CHINA CLASSIFICATION SOCIETY

RULES FOR MATERIALS AND WELDING

RULE CHANGE NOTICE NO.2

2020

Effective from 1 January 2021

Revision explanation

1. Blue underline is to highlight new insertions, strikethrough line is to highlight deleted contents and cross line may be used to highlight deleted tables or figures.

2. No change in the English text means that only Chinese text is editorially revised while the change of corresponding English version is not needed.

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PART ONE METALLIC MATERIALS

CHAPTER 6 STEEL CASTINGS

Section 5 STEEL CASTINGS FOR PROPELLERS[1]

6.5.2 Chemical composition

6.5.2.1 The chemical composition of ladle samples for castings for carbon and carbon-manganese steel propellers is to be in accordance with the requirements given in Table 6.5.2.1 of this Section.

Chemical Composition of Castings for Carbon and Carbon-Manganese Steel Propellers

Table 6.5.2.1

Steel type	Chemical composition (%)								
	C	Si	Mn	P	S	Residual elements①			
						Ni	Cr	Mo	Cu
Carbon and carbon-manganese steel	≤ 0.25	≤ 0.60	0.50~1.60	≤ 0.04	≤ 0.04	≤ 0.40	≤ 0.30	≤ 0.15	≤ 0.30

Note: ① The total content of residual elements is to be not more than 0.80%.

6.5.2.2 The chemical composition of ladle samples for castings for stainless steel propellers is to be in accordance with the requirements given in Table 6.5.2.2 of this Section~~,~~. Cast steel whose chemical composition deviate from the typical values of the Table below must be specially approved by CCS.

6.5.4 Mechanical properties

6.5.4.1 At least one test sample is to be taken from material representing each casting. Where a number of propeller castings of the same size, and less than 1 m in diameter are made from one cast and heat treated in the same furnace charge, the thickness of test coupon is to be in accordance with a recognized standard, at least one test sample of suitable dimensions is to be provided for each multiple of five castings in the batch.

6.5.5 Inspections

6.5.5.2 All propellers are subject to non-destructive testing. Minor casting defects such as small sand and slag inclusions, small cold shuts and scabs are to be trimmed. Casting defects which may impair the serviceability of the castings, e.g. major non-metallic inclusions, shrinkage cavities, blow holes and cracks are to be removed by a proper method. The categorization of important portions of the propellers and the corresponding non-destructive testing are to comply with the provisions given in 8.4.2 and 8.4.3, Section 4 of Chapter 8 in PART THREE of the Rules.

6.5.5.3 ~~The dimensions of the propellers are to be the responsibility of the manufacturer and the report on the dimensional inspection is to be handed over to the Surveyor for confirmation in his presence.~~ The dimensions, geometrical tolerances and surface roughness are to be checked by the manufacturer and the report on the dimensional inspection is to be handed over to the Surveyor, who may require checks to be made in his presence. The inspection results are to be in accordance with the approved drawings.

6.5.6 Identification and certification

6.5.6.1 Each casting is to be suitably identified by the manufacturer with the following:

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

b) CCS certificate number;

c) Grade of cast material or corresponding abbreviated designation;

~~e~~d) ice class symbol, where applicable;

~~d~~e) skew angle for high skew propellers;

~~e~~f) date of final inspection;

~~f~~g) CCS stamp is to be put on when the casting has been accepted.

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[1] This content will take effect on 1 July 2021.

CHAPTER 9 OTHER NON-FERROUS MATERIALS

Section 1 COPPER ALLOY PROPELLERS[2]

9.1.3 Chemical composition

9.1.3.1 The chemical composition of copper alloy propellers and their components is generally to be as given in Table 9.1.3.1. For chemical composition of alloys other than those given in Table 9.1.3.1, the related information (including chemical composition, heat treatment procedure, mechanical properties and seawater corrosion resistance) is to be submitted, which may be accepted in accordance with relevant recognized standards subject to agreement of CCS.

