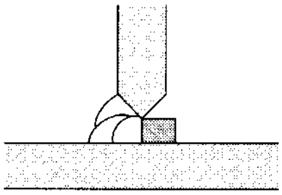
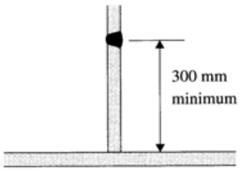
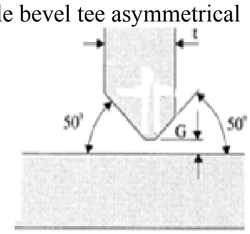
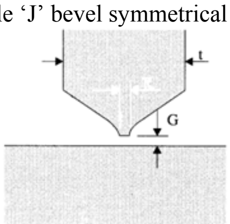
Typical butt weld plate edge preparation remedial (manual welding and semi-automatic welding) **Table 6A-1**

<table>
<tr><th>Detail</th><th>Remedial standard</th><th>Remark</th></tr>
<tr><td>Square butt
</td><td>When G ≤ 10 mm
chamfer to 45° and build up by welding
When G > 10 mm
build up with backing strip; remove, back gouge and seal weld;
or, insert plate, min. width 300 mm</td><td></td></tr>
<tr><td>Single bevel butt
</td><td rowspan="4">When 5 mm < G ≤ 1.5t (maximum 25 mm) build up gap with welding on one or both edges to maximum of 0.5t, using backing strip, if necessary.
Where a backing strip is used, the backing strip is to be removed, the weld back gouged, and a sealing weld made.

Different welding arrangement by using backing material approved by CCS may be accepted in accordance with an appropriate welding procedure specification.
When G > 25 mm or 1.5t, whichever is smaller, use insert plate, of minimum width 300 mm

Min.</td><td></td></tr>
<tr><td>Double bevel butt
</td><td></td></tr>
<tr><td>Double vee butt, uniform bevels
</td><td></td></tr>
<tr><td>Double vee butt, non-uniform bevel
</td><td></td></tr>
<tr><td>Single vee butt, one side welding
</td><td rowspan="2">When 5 mm < G ≤ 1.5t mm (maximum 25 mm), build up gap with welding on one or both edges, to “Limit” gap size preferably to “Standard” gap size as described in Table 6.1.4.1(1).
Where a backing strip is used, the backing strip is to be removed, the weld back gouged, and a sealing weld made.
Different welding arrangement by using backing material approved by CCS may be accepted in accordance with an appropriate welding procedure specification.

When G > 25 mm or 1.5t, whichever is smaller, use insert plate of minimum width 300 mm.

Min.</td><td></td></tr>
<tr><td>Single vee butt
</td><td></td></tr>
</table>

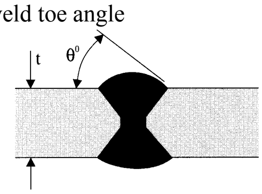
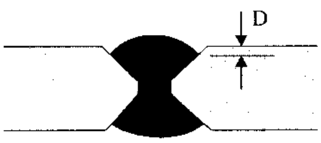
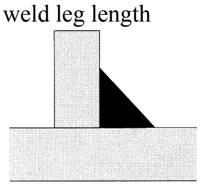
Typical fillet weld plate edge preparation remedial (manual welding and semi-automatic welding) **Table 6A-2**

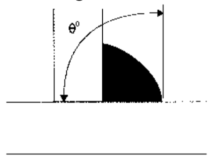
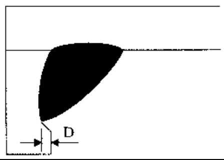
<table>
<tr><th>Detail</th><th>Remedial standard</th><th>Remark</th></tr>
<tr><td rowspan="3">Tee Fillet
</td><td>3 mm < G ≤ 5 mm – leg length increased to Rule leg + (G-2)</td><td rowspan="3"></td></tr>
<tr><td>5 mm < G ≤ 16 mm or G ≤ 1.5t - chamfer by 30° to 45°, build up with welding, on one side, with backing strip if necessary, grind and weld.
</td></tr>
<tr><td>G > 16 mm or G > 1.5t use insert plate of minimum width 300 mm
</td></tr>
<tr><td></td><td>t2≤t≤t1
G≤2 mm
A=5 mm+fillet leg length</td><td>Not to be used in cargo area or areas of tensile stress through the thickness of the liner</td></tr>
<tr><td rowspan="3"></td><td>3 mm<G≤5 mm, build up weld</td><td></td></tr>
<tr><td>5 mm < G ≤ 16 mm - build up with welding, with backing strip if necessary, remove backing strip if used, back gouge and back weld.
</td><td></td></tr>
<tr><td>G > 16 mm new plate to be inserted of minimum width 300 mm
</td><td></td></tr>
</table>

Typical fillet weld plate edge preparation remedial (manual welding and semi-automatic welding) **Table 6A-3**

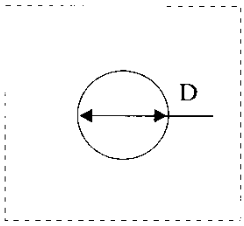
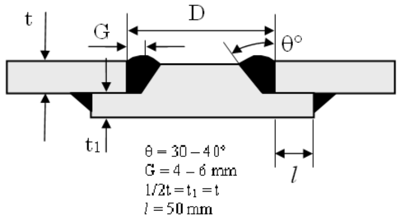
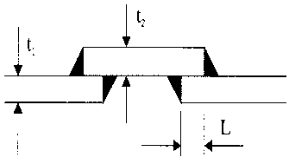
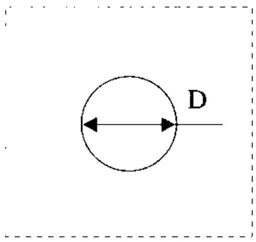
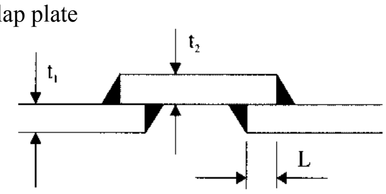
Detail	Remedial standard	Remark
Single 'J' bevel tee 	as single bevel tee	
Double bevel tee symmetrical 	When 5 mm < G ≤ 16 mm build up with welding using ceramic or other approved backing bar, remove, back gouge and back weld.  When G > 16 mm-insert plate of minimum height 300 mm to be fitted. 	
Double bevel tee asymmetrical 		
Double 'J' bevel symmetrical 		

Typical fillet and butt weld profile remedial (manual welding and semi-automatic welding) **Table 6A-4**

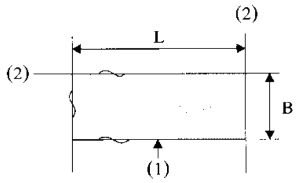
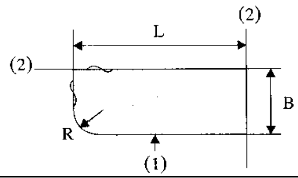
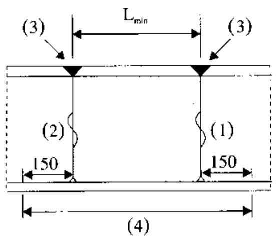
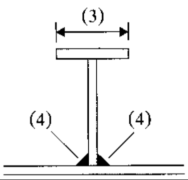
Detail	Remedial standard	Remark
Butt weld toe angle 	θ > 90° grinding, and welding, where necessary, to make θ ≤ 90°	Minimum short bead to be referred Table 6A-8
Butt weld undercut 	For strength member, where 0.5 < D ≤ 1 mm, and for other, where 0.8 < D ≤ 1 mm, undercut to be ground smooth (localized only) or to be filled by welding Where D > 1 mm undercut to be filled by welding	
Fillet weld leg length 	Increase leg or throat by welding over	

Detail	Remedial standard	Remark
Fillet weld toe angle  	θ > 90°grinding, and welding, where necessary, to make θ ≤ 90°	
Fillet weld undercut  	Where 0.8 < D ≤ 1 mm undercut to be ground smooth (localized only) or to be filled by welding Where D > 1 mm undercut to be filled by welding	

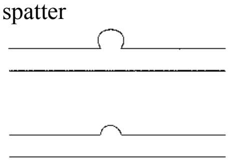
Erroneous hole remedial **Table 6A-5**

Detail	Remedial standard	Remark
Holes made erroneously D < 200 mm  	Strength member open hole to minimum 75 mm dia., fit and weld spigot piece  Or open hole to over 300 mm and fit insert plate	
	Other open hole to over 300 mm and fit insert plate Or fit lap plate  $t_1 = t_2$ L = 50 mm, min	
Holes made erroneously D ≥ 200 mm  	Strength member open hole and fit insert plate	
	Other open hole to over 300 mm and fit insert plate Or fit lap plate  $t_1 = t_2$ L = 50 mm, min	

Remedial by insert plate **Table 6A-6**

Detail	Remedial standard	Remark
Remedial by insert plate  	L = 300 mm minimum B = 300 mm minimum R = 5t mm 100mm minimum (1) seam with insert piece is to be welded first (2) original seam is to be released and welded over for a minimum of 100 mm.	
Remedial of built section by insert plate  	L_{min}≥300 mm Welding sequence (1) →(2) →(3) →(4) Web butt weld scallop to be filled during final pass (4)	

Weld surface remedial **Table 6A-7**

Detail	Remedial standard	Remark
Weld spatter 	Remove spatter observed before blasting with scraper or chipping hammer, etc. For spatter observed after blasting: a) Remove with a chipping hammer, scraper, etc. b) For spatter not easily removed with a chipping hammer, scraper, etc., grind the sharp angle of spatter to make it obtuse.	In principle, no grinding is applied to weld surface.
Arc strike (HT steel, Cast steel, Grade E of mild steel, TMCP type HT steel, Low temp steel)	Remove the hardened zone by grinding or other measures such as overlapped weld bead etc.	Minimum short bead to be referred Table 6.1.5.1(8)

Welding remedial by short bead **Table 6A-8**

Detail	Remedial standard	Remark
Short bead for remedying scar (scratch)	1) HT steel, Cast steel, TMCP type HT steel (Ceq > 0.36%) and Low temp steel (Ceq > 0.36%) Length of short bead ≥ 50 mm 2) Grade E of mild steel Length of short bead ≥ 30 mm 3) TMCP type HT steel (Ceq ≤ 0.36%) and Low temp steel (Ceq ≤ 0.36%) Length of short bead ≥ 10 mm	Preheating is necessary at 100 ± 25°C
Remedying weld bead	1) HT steel, Cast steel, TMCP type HT steel (Ceq > 0.36%) and Low temp steel (Ceq > 0.36%) Length of short bead ≥ 50 mm 2) Grade E of mild steel	