Typical Chemical Composition of Copper Alloy Propellers **Table 9.1.3.1**

Copper alloy	Chemical composition (%)							
Type	Cu	Al	Mn	Zn	Fe	Ni	Sn	Pb
Grade 1 manganese bronze (C~~u~~U1)	52 ~ 62	0.5 ~ 3.0	0.5 ~ 4.0	35 ~ 40	0.5 ~ 2.5	≤ 1.0	≤ 1.5	≤ 0.5
Grade 2 Ni-manganese bronze (C~~u~~U2)	50 ~ 57	0.5 ~ 2.0	1.0 ~ 4.0	33 ~ 38	0.5 ~ 2.5	3.0 ~ 8.0	≤ 1.5	≤ 0.5
Grade 3 Ni-aluminum bronze (C~~u~~U3)	77 ~ 82	7.0 ~ 11.0	0.5 ~ 4.0	≤ 1.0	2.0 ~ 6.0	3.0 ~ 6.0	≤ 0.1	≤ 0.03
Grade 4 Mn-aluminum bronze (C~~u~~U4)	70 ~ 80	6.5 ~ 9.0	8.0 ~ 20.0	≤ 6.0	2.0 ~ 5.0	1.5 ~ 3.0	≤ 1.0	≤ 0.05

9.1.3.2 For alloys Grades C~~u~~U1 and C~~u~~U2, the proportions of α and β phases are to be determined by the manufacturer. The proportion of α phase is to be not less than 25% and that of β phase is to be kept low so as to ensure adequate cold ductility and corrosion fatigue resistance.

9.1.3.3 In order to ensure the proportions of α phase in microstructure of C~~u~~U1 and C~~u~~U2, zinc equivalent of copper alloy is not to exceed 45%. Zinc equivalent is to be defined by the following formula:

$$\text{Zinc equivalent} = 100 - \frac{100 \times \text{Cu}\%}{100 + A} \quad (\%)$$

where: $A = 1\times\text{Sn}\% + 5\times\text{Al}\% - 0.5\times\text{Mn}\% - 0.1\times\text{Fe}\% - 2.3\times\text{Ni}\%$.

Where the proportion of α phase is or above 25%, the zinc equivalent may not be required.

9.1.4 Manufacture and heat treatment

9.1.4.4 For castings of propellers or their components, subsequent stress relieving heat treatment may be performed to reduce the residual stresses. A specification containing the details of the heat treatment is to be submitted to CCS for examination. For stress relieving temperatures and soaking time, see Table 9.1.4.4.

[2] This content will take effect on 1 July 2021.

Soaking Times for Stress Relief Heat Treatment of Copper Alloy Propellers **Table 9.1.4.4**

Alloy grade / Soaking time; Stress relief temperature (℃)	CuU1 and CuU2		CuU3 and CuU4	
	Hours per 25 mm thickness (h)	Max. recommended total time hours (h)	Hours per 25 mm thickness (h)	Max. recommended total time hours (h)
350	5	15	-	-
400	1	5	-	-
450	1/2	2	5	15
500	1/4	1	1	5
550	1/4①	1/2①	1/2②	2②
600	–	–	1/4②	1②

Notes: ① Applicable to CuU2 alloys.
② Applicable to CuU4 alloys only.

9.1.5.6 Where test specimens are to be taken from integrally cast test samples, this is to be the subject of special agreement with CCS. Wherever possible, the test samples are to be located on the blades in an area lying between 0.5 to 0.6 R, where R is the radius of the propeller. The test sample material must be removed from the casting by non thermal procedures.

9.1.6 Testing and inspections

9.1.6.2 Samples for metallographic examination are to be prepared from every melt of Grades CuU1 and CuU2 alloys. The proportion of α phase determined from the average of 5 counts is to comply with the requirements of 9.1.3.2.

9.1.6.3 The tensile strength, 0.2% proof strength and elongation are to be determined by mechanical tests. Test results of test specimens taken from separately cast samples are to comply with the values given in Table 9.1.6.3. For integrally cast test specimens the mechanical characteristics are to be specially agreed with CCS.

Mechanical Properties of Copper Propeller Castings **Table 9.1.6.3**

Type of coppery alloy	Proof strength $R_{p0.2}$ N/mm^2	Tensile strength R_m N/mm^2	Elongation A_5 (%)
Grade 1 manganese bronze (CuU1)	≥ 175	≥ 440	≥ 20
Grade 2 Ni-manganese bronze (CuU2)	≥ 175	≥ 440	≥ 20
Grade 3 Ni-aluminum bronze (CuU3)	≥ 245	≥ 590	≥ 16
Grade 4 Mn-aluminium bronze (CuU4)	≥ 275	≥ 630	≥ 18

9.1.7.2 Each satisfactorily inspected propeller casting is to be provided with a marine product certificate or equivalent document containing the following details:
a) purchaser's name and order number;
b) ship's name, if known;
c) description of the casting with drawing number;
d) diameter, number of blades, pitch, direction of turning;
e) skew angle for high skew propellers;
f) final weight;
g) alloy type, heat number and chemical composition;
h) heat or casting number;
i) casting identification number;
j) method and results of non-destructive testing;
k) results of mechanical tests;
l) proportion of α phase in metallographic examination (for CuU1 and CuU2 alloys only).

PART THREE WELDING

CHAPTER 4 QUALIFICATION TESTS OF WELDERS[3]

Section 1 GENERAL PROVISIONS

4.1.1 Application

4.1.1.1 The requirements of this Chapter apply to the qualification tests of welders intended to be engaged in the fusion welding (including shielded metal arc welding, semi-automatic welding and TIG welding) of ship structures, offshore structures, machinery, boilers and pressure vessels as well as piping with carbon steels, carbon-manganese steels, alloy steels or aluminum alloys as the base metal.Notes

Notes: ① The requirements of this Chapter apply to applications for welder or welding operator qualification (initial or renewal) dated on or after 1 January 2018.

② The requirements of this Chapter do not invalidate welder's qualifications issued and accepted by CCS before 1 January 2018. These qualifications are to be renewed in accordance with the requirements of this Chapter latest by 31 December 2020.

③ Certificates that expire on or after 1 January 2022~~18~~ are to be renewed in accordance with the requirements of this Chapter.

④ The welder's or welding operator's qualifications which have not been required before 1 January 2018, are to be initially issued in accordance with the requirements of this Chapter by the 31 December 2020 at the latest.

4.1.2 General requirements

4.1.2.4 Welders or welding operators qualified in accordance with national or international welder qualification standards may also be engaged in welding of hull structures and relevant products at the discretion of CCS provided that the qualification testing, range of approval and revalidation requirements are considered equivalent to the requirements of this Chapter. Alternative welding Standards or Codes are to be applied in full, cross-mixing requirements of Standards and Codes is not permitted.

4.1.7 Validity of the qualification

4.1.7.3 If any of these conditions is not fulfilled, CCS is to be informed and the certificate is to be cancelled. The validity of the certificate may be maintained in agreement with CCS if the maintenance scheme of qualification is in accordance with either one of 4.1.7.4. Even if the requirements stipulated in the standards are applied, the requirement for revalidation of welders' qualification is to be in accordance with 4.1.7.4.

4.1.7.4 Except that the Qualification Certificate of Welder for tact welding is valid for an unlimited period, revalidation is to be carried out by CCS for the Qualification Certificate of all welders. The skill of the welder is to be periodically verified by one of the following:

(1) The welder is to be re-tested every 3 years.

(2) Every 2 years, two welds made during the last 6 months of the 2 years validity period are to be tested by radiographic or ultrasonic testing or destructive testing and are to be recorded. The welds tested are to reproduce the initial test conditions except for the thickness. These tests revalidate the welder's qualifications for an additional 2 years.

(3) A welder's qualification for any certificate is to be valid as long as it is signed according to 4.1.7.2 subject that all the following conditions are fulfilled. In this option, the fulfillment of all the conditions is to be verified by CCS. The frequency of verification by CCS is to be no longer than 3 years and is to be agreed between CCS and the shipyards/manufacturers.

① The welder is working for the same shipyard/manufacturer which is responsible for production weld quality as indicated on his or her qualification certificate.

② CCS is to verify that the welder quality management system of the shipyard/manufacturer includes as minimum:

- A designated person responsible for the coordination of the welder quality management system;
- List of welders and welding supervisors in shipyard/manufacturer;
- If applicable, list of subcontracted welders ;
- Qualification certificate of welders and description of the associated management system;

[3] This content will take effect on 1 January 2022.

- Training requirements for welder qualification programme;
- Identification system for welders and WPS used on welds;
- Procedure describing the system in place to monitor each welder performance (Results of welds examination records).

③ The shipyards/manufacturers have to document at least once a year that the welder has produced acceptable welds in accordance with construction quality standards and CCS' requirements, which should be in agreement between CCS and the shipyards/manufacturers.

CHAPTER 8 WELDING OF IMPORTANT MACHINERY COMPONENTS

Section 4 NON-DESTRUCTIVE INSPECTION AND WELD REPAIRS OF PROPELLERS[4]

8.4.2 Skew angle of a propeller and division of its severity zones

8.4.2.1 The skew of a propeller is described by the skew angle of the propeller blade. The maximum skew angle of a propeller blade is defined as the angle, in projected view of the blade, between a line drawn through the blade tip and the shaft centerline and a second line through the shaft centerline which acts as a tangent to the locus of the midpoints of the helical blade sections (see Figure 8.4.2.1). High skew propellers have a skew angle greater than 25°, low skew propellers a skew angle of up to 25°.