Detail	Remedial standard	Remark
	Length of short bead ≥ 30 mm 3) TMCP type HT steel (Ceq ≤ 0.36%) and Low temp steel (Ceq ≤ 0.36%) Length of short bead ≥ 30 mm	
Notes: 1. When short bead is made erroneously, remove the bead by grinding. 2. $C_{eq} = \mathrm{C} + \frac{\mathrm{Mn}}{6} + \frac{\mathrm{Cr}+\mathrm{Mo}+\mathrm{V}}{5} + \frac{\mathrm{Ni}+\mathrm{Cu}}{15} (\%)$		

Appendix 6B

Common joint types of stainless steel hull structure

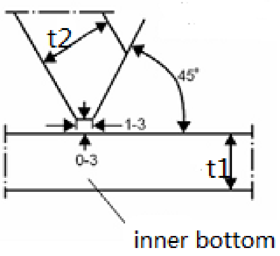


Figure 1 Joint design between lower sloping plate, bulkhead stool sloping plate and inner bottom

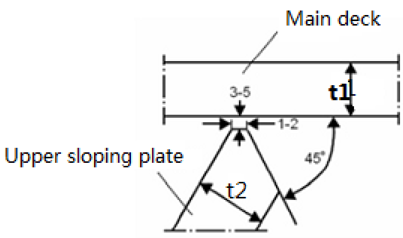


Figure 2 Joint design between main deck and upper sloping plate

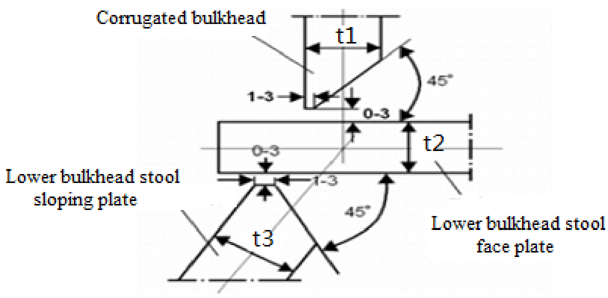


Figure 3 Joint design in way of face plate of lower bulkhead stool of corrugated bulkhead

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 hull 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), liquid penetrant testing (PT), magnetic particle testing (MT), eddy current testing (ET), ultrasonic testing (UT) and radiographic testing (RT).

7.1.1.4 The structural tightness testing of welds for hull structure is to comply with the relevant requirements of Section 3, Chapter 4, PART ONE of CCS Rules for Classification of Sea-Going Steel Ships.

7.1.1.5 The Guidelines give the minimum requirements for the methods and quality levels that may be adopted for the normal non-destructive testing of hull structural steel welds during construction of new ships and ship repairs. In special circumstances, the specific application of non-destructive test techniques and the acceptance quality requirements are to be agreed between the designer and the owner according to actual needs.

7.1.2 Responsibilities

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

7.1.2.2 It should be the responsibility of the shipbuilder or his subcontractors 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 assessment of the findings made by the non-destructive testing is the responsibility of the inspection department of the shipbuilder.

7.1.3 Testing organizations and personnel

7.1.3.1 The organizations engaged in the non-destructive testing of ships are to be qualified for their services according to CCS Provisions for Qualification of Non-Destructive Testing Organizations.

7.1.3.2 For each test method, operators are to pass qualification examinations in accordance with CCS Rules for Qualification and Certification of Non-Destructive Testing Personnel or a scheme equivalent to ISO 9712 and other internationally recognized standards, obtain qualification certificates issued or accepted by CCS and thereafter perform the non-destructive testing appropriate to their qualification, subject to authorization by the representative of the production unit.

7.1.3.3 Defect assessment and test reports are to be reviewed and issued by operators qualified to level II or a higher level appropriate to the test method.

7.1.3.4 Personnel responsible for the preparation and approval of NDT procedure specifications are generally to be qualified to level III. In special circumstances, such work may also be done by senior personnel qualified to level II.

7.1.3.5 Qualified operators are to hold a written qualification certificate and to be authorized by the employer. The NDT personnel engaged in on-site testing are to carry a copy of the certificate for check by the Surveyor.

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.

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. It is recommended that magnetic particle testing be preferred over liquid 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
Ferromagnetic material (ferritic steel)	VT, MT, PT	MT, ET
Non-ferromagnetic materials (austenitic steel, aluminum, copper, etc.)	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.

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)		
		$t \leq 8$	$8 < t \leq 40$	$t > 40$
Ferritic steel	Butt joint	RT or (UT)	RT or UT	(RT) or UT
	T-joint	(UT) or (RT)	UT or (RT)	UT or (RT)
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 shipbuilder 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 shipbuilder 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 and used in the NDT documentation to identify the exact locations and lengths of welds examined.

7.1.6.5 The inspection department of the shipyard 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 shipbuilder. 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 hull structures, 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 standards and acceptance criteria for hull structures (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.

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 For high strength steels with specified minimum yield stress of 420 N/mm^2 and above, NDT is not to be carried out before 48 hours after completion of welding or of hot work. 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. For normal strength steels of less than 100 mm in thickness, such requirement may be relaxed.

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 parent 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 defect beyond those given in Table 7.3.4.2 is allowed during visual examination.

"Acceptance criteria for visual examination Table 7.3.4.2

<table>
<tr><th>Defect</th><th>Classification according to ISO 6520-1</th><th colspan="2">Acceptance criteria[1)]</th></tr>
<tr><td>Crack</td><td>100</td><td colspan="2">Not allowed</td></tr>
<tr><td>Lack of fusion</td><td>401</td><td colspan="2">Not allowed</td></tr>
<tr><td>Incomplete root penetration in butt joints welded from one side</td><td>4021</td><td colspan="2">Not allowed</td></tr>
<tr><td>Surface pore</td><td>2017</td><td colspan="2">Single pore diameter $d \le 0.25t$ for butt welds (or $d \le 0.25a$ for fillet welds) with maximum diameter of 3 mm.[1)]
2.5d as minimum distance to adjacent pore</td></tr>
<tr><td rowspan="2">Undercut</td><td rowspan="2">501</td><td>Butt welds</td><td>Depth ≤ 0.5 mm whatever is the length
Depth ≤ 0.8 mm with a maximum continuous length of 90 mm[2)]</td></tr>
<tr><td>Filler welds</td><td>Depth ≤ 0.8 mm whatever is the length</td></tr>
</table>

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.

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/σ)min
				D = 2.0	D = 4.0	D = 2.0	D = 2.0
T1	Low	High	Tiny	4.3	7.4	0.018	270
T2	Relatively low	Relatively high	Fine	4.1	6.8	0.028	150
T3	Medium	Medium	Medium	3.8	6.4	0.032	120
T4	High	Low	Coarse	3.5	5.0	0.039	100

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

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

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

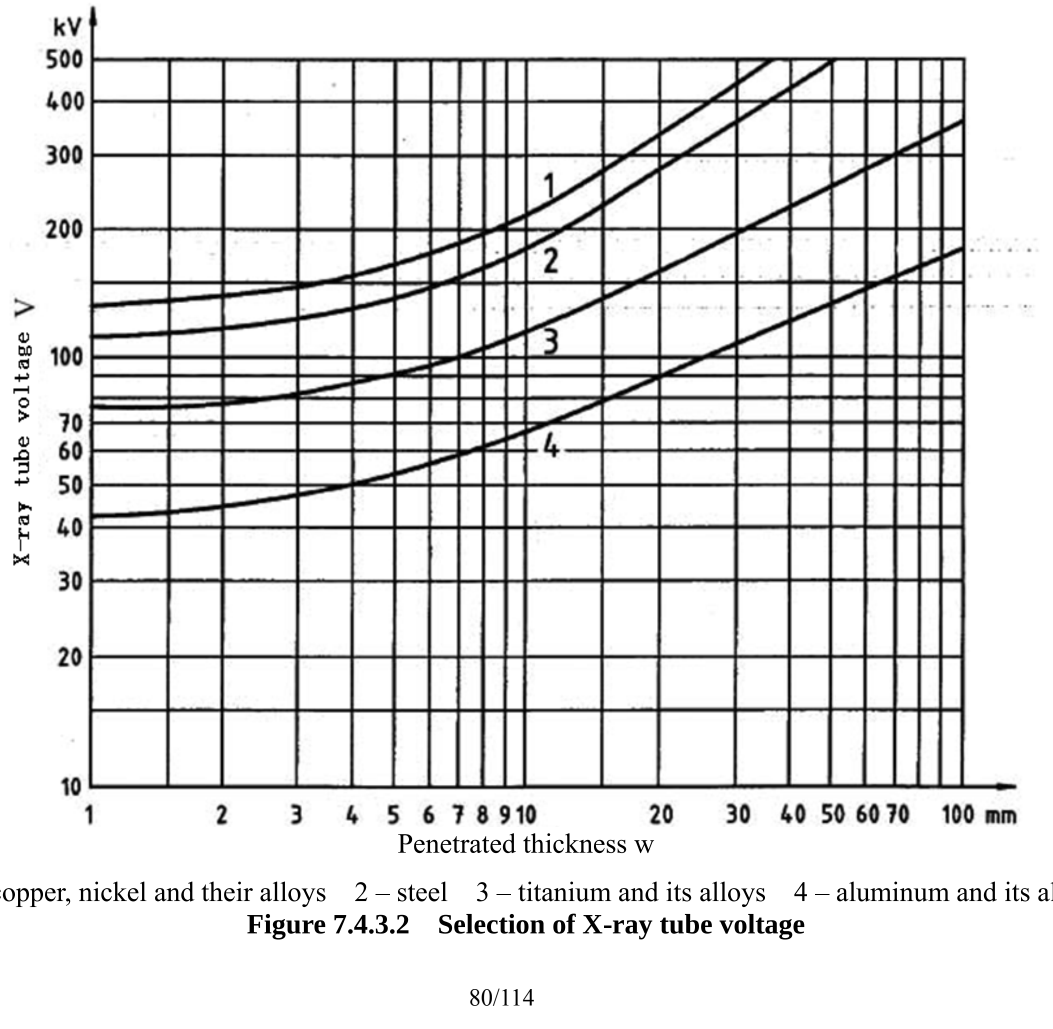
7.4.2.4 The intensifying screen is to be free from any damage such as scratch that may lead to a false defect image in the radiograph.