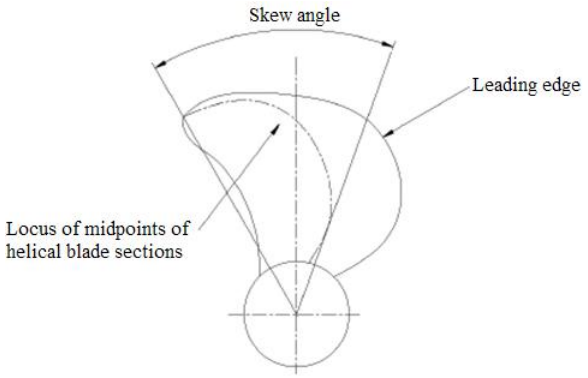

Figure 8.4.2.1 Definition of Skew Angle

8.4.2.2 In order to relate the degree of inspection to the criticality of defects in the propeller blade and to help reduce the risk of failure by fatigue cracking after repair, the propeller blade is divided into the three zones designated A , B and C:

(1) Zone A is the region carrying the highest operating stresses and which, therefore, requires the highest degree of inspection. Generally, the blade thicknesses are greatest in this area giving the greatest degree of restraint in repair welds and this in turn leads to the highest residual stresses in and around any repair welds. High residual tensile stresses frequently lead to fatigue cracking during subsequent service so that relief of these stresses by heat treatment is essential for any welds made in this zone.

(2) Zone B is a region where the operation stresses may be high.

(3) Zone C is a region in which the operation stresses are low and where the blade thicknesses are relatively small.

8.4.3 Non-destructive inspections

8.4.3.1 Qualification of personnel involved in non-destructive inspections refer to Annex 1 in PART THREE.

8.4.3.2 All finished castings are to be 100% visually inspected by the manufacturer. Castings are to be free from cracks, hot tears or other imperfections which, due to their nature, degree or extent, will interfere with the use of the castings. A general visual examination is to be carried out by the CCS Surveyor.

8.4.3.~~1~~3 Surfaces of all finished propeller castings are subject to non-destructive inspections in accordance with the three zones specified in 8.4.2.3 and 8.4.2.4. The inspections of zone A are generally to be carried out in the presence of the Surveyor, while the inspections of zones B and C may be witnessed by the Surveyor upon his request.

8.4.3.~~2~~4 Surface inspections of propellers are generally to be carried out as ~~dye~~liquid penetrant inspections. The ~~dye~~liquid penetrant inspection is to be carried out in accordance with ISO 3452-1~~a standard~~ or specification approved by CCS. The acceptance criteria are specified in 8.4.3.5-8.4.3.7. Magnetic particle examination is not applicable to copper and austenitic stainless steel propellers. Magnetic particle testing procedure is to be submitted to CCS and is to be in accordance with ISO 9934-1 or a recognized standard.

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[4] This content will take effect on 1 July 2021.

8.4.3.~~3~~5 In the ~~dye~~liquid penetrant inspection, an indication is the presence of detectable bleed-out of the penetrant liquid from the material discontinuities appearing at a time as recommended by the dye liquid manufacturer or at least 10 minutes after the developer has been applied.

8.4.3.~~4~~6 For the judgment, the surface to be inspected is to be divided into square or rectangular (with the major dimension not exceeding 250 mm) reference areas of 100 cm^2. The area is to be taken in the most unfavourable location relative to the indication being evaluated.

8.4.3.~~5~~7 A distinction is made between ~~circular,~~ non-linear, linear and aligned ~~dye~~liquid penetrant indications, as shown in Figure 8.4.3.~~5~~7. The indications detected are, with respect to their size and number, not to exceed the values given in Table 8.4.3.~~5~~7.

Indication: In the liquid penetrant testing an indication is the presence of detectable bleed-out of the penetrant liquid from the material discontinuities appearing at least 10 minutes after the developer has been applied.

Relevant indication: Only indications which have any dimension greater than 1.5mm shall be considered relevant for the categorization of indications.

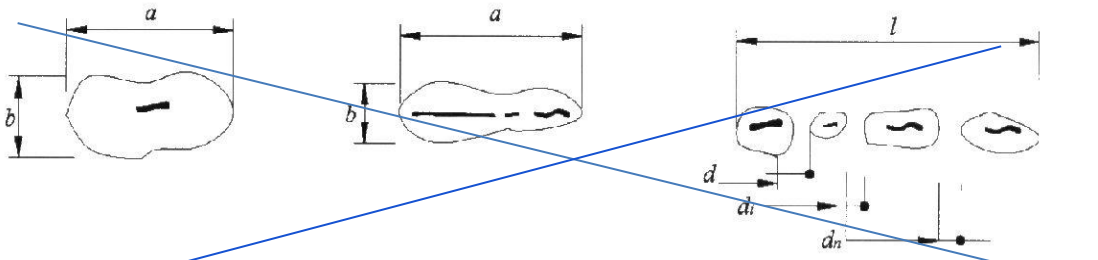
Non-linear indication: an indication with a largest dimension less than three times its smallest dimension.

Linear indication: an indication with a largest dimension three or more times its smallest dimension.

Aligned indications:

a) Non-linear indications form an alignment when the distance between indications is equal to or less than 2mm and at least three indications are aligned.

b) Linear indications form an alignment when the distance between two indications is same as or smaller than the length of the longest indication (l_{max}).



~~a/b<3~~ Circular | a/b≥3 Linear | number of indications≥3 and 0<d_i≤~~2~~ mm Aligned