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)
3.5 < 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).

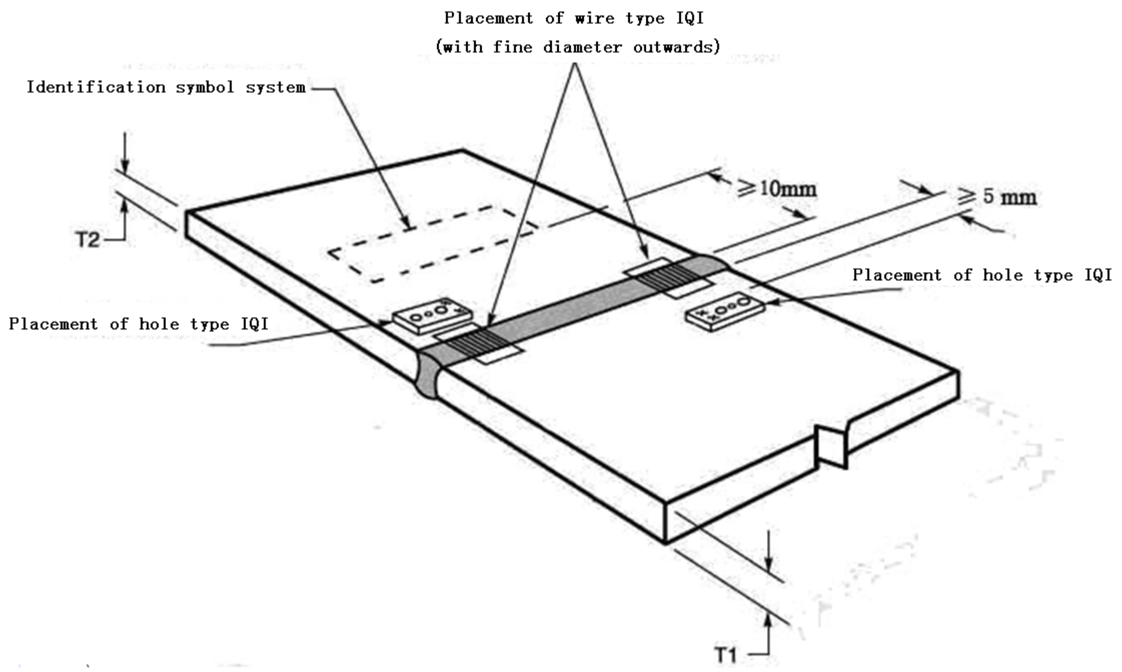


Figure 7.4.4.4 (Recommended) placement of identification system and IQI

(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)
3.5 < 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 ≤ 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 test report is at least to include the following:
(1) name, type, material, thickness and condition of product;
(2) test areas, positions and numbering (usually the diagrams or description showing the arrangement of testing positions are attached);
(3) welding process and type of welded joints (for welds);
(4) type or size of radiation source, size of focal spot;
(5) film system (type of film and intensifying screen);
(6) used tube voltage and current or source activity;
(7) exposure technique, time of exposure and source-to-film distance;
(8) type, position of IQI and sensitivity,;
(9) acceptance criteria and test results (including density, geometric un-sharpness, nature and size of defects);
(10) constraining conditions or factors in the testing that may affect the testing results (if any);
(11) names, qualification level and signature of personnel that have performed the testing;
(12) date of testing.

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

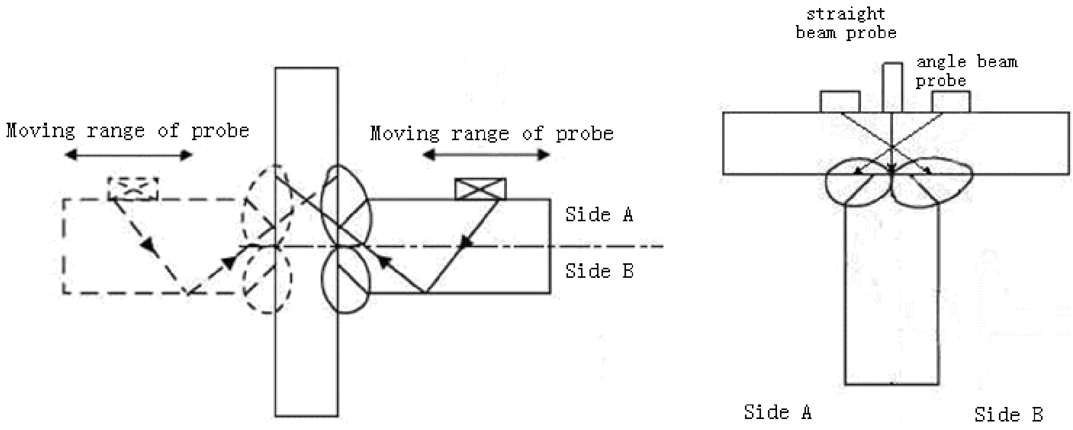
7.5.3.1 The scanning surfaces are to be clean and free from impurities like rust, paint which may interfere with probe coupling, and to have suitable profile and roughness.

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 parent material 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 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 test report is at least to include the following:
(1) name, type, material, thickness and condition of product;
(2) test areas, positions and numbering (usually the diagrams or description showing the arrangement of testing positions are attached);
(3) welding process and type of welded joints (for welds);
(4) type and numbering of ultrasonic tester and probes as well as coupling medium;
(5) nominal frequency and measured incident angle of the probe (for angle beam probes) and calibration sensitivity;
(6) type of the reference block used;
(7) sensitivity, corrections of transmission, signal response used for defect detection (e.g. echo height or defect equivalent);
(8) temperature of testing positions;
(9) acceptance criteria and test results;
(10) constraining conditions or factors in the testing that may affect the testing results (if any);
(11) names, qualification level and signature of personnel that have performed the testing;
(12) date of testing.

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.

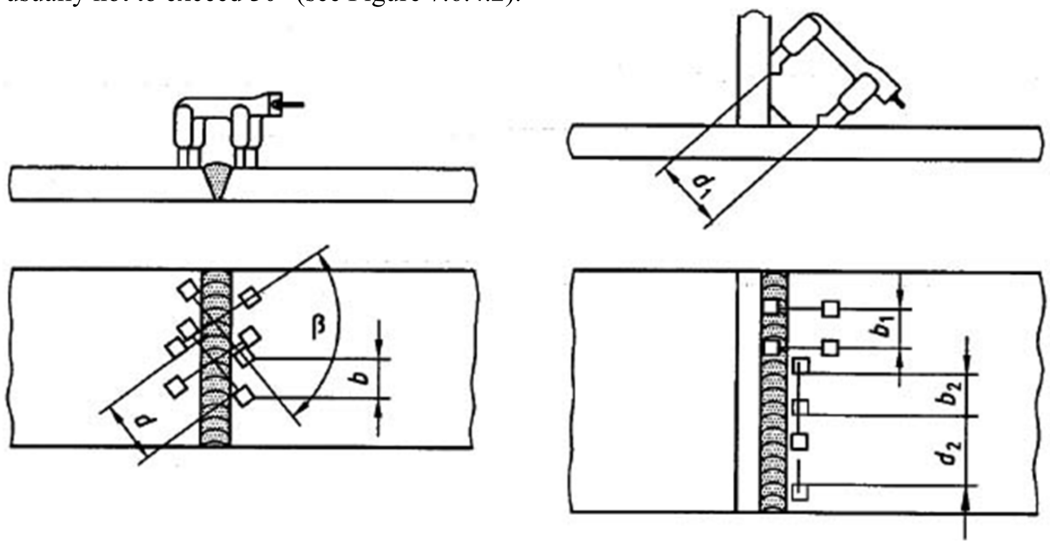
7.6.3.3 Prior to testing, an overall performance test of the system is to be carried out for ensuring the specified test sensitivity of the system.

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.

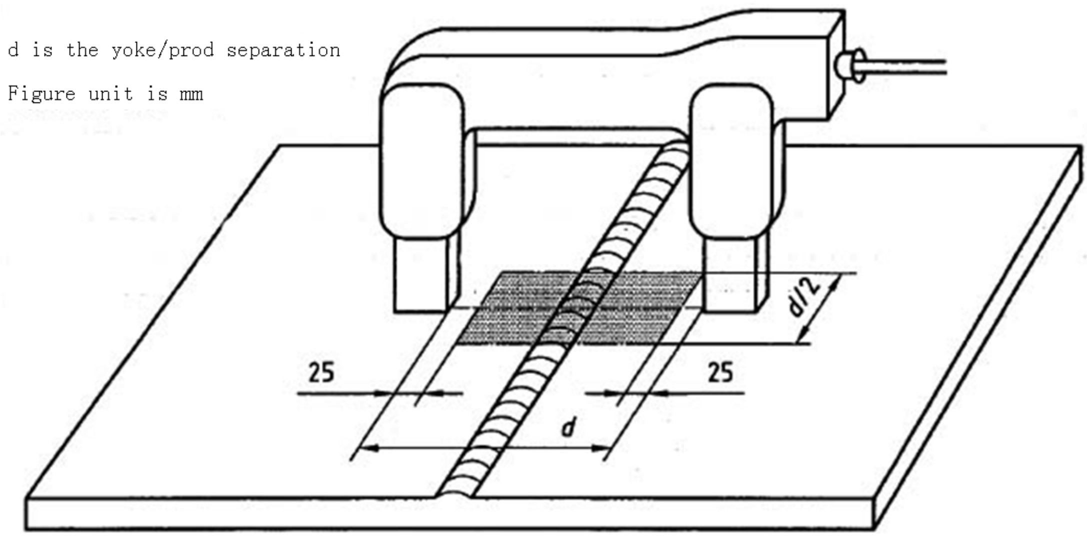


Figure 7.6.4.3 Effective test area for magnetizing with yokes or prods

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 test report is at least to include the following:
(1) name, type, material, thickness and condition of product;
(2) test areas, positions and numbering (usually the diagrams or description showing the arrangement of testing positions are attached);
(3) welding process and type of welded joints (for welds only);
(4) magnetizing method and strength of magnetic field;
(5) temperature of testing positions;
(6) detection media;
(7) viewing conditions (surface roughness and illumination);
(8) demagnetization (if necessary);
(9) acceptance criteria and test results;
(10) constraining conditions or factors in the testing that may affect the testing results (if any);
(11) names, qualification level and signature of personnel that have performed the testing;
(12) date of testing.

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 parent 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 test report is at least to include the following:
(1) name, type, material and condition of product;
(2) test areas, positions and numbering (usually the diagrams or description showing the arrangement of testing positions are attached);
(3) welding process and type of welded joints (for welds);
(4) type and name of penetrant, cleaner and developer;
(5) temperature of testing positions, penetration time and development time;
(6) type of reference blocks used;
(7) acceptance criteria and test results;
(8) constraining conditions or factors in the testing that may affect the testing results (if any);
(9) names, qualification level and signature of personnel that have performed the testing;
(10) date of testing.

Appendix 7A

Non-Destructive Testing of Hull and Machinery Steel Forgings

7A.1 Application

7A.1.1 This Appendix applies to the non-destructive testing of hull structural steel forgings covered by CCS Rules for Materials and Welding.

7A.1.2 For steel forgings (e.g. machinery 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 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 5.1.5.2, PART ONE of CCS Rules for Materials and Welding.

7A.3 Preparation for inspections and visual examination

7A.3.1 Steel forgings are to be subjected to a 100% visual examination.

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 are to be visually examined for their internal surface imperfections uncovered by the machining operation. If necessary, auxiliary tools may be used in the inspection.

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 are to be free of cracks, crack-like indications, laps, folds or other injurious indications affecting the subsequent use.

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 is usually recommended with the exception of austenitic stainless steels or other special cases.

7A.4.2 Surface inspections by magnetic particle and/or liquid penetrant methods generally apply to the following steel forgings:
(1) crankshafts with minimum crankpin diameter not less than 100 mm;
(2) propeller shafts, intermediate shafts, thrust shafts and rudder stocks with minimum diameter not less than 100 mm;
(3) connecting rods, piston rods and crossheads with minimum diameter not less than 75 mm or equivalent cross section;
(4) bolts with minimum diameter not less than 50 mm, which are subjected to dynamic stresses such as cylinder cover bolts, tie rods, crankpin bolts, main bearing bolts, propeller blade fastening bolts.

7A.4.3 The surface inspections of the relevant areas of typical essential marine forgings are to be in accordance with 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 is to be performed on a forging in the final machined surface condition and final thermally treated condition or within 0.3 mm of the final machined surface condition for AC techniques (0.8 mm for DC techniques).

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.

Allowable number and size of 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 forgings	I	3	Linear Nonlinear Aligned	0② 3 0②	– 3.0 –
	II	10	Linear Nonlinear Aligned	3② 7 3②	3.0 5.0 3.0

Notes: ① Linear indication means an indication in which the length is at least three times the width; nonlinear indication means an indication of circular or elliptical shape with a length less than three times the width; aligned indication means three or more indications in a line, separated by 2 mm or less edge-to-edge.
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.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.

7A.5.2 The ultrasonic testing generally applies to the following steel forgings:
(1) crankshaft with minimum crankpin diameter not less than 150 mm;
(2) propeller shafts, intermediate shafts, thrust shafts and rudder stocks with minimum diameter not less than 200 mm;
(3) connecting rods, piston rods and crossheads with minimum diameter not less than 200 mm or equivalent cross section.

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.

7A.5.5 The internal evaluation of forgings and their acceptance criteria are to comply with Table 7A.5.5.

Acceptance criteria for internal ultrasonic testing of forgings Table 7A.5.5

Type of forging	Inspection zone	Allowable disc shape according to distance-gain size	Allowable length of indication	Allowable distance between two indications②

Crankshaft	I	d ≤ 0.5 mm	–	–
	II	d ≤ 2.0 mm	≤ 10 mm	≥ 20 mm
	III	d ≤ 4.0 mm	≤ 15 mm	≥ 20 mm
Propeller shaft Intermediate shaft Thrust shaft Rudder stock	II	Outer: d ≤ 2.0 mm Inner: d ≤ 4.0 mm	≤ 10 mm ≤ 15 mm	≥ 20 mm ≥ 20 mm
	III	Outer: d ≤ 3.0 mm Inner: d ≤ 6.0 mm	≤ 10 mm ≤ 15 mm	≥ 20 mm ≥ 20 mm
Connecting rod Piston rod Crosshead	II	d ≤ 2.0 mm	≤ 10 mm	≥ 20 mm
	III	d ≤ 4.0 mm	≤ 10 mm	≥ 20 mm

Notes: ① Outer part means the part beyond one third of the shaft radius from the center, the inner part means the remaining core area.

② In case of accumulations of two or more isolated indications which are subjected to registration, the minimum distance between two neighboring indications must be at least the length of the bigger indication. This applies as well to the distance in axial direction as to the distance in depth. Isolated indications with less distance are to be determined as one single indication.

7A.6 Rectification of surface defects of steel forgings

7A.6.1 If defect indications are unacceptable, the rectification of surface defects is allowed in accordance with Table 7A.6.1. Excessive internal defects are not to be accepted.

Repair requirements for surface defects of forgings **Table 7A.6.1**

Test assembly	Zone	Allowable repairs
Crankshaft forgings	I	Neither indications nor repairs are permitted
	II	Indications must be removed by grinding to a depth no greater than 1.5 mm; Indications detected in the journal bearing surfaces may be removed by grinding to a depth no greater than 3.0 mm. The total ground area is not to be less than 1% of the total bearing surface area concerned. Non-open indications, except those evaluated as segregation, are to be depressed but need not be removed.
	III	Defects must be removed by grinding to a depth no greater than 5% of the diameter or 10 mm, whichever is smaller. The total ground area is to be less than 2% of the forging surface area
Other forgings	I	Indications must be removed by grinding to a depth no greater than 1.5 mm. However, grinding is not permitted in way of finished machined threads
	II	Indications must be removed by grinding to a depth no greater than 2% of the diameter or 4.0 mm, whichever is smaller
	III	Defects must be removed by grinding to a depth no greater than 5% of the diameter or 10 mm, whichever is smaller. The total ground area is to be less than 2% of the forging surface area

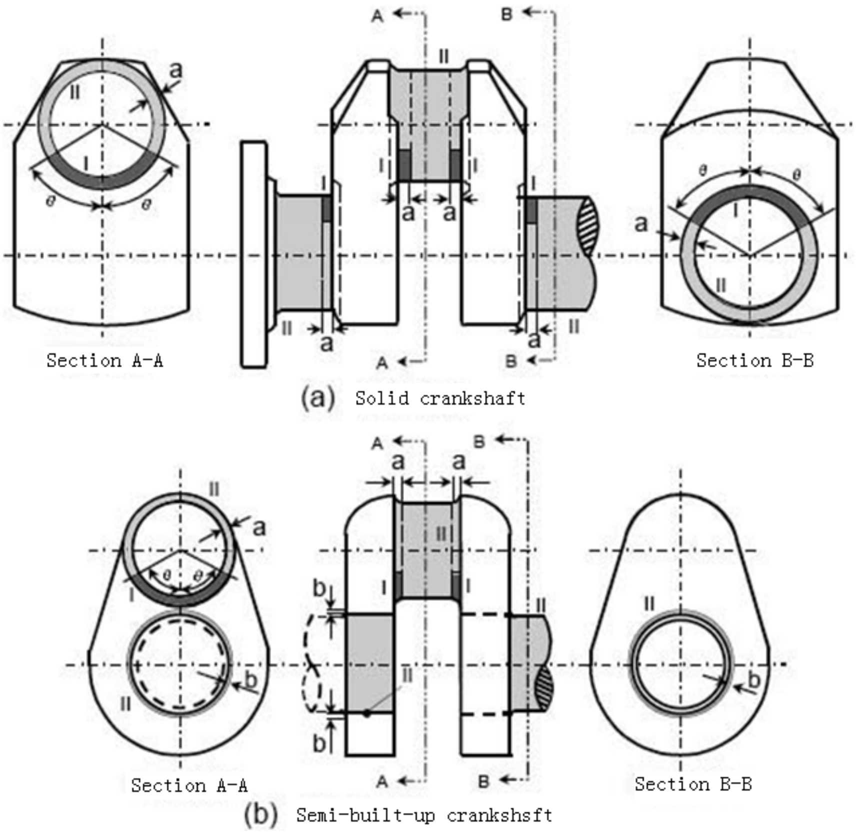
7A.6.2 Defective parts of material may be removed by grinding, or by chipping and grinding. All grooves are to have a bottom radius of approximately three times the groove depth and to be smoothly blended to the surface area with a finish equal to the adjacent surface.

7A.6.3 To depress is to flatten or relieve the edges of a non-open indication with a fine pointed abrasive stone with the restriction that the depth beneath the original surface is to be 0.08 mm minimum to 0.25 mm maximum and that the depressions be blended into the bearing surface.

7A.6.4 Non-open indications evaluated as segregation need not be rectified.

7A.6.5 If necessary, complete removal of the defect is to be proved by magnetic particle testing or penetrant testing.

7A.6.6 Repair welding is not permitted for crankshafts. Repair welding of other forgings is subjected to agreement of CCS Surveyor.



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:
   $\theta = 60°$,
   $a = 1.5\ r$,
   $b = 0.05\ d$ (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.