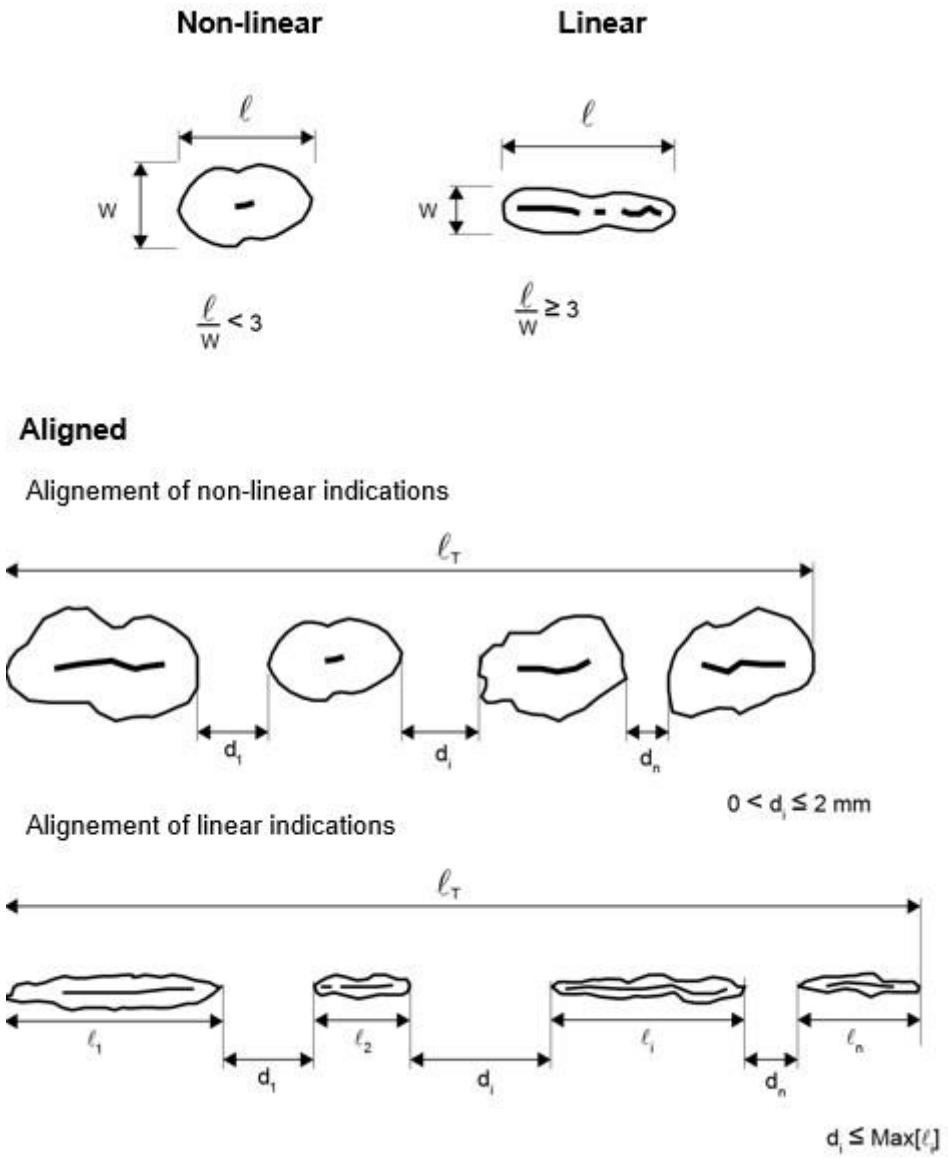


Figure 8.4.3.~~5~~7 Shape of Indications

Allowable Number and Size of Indications in a Reference Area Table 8.4.3.~~5~~7

Severity zone	Max. total number of indications	Indication type	Max. number for each type	Max. size of indication (mm)
A	7	~~Circular~~Non-linear indication	5	4
		Linear	2	3
		Aligned	2	3
B	14	~~Circular~~Non-linear indication	10	6
		Linear	4	6
		Aligned	4	6
C	20	~~Circular~~Non-linear indication	14	8
		Linear	6	6
		Aligned	6	6

Notes: ① Single ~~Circular~~non-linear indication indications less than 2 mm in zone A and less than 3 mm in other zones are not considered relevant.~~may be disregarded~~.

② The total number of ~~Circular~~non-linear indication indications may be increased to the maximum total number, or part thereof, represented by the absence of linear or aligned indications.

8.4.3.~~6~~8 Where serious doubt exists that the castings are not free from internal defects, radiographic and/or ultrasonic tests may be carried out upon request of the Surveyor. The acceptance criteria are then to be agreed between the manufacturer and CCS. For this purpose, the following are to be observed:
(1) due to the limited thicknesses that can be radiographed as well as for other practical reasons readiography is generally not a realistic method for checking of the thickest parts of large propellers;
(2) as a general rule, ultrasonic testing of stainless steel, C~~u~~U1 and C~~u~~U2 is not feasible due to the high damping capacity of these materials. For C~~u~~U3 and C~~u~~U4, ultrasonic inspection of subsurface defects is possible.
(3) due to the attenuating effect of ultrasound within cast copper alloys and austenitic steel castings, ultrasonic testing may not be practical in some cases, depending on the shape/type/thickness, and grain-growth direction of the casting. In such cases, effective ultrasound penetration into the casting should be practically demonstrated on the item. This would normally be determined by way of back-wall reflection, and/or target features within the casting.
8.4.3.~~7~~9 If repairs have been made either by grinding, straightening or by welding, the repaired areas are additionally to be subjected to the liquid penetrant testing independent of their location and/or severity zone. Weld repairs are, independent of their location, always to be assessed according to zone A.
8.4.3.~~8~~10 The foundry is to maintain records of inspections traceable to each casting. These records are to be confirmed by the Surveyor.

8.4.4 General requirements for repairs

8.4.4.4 After milling or chipping, grinding is to be applied for such defects which are not to be welded. Grinding is to be carried out in such a manner that the contour of the ground depression is as smooth as possible in order to avoid stress concentrations or to minimize cavitation corrosion. Complete elimination of the defective material is to be verified by liquid penetrant testing or magnetic particle testing.
8.4.4.6 Weld repairs of defects in zone A are to be as follows:
(1) In zone A, repair welding is generally not allowed unless specially approved by CCS. Where such weld repair is applied, all welds are to be stress relieved by heat treatment, and the heat treatment procedure is to be agreed by CCS Surveyor.
(2) Grinding is to be carried out to an extent which maintains the blade thickness of the approved drawing.
(3) The possible repair of defects which are deeper than those referred to in (2) above is to be specially considered by CCS.
(4) In some cases the propeller designer may submit technical documentation to propose a modified zone A based on detailed hydrodynamic load and stress analysis for consideration by CCS.
8.4.4.9 The foundry is to maintain a report of repairing and welding, subsequent heat treatment and final inspection results traceable to each casting repaired, and such report is to be confirmed by the Surveyor. Before welding is started, full details of the extent and location of the repair, the proposed welding procedure, heat treatment and subsequent inspection procedures are to be submitted to CCS for approval.

8.4.5 Welding ~~repairs~~ repair procedure

8.4.5.3 The use of any welding procedure without prior approval is subject to a satisfactory approval test witnessed by the Surveyor (detailed test requirements are given in Table 8.4.5.3(1) and Figure 8.4.5.3). The test is to be carried out with the ~~same~~ base metal, welding process, filler metal, preheating and stress-relieving treatment as those ~~intended applied by~~ covered in Table 8.4.5.3(2)~~the actual repair work~~. All weld repairs are to be carried out in accordance with the procedure specification qualified at valid workshops under the same technical and quality management. Welding Procedure Qualification Tests are to be signed by the CCS Surveyor witnessing the tests. All weld repairs are to be made by certified welders strictly in accordance with approved procedures.