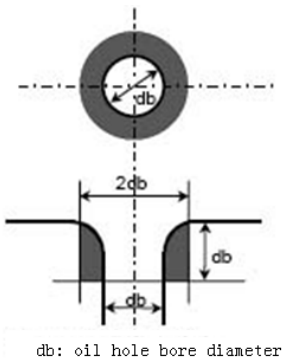
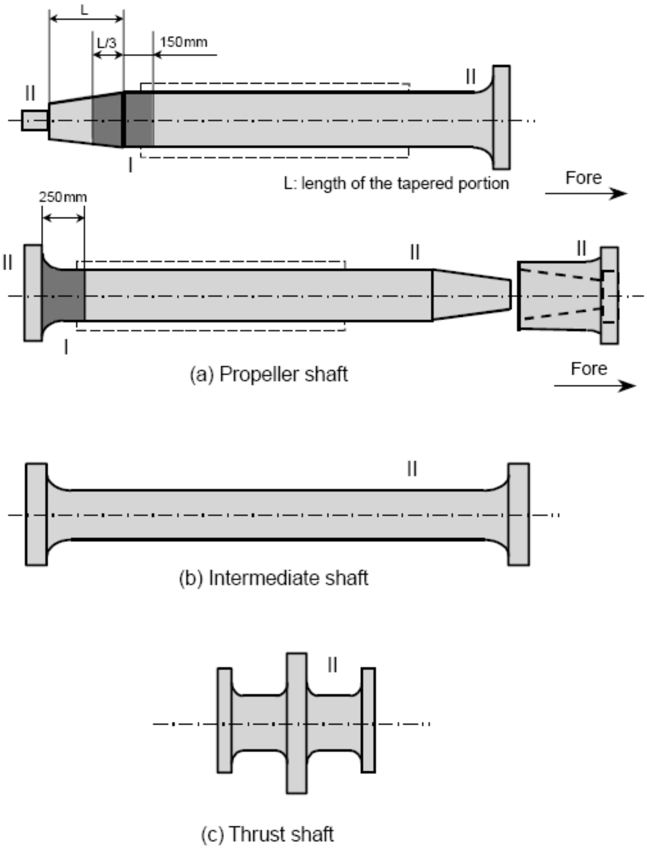


Figure 7A.4.3(1) Zones for magnetic particle/liquid penetrant testing on crankshafts



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/liquid penetrant testing on shafts

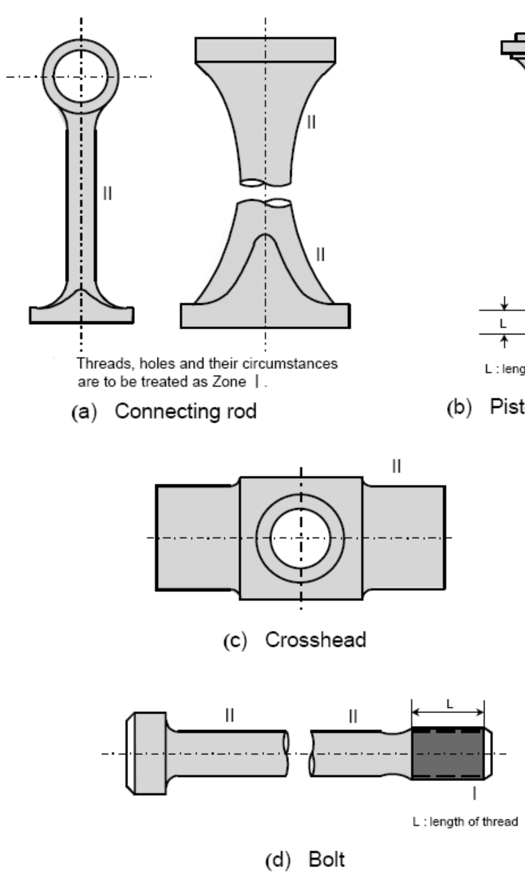


Figure 7A.4.3(3) Zones for magnetic particle/liquid penetrant testing on machinery components

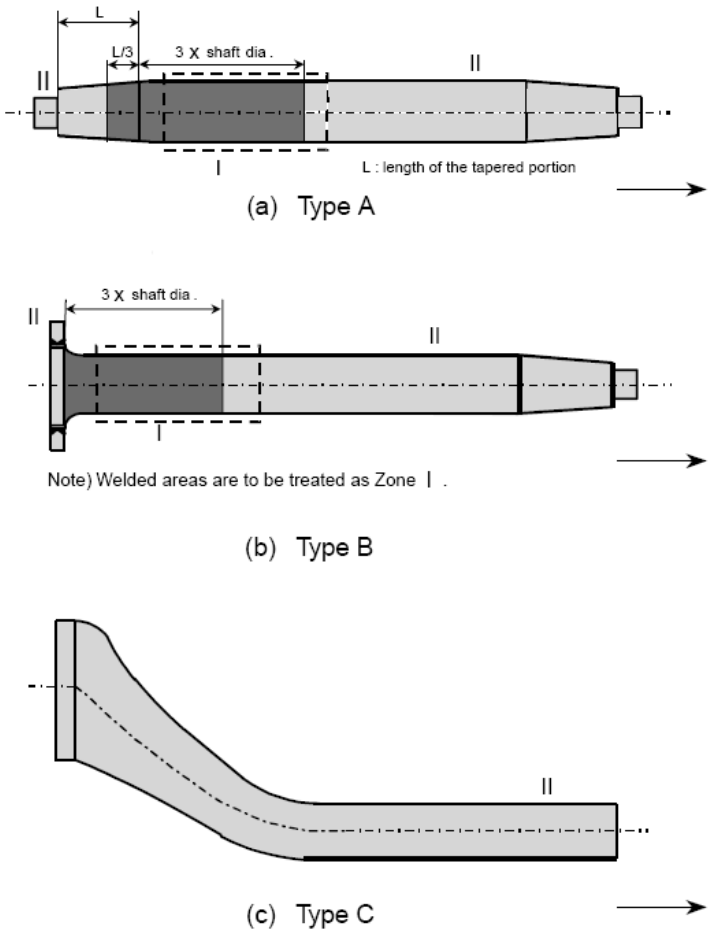
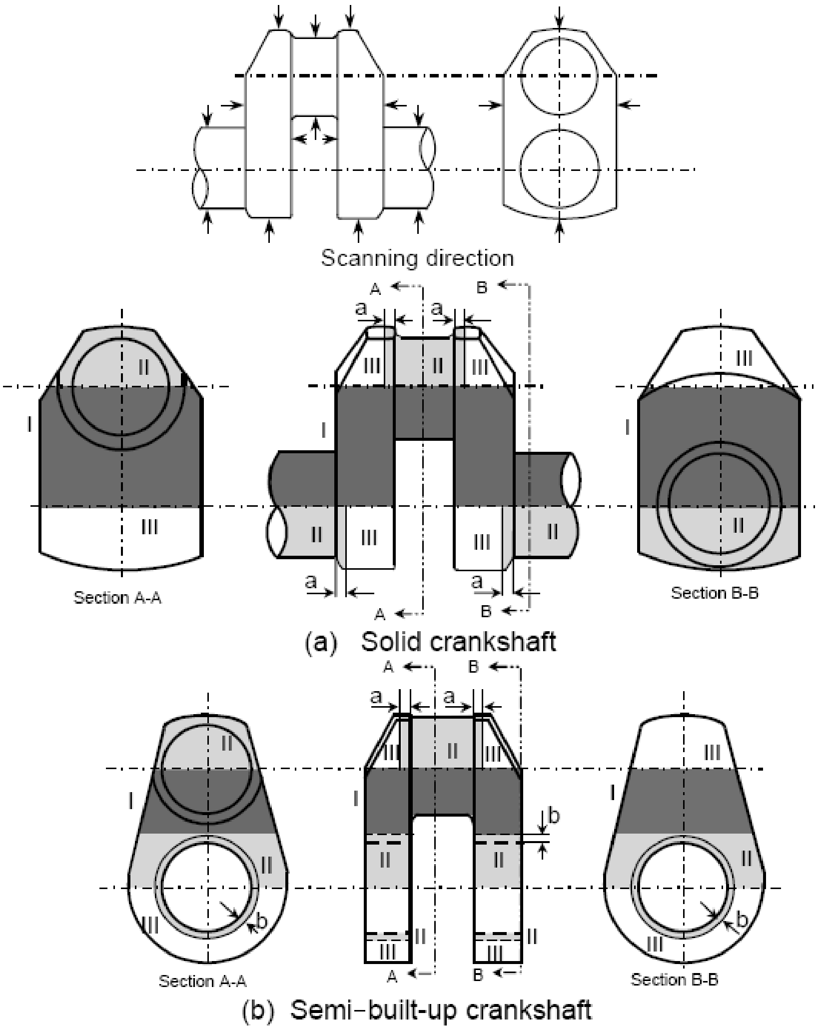
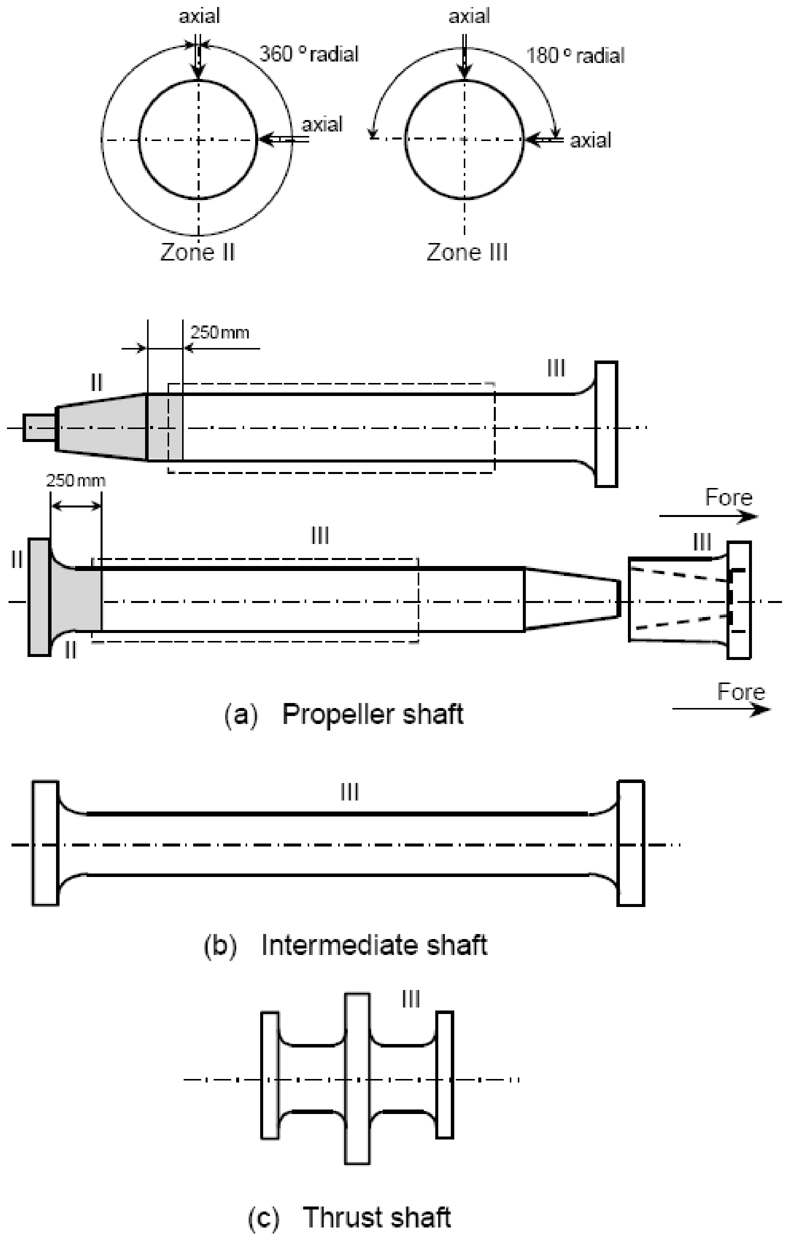


Figure 7A.4.3(4) Zones for magnetic particle/liquid penetrant testing on rudder stocks



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

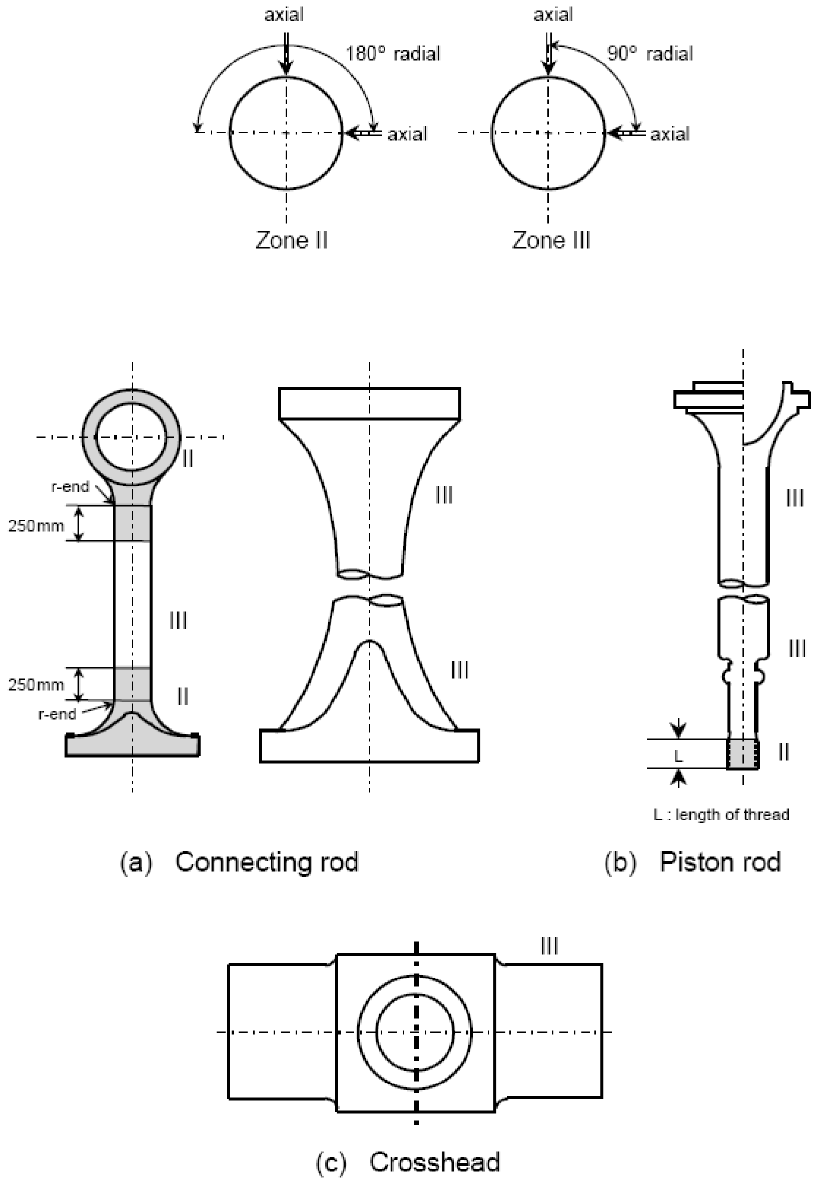


Figure 7A.5.3(3) Zones for ultrasonic testing on machinery components

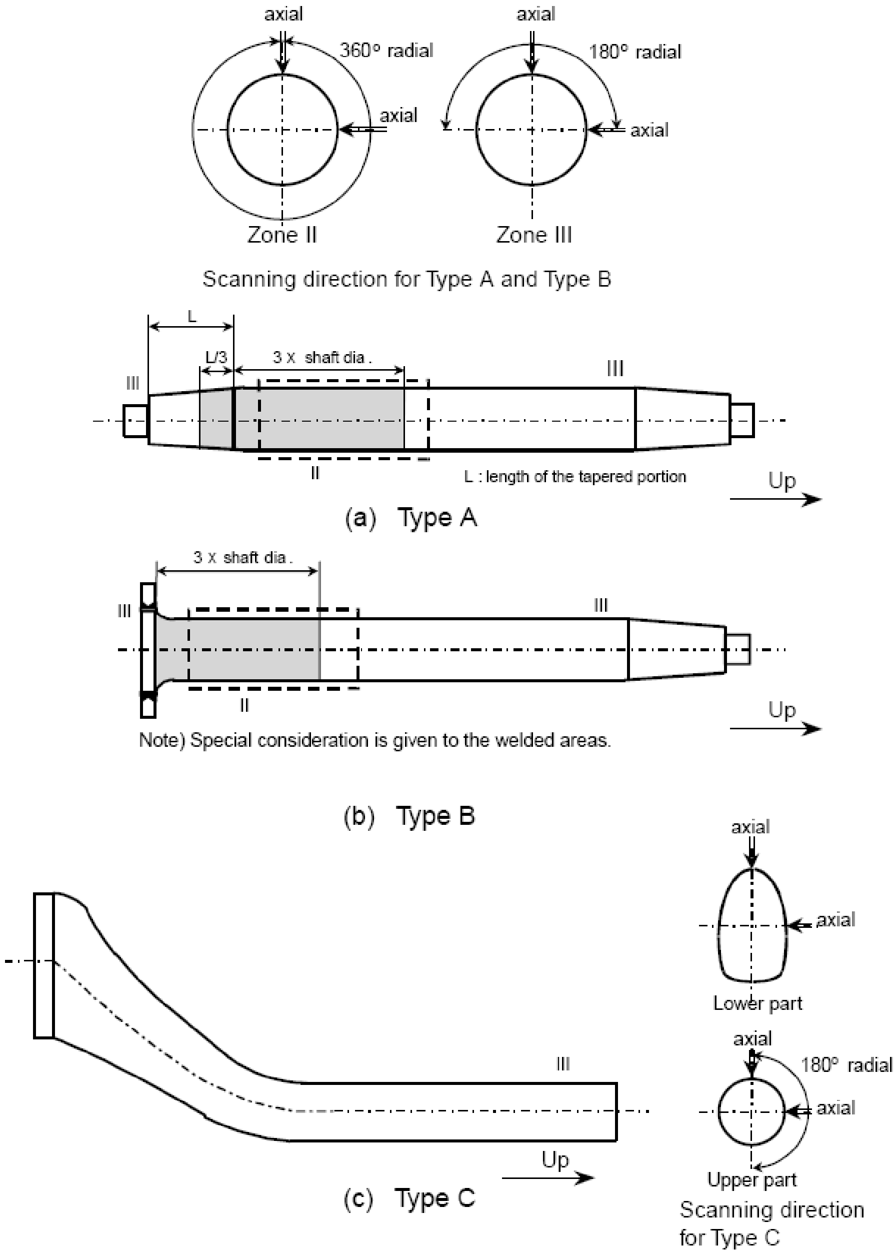


Figure 7A.5.3(4) Zones for ultrasonic testing on rudder stocks

Appendix 7B

Non-Destructive Testing of Hull and Machinery Steel Castings

7B.1 Application

7B.1.1 This Appendix applies to the non-destructive testing of hull and machinery 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 and service conditions.

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.

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.3 Preparation for inspections and visual examination

7B.3.1 Steel castings are to be subjected to a 100% visual examination.

7B.3.2 Prior to inspection, forgings are to be cleaned to remove all sand fusions, scales, oil, rust, grease and other impurities and contaminants that will affect the inspection.

7B.3.3 The visual examination may be carried out in accordance with the relevant requirements of Section 3 of this Chapter.

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.

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). Criteria for the examination of other castings not listed in this paragraph will 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 Where castings are to be machined, NDT is to be carried out in their final machined surface condition. The magnetic particle test may be carried out within following allowance:

0.3 mm in the final machined surface condition for AC techniques, or

0.8 mm in the final machined surface condition for DC techniques.

7B.4.5 Non-destructive surface inspections may be carried out in accordance with Section 6 or 7 of this

Chapter.

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 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.

Acceptance criteria for surface testing of castings **Table 7B4.6**

Inspection zone	Max. number of indications	Type of indication①	Max. number for each type②	Max. dimension of single indication③
Fabrication weld preparation and weld repairs	4	Linear Nonlinear Aligned	4 4 4	3 mm^2 5 mm^2 3 mm^2
Locations other than welds	20	Linear Nonlinear Aligned	6 10 6	5 mm^2 7 mm^2 5 mm^2

Notes: ① Linear indication means an indication in which the length is at least three times the width; nonlinear indication means an indication of circular or elliptical shape with a length less than three times the width; aligned indication means three or more indications in a line, separated by 2 mm or less edge-to-edge.

② The minimum dimension between relevant indications is 30 mm.

③ 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. Radiographic testing may be carried out on the basis of prior agreement with CCS.

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. 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 without evidence of intervening defects is to be corrected. Attenuation in excess of 30 dB/m could be indicative of an unsatisfactory annealing heat treatment or defects such as dispersed shrinkage and is to be noted in the test report.

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 (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;
(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.

7B.5.6 The reference sensitivity of ultrasonic testing is to be established against a 6 mm diameter disk 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.

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 reference level as shown by the DGS curve is to be marked for additional scans with angle probes in order that the extent and location of the discontinuity can be plotted.

7B.6 Evaluation of defects detected by ultrasonic testing

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;
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.6(1) to (5) 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;
discontinuities within the examined zones interpreted to be cracks or hot tears.