Test requirements for approval of repair welding techniques for propeller① Table 8.4.5.3(1)

Material of propeller	Min. thickness of assembly② (mm)	Test item③	Requirements for test results
Cast copper alloy propeller	30	Visual inspection and ~~surface~~ liquid penetrant testing④: weld length	No surface cracking
		Radiographic testing: weld length	In compliance with recognized standards
		Transverse tensile: 2	C~~u~~U1: R_m≥370 N/mm^2 C~~u~~U2: R_m≥410 N/mm^2

			C~~u~~U3: R_m≥500 N/mm^2 C~~u~~U4: R_m≥550 N/mm^2
		Macro examination : 3	No cracking, lack of fusion or pores and slag inclusions over 3 mm in diameter
Cast steel propeller	~~30~~	Visual inspection and ~~surface~~ liquid penetrant testing③: weld length	Satisfying requirements for Zone A in Table 8.4.3.~~5~~7
		Radiographic testing: weld length	In compliance with recognized standards
		Transverse tensile: 2	R_m satisfies the minimum requirements specified for base metal, the location of fracture is to be reported
		Bend④: Two root and two face bend specimens ~~Side bends: 2~~	Bend degree: 180° Diameter of former: austenitic stainless steel 3t, other materials 4t; after the specimens are bent, they are not to exhibit cracking over ~~2~~3 mm in length on the surface; defects appearing at the corners of a test specimen during testing are to be investigated case by case by CCS.
		Macro examination: 2	No cracking or defects similar to cracking, no slag inclusions or pores over 3 mm in diameter
		Impact: where there are impact requirements for base metal, one set for the center weld and the fusion line respectively	The impact temperature and impact energy satisfy the requirements for base metal
		Hardness: start of welding	Reported for information.

Notes: ① For the repair of cast copper alloy propellers, the test items and requirements specified in the Table are also applicable to the welder's qualification test.

② Back sealing runs are allowed in single V weld assemblies. The specimen is in general to be welded in down-hand (flat) position.

③ ~~The dimensions and specific locations of test specimens are shown in Figure 8.4.5.3~~Test assembly is to be examined by visual and liquid penetrant testing prior to the cutting of test specimen. In case that any post-weld heat treatment is required or specified, non-destructive testing is to be performed after heat treatment. Magnetic particle testing may be used in lieu of liquid penetrant testing for martensitic stainless steels.