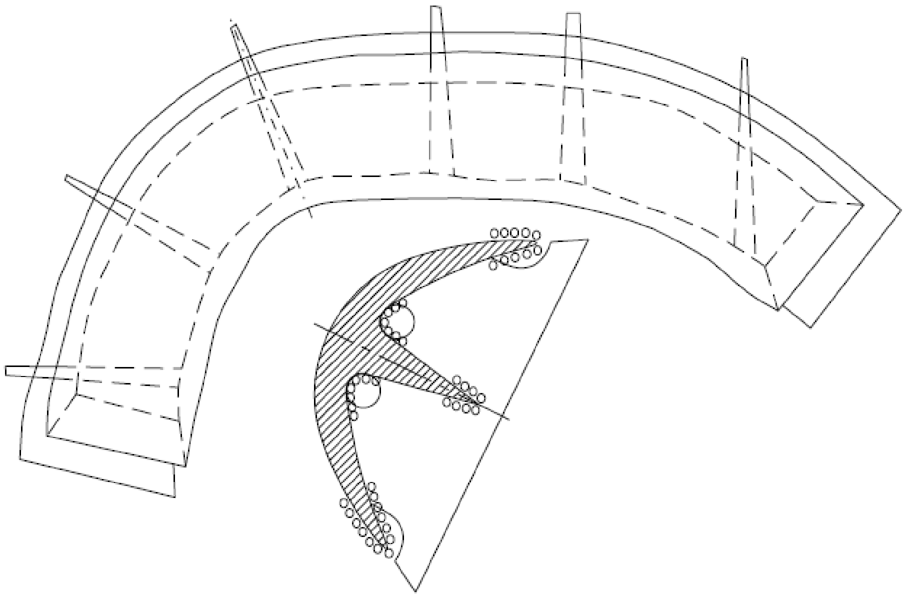
7B.6.2 The acceptance criteria for ultrasonic testing of different zones are to be in accordance with Table 7B.6.2.

Acceptance criteria for ultrasonic testing of steel castings **Table 7B.6.2**

Inspection zone	Allowable disc shape according to DGS (mm)	Max. number of indications to be registered①	Allowable length of linear indications (mm)②
UT1	> 6	0	0
UT2	12 ~ 15	5	50
	> 15	0	0

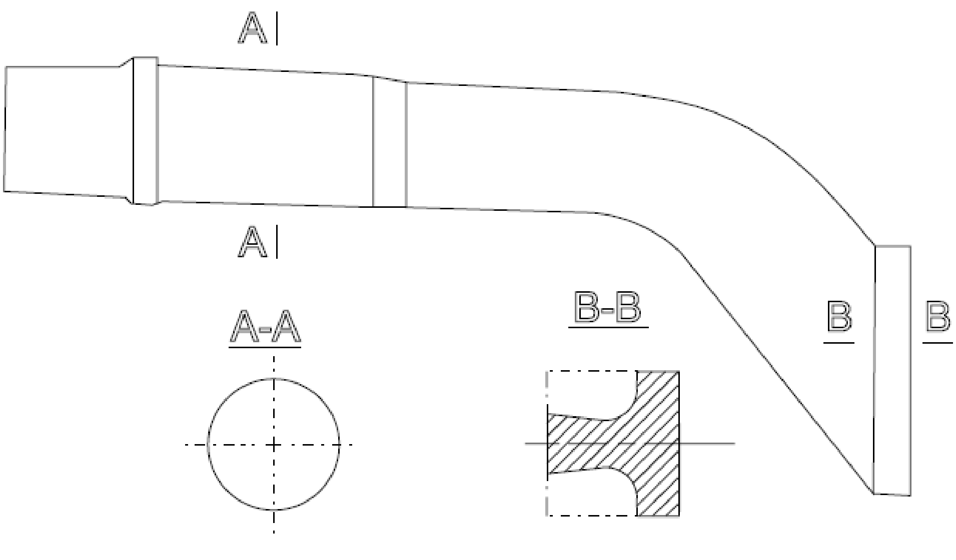
Notes: ① Grouped in an area measuring 300 × 300 mm.
② Measured on the scanning surface.

7B.6.3 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.



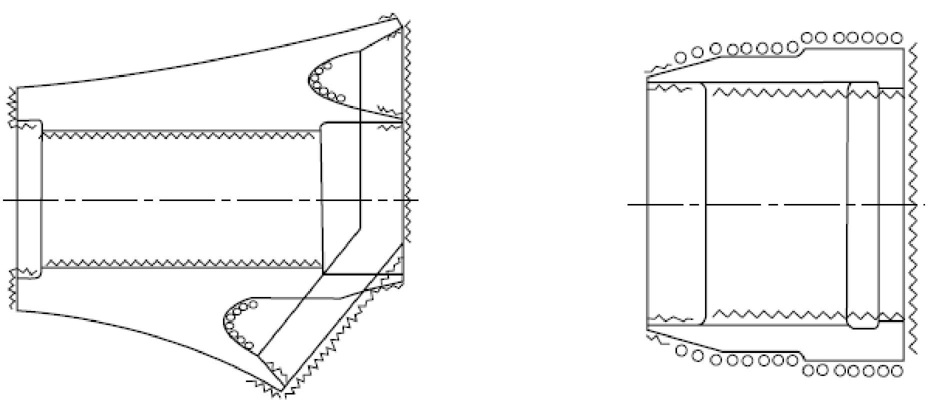
Notes: 1. All surfaces are to be visually examined.
2. Locations indicated with "O" are to be subjected to magnetic particle and ultrasonic testing.

Figure 7B4.2(1) Inspection zones of stern frame



All supporting surfaces are to be subjected to visual examination, magnetic particle and ultrasonic testing

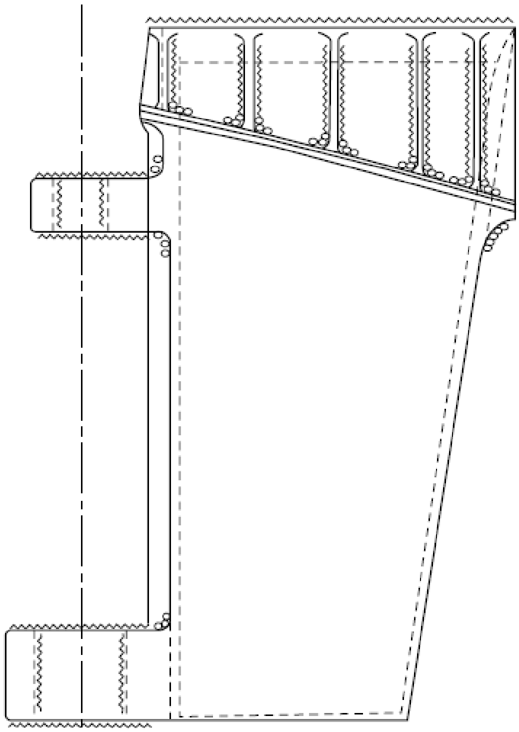
Figure 7B4.2(2) Inspection zones of rudder stock



Notes: 1. All surfaces are to be visually examined.

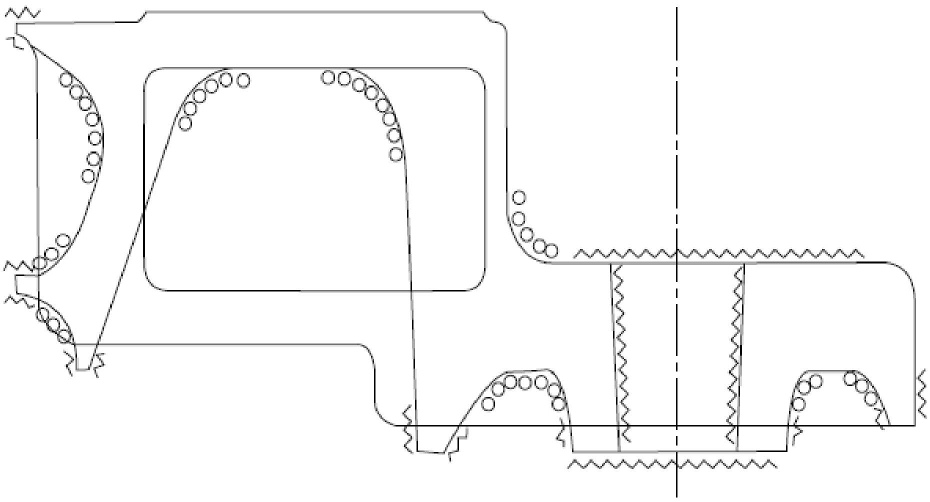
2. Locations indicated with “O” are to be subjected to magnetic particle and ultrasonic testing.
3. Locations indicated with “∧∧” are to be subjected to ultrasonic testing.

Figure 7B4.2(3) Inspection zones of stern boss



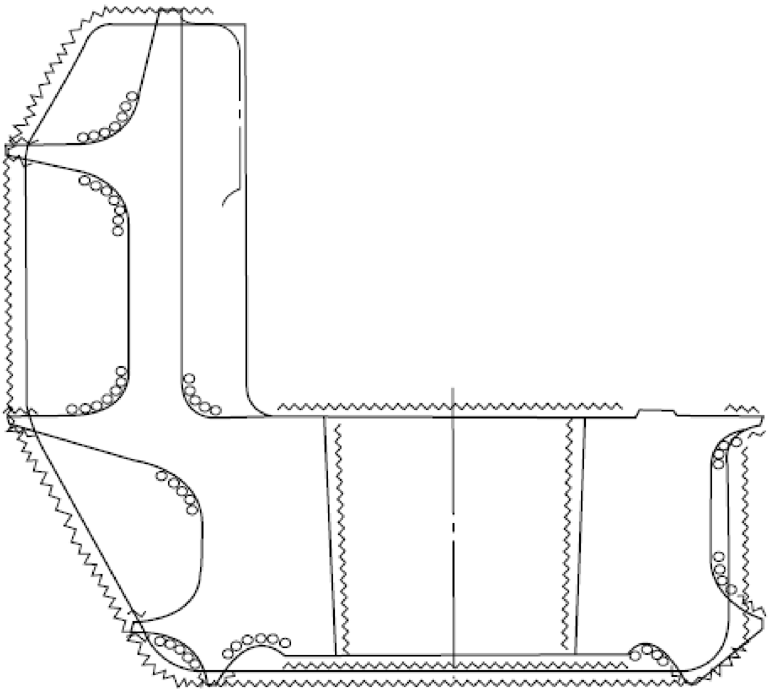
Notes: 1. All surfaces are to be visually examined.
2. Locations indicated with “O O” are to be subjected to magnetic particle and ultrasonic testing.
3. Locations indicated with “∧∧” are to be subjected to ultrasonic testing.
4. Inspection zones are fabrication weld preparations for a distance of 50 mm from the edge and surface areas of both components having relative movements when fitted up.

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.

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.

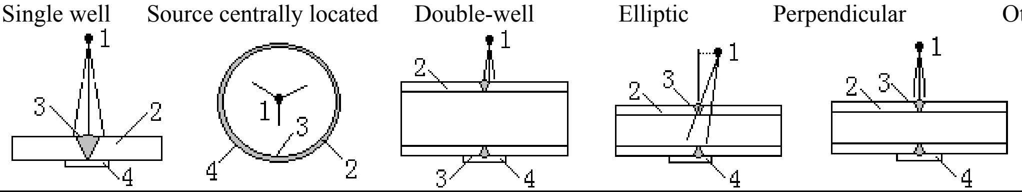
3. Locations indicated with “⋀⋀” are to be subjected to ultrasonic testing.

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.：

<table>
<tr><td>委托单位
Client</td><td colspan="2"></td><td>工程名称/编号
Project name/No.</td><td colspan="2"></td></tr>
<tr><td>构件名称
Component name</td><td colspan="2"></td><td>检测部位
Test location</td><td colspan="2"></td></tr>
<tr><td>钢材等级/材质
Steel grade /Material</td><td colspan="2"></td><td>产品类型
Type of production</td><td colspan="2">☐铸件 ☐锻件 ☐焊接件 ☐母材
Castings forging welding base metal</td></tr>
<tr><td>焊接方法/接头形式
Welding process/joints</td><td colspan="2"></td><td>母材厚度/规格
Thickness
/Specification</td><td colspan="2"></td></tr>
<tr><td>射线源型号/编号
Radiation source type/S.N.</td><td></td><td>射线源活度
Radiation source activity</td><td></td><td>检测技术等级
Level of test technique</td><td></td></tr>
<tr><td>管电压
Tube voltage</td><td></td><td>管电流
Tube current</td><td></td><td>曝光时间
Exposure time</td><td></td></tr>
<tr><td>焦点尺寸
Focus spot size</td><td></td><td>焦距
Focus-to-film distance</td><td></td><td>像质计类型/位置
IQI Type/Position</td><td></td></tr>
<tr><td>胶片类型
Film type</td><td></td><td>增感屏类型/厚度
Intensifying type/Thickness</td><td></td><td>有效评定长度
Availability length</td><td></td></tr>
<tr><td>检测时机
Test time after welding</td><td></td><td>几何不清晰度
Geometric un-sharpness (Ug)</td><td></td><td>黑度范围
Density range</td><td></td></tr>
<tr><td>检测标准
Test standard</td><td></td><td>验收标准和级别
Acceptance levels</td><td></td><td>检测比例/数量
Spot-test rate/
Total quantity</td><td></td></tr>
<tr><td>其他报告事项
Other items</td><td colspan="5"></td></tr>
<tr><td colspan="6">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 ☐其它
Single well Source centrally located Double-well Elliptic Perpendicular Other
</td></tr>
<tr><td colspan="6">检测结论：
Statement of test results</td></tr>
<tr><td>审核人员(级别)
Auditing (level)</td><td>( )</td><td>检验人员(级别)
Inspector (level)</td><td>( )</td><td>检测日期
Test date</td><td></td></tr>
</table>

注：1、其他报告事项，指检测限制条件、观察条件、温度、返修次数等事项（如有时）。
2、检测位置示意图另附

Notes: 1.Other items refer to any test limitations, viewing conditions, temperature and repair 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	母材厚度 Thickness (mm)	像质指数 IQI index	缺陷性质 Defect type	缺陷位置 Defect location	评级 Level	合格/ 不合格 Acc. / Rej.	备注 Remark
缺陷性质代号 Defect type: A-无缺陷 no defect　S-夹渣 slag　P-气孔 porosity　C-裂纹 crack U-咬边 undercut　L-未熔合 lack of fusion　I-未焊透 incomplete penetration								
“备注”栏：R1-返修一次，R2-返修两次，另外视客户需要填写 Remark：　Repair once,　Repair twice,　Client required								

超声波检测报告
Ultrasonic Test Report

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 castings forging welding base metal
焊接方法/接头形式 Welding process/joints		母材厚度/规格 Thickness /Specification	

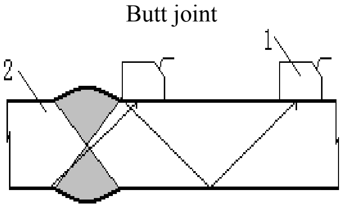
检测时机 Test occasion		表面状况 Surface status		检测部位温度 Test location temp.	℃
仪器型号和编号 Unit type / Reg. No.		耦合剂 Coupling		检测灵敏度 Sensitivity	
检测技术等级 Level of test technique		标准/对比试块 Sta. /Cal. block		传输修正 Transfer correction	dB
检测标准 Test standard		验收标准和级别 Acceptance levels		检测比例/数量 Spot-test rate/ Total quantity	/

	探头规格 Probe type	探头编号 Reg. No.	频率 Frequency	晶片尺寸 Crystal size	实测折射角度 Actual angle of refraction	基准灵敏度 Sensitivity levels calibrated
探头 Probes			MHz			
			MHz			
			MHz			

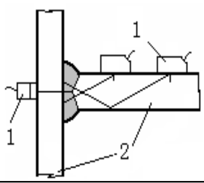
其他报告事项 Other items	

超声检测布置图 Sketch：（图示说明：1-探头 Probes，2-构件 Component）

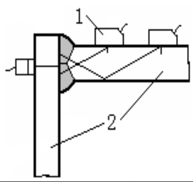
□平对接
Butt joint



□T 型角接
T joint



□C 型角接
C joint



□其它
Others

检测结论：
Statement of test results

审核人员(级别) Auditing (level)	( )	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、返修次数等事项（如有时），
2、检测位置示意图另附
Notes: 1. Other items refer to any test limitations, viewing conditions, and repair etc. (if any).
2. The sketch of test positions is attached.

超声波检测报告
Ultrasonic Test Report

序号 NO.	构件或焊缝编号 Part or weld film No.	检测厚度 Thickness. (mm)	缺陷编号 Defect No.	实测折射角 Actual angle of refraction	缺陷当量 Defect equivalent (dB)	L mm	X mm	Y mm	H mm	评级 Class	合格/不合格 Acc./Rej.	备注 Remark

注：
Notes:
1 X：距基准点距离 distance to the base point
Y：缺陷距焊缝中心距离 distance from the defection to the welded seam center
H：缺陷深度距离 defect depth
L：缺陷指示长度 defect indicating length.

2“备注”栏：R1-返修一次， R2-返修两次，另外视客户需要填写
Remark: Repair once, Repair twice, Client required

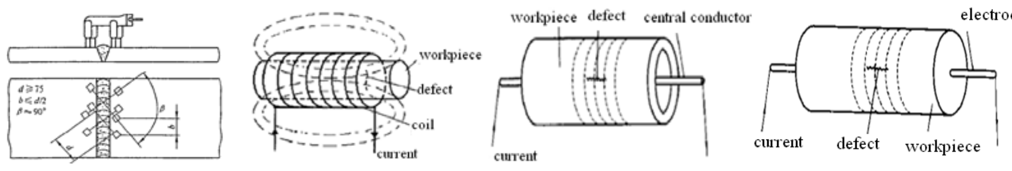
磁粉检测报告
Magnetic Particle Test Report

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 castings 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 Test occasion		表面状况 Surface status		检测部位温度 Test location temp.	
仪器型号和编号 Unit type / Reg. No.		磁悬液类型 Type of magnetic particle		磁悬液浓度 Magnetic density	
检测方法 Test technique	☐连续 Continuous ☐剩磁 Residual	☐荧光 Fluorescent ☐非荧光 Un-fluorescent	☐干法 Dry ☐湿法 Wet		
反差增强剂 White Contrast		磁化电流/提升力 Current / Power		灵敏度试片 Sensitivity indicator	
磁化时间 Magnetization time		退磁 Demagnetization		观察条件 Viewing condition	
检测标准 Test standard		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 ☐轴向通电法 axial current flow ☐其它 other



检测结论：
Statement of test results

审核人员(级别) Auditing (level)	( )	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、返修次数等事项（如有时）
2、检测位置示意图另附

Notes: 1.Other items refer to any test limitations, viewing conditions and temperature (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 film No	检测长度 (mm) Inspected length	缺陷编号 Defect No	X (mm)	缺陷性质 Defect type	缺陷尺寸 Defect length (mm)	评级 Class	合格/不合格 Acc. / Rej.	备注 Remark

缺陷性质代号 Defect type: A-无缺陷 no defect S-夹渣 slag P-气孔 porosity
C-裂纹 crack U-咬边 undercut L-未熔合 lack of fusion
X：距基准点距离 distance to the base point

“备注”栏：R1-返修一次，R2-返修两次，另外视客户需要填写
Remark： Repair once, Repair twice, Client 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 Type of production	☐铸件 castings ☐锻件 forging ☐焊接件 welding ☐母材 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 Test time after welding		表面状况 Surface status		检测部位温度 Test location temp.	
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 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 Test standard		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					

审核人员(级别) Auditing(level)	( )	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、返修次数等事项（如有时）.
Note: 1. Other items refer to any test limitations and repair 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 film No	检测长度 Inspected length (mm)	缺陷编号 Defect No.	X (mm)	缺陷性质 Defect type	缺陷尺寸 Defect size (mm)	评级 Class	合格 不合格 Acc. / Rej.	备注 Remark

缺陷性质代号 Defect type: A-无缺陷 no defect S-夹渣 slag P-气孔 porosity C-裂纹 crack
U-咬边 undercut L-未熔合 lack of fusion
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“备注”栏：R1-返修一次，R2-返修两次，另外视客户需要填写
Remark： Repair once, Repair twice, Client required