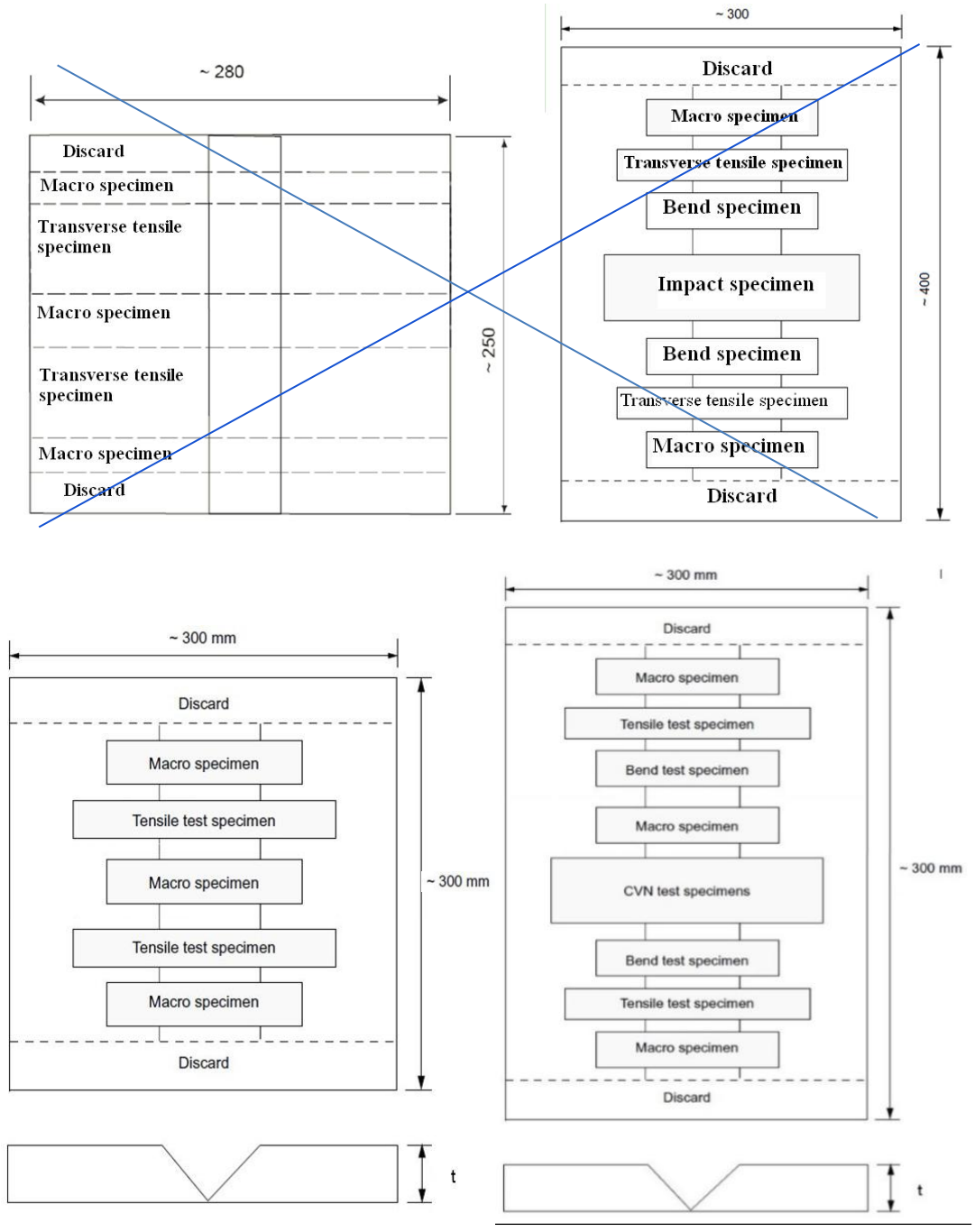
④ Transverse bend tests for butt joints are to be in accordance with Section 2, Chapter 2, PART ONE or, according to a recognized standard. For thickness of 12 mm and over, four side bend specimens may alternatively be tested in lieu of root and face bend specimens.

⑤ If the test piece fails to comply with any of the requirements, reference is made to re-test procedures given in Section 2, Chapter 1, PART THREE.

Range of approval of repair welding techniques for propeller Table 8.4.5.3(2)

Parameters	Range of approval	
Base metal	Materials (materials grade):	Range of materials of approval:
	CU1	CU1
	CU2	CU1, CU2
	CU3	CU3
	CU4	CU4
	Cast steel	Same steel grade
Thickness	Copper alloy t≥30mm	≥3mm
	Cast steel 15<t≤30mm	3mm-2t
	Cast steel t>30mm	0.5t to 2t or 200mm, whichever is greater
Welding position	Approval for a test made in any position is restricted to that position.	
Welding process	The approval is only valid for the welding process used in the welding procedure test. Single run is not qualified by multi-run butt weld test.	
Filler metal	The approval is only valid for the filler metal used in the welding procedure test.	
Heat input	Copper alloy:The upper limit of heat input approved is 25% greater than that used in welding the test piece. The lower limit of heat input approved is 25% lower than that used in welding the test piece.	
	Cast steel:The upper limit of heat input approved is 15% greater than that	

	used in welding the test piece. The lower limit of heat input approved is 15% lower than that used in welding the test piece.
Preheating temperature Interpass temperature	The minimum preheating temperature is not to be less than that used in the qualification test. The maximum interpass temperature is not to be higher than that used in the qualification test.
Post-weld heat treatment	The heat treatment used in the qualification test is to be specified in pWPS. Soaking time may be adjusted as a function of thickness.



(1) Cast copper alloy propeller (2) Cast steel propeller

Figure 8.4.5.3 Test specimen locations for approval of repair welding techniques for propeller

8.4.5.4 Defects to be repaired by welding are to be ground to sound material. To ensure complete removal

of the defects the ground areas are to be examined by ~~dye~~liquid penetrant methods in the presence of the Surveyor.

8.4.5.8 Metal arc welding is to be used for all types of welding repair on cast copper alloy or cast steel propellers. Based on the experience of the manufacturer, arc welding with coated electrodes or gas-shielded metal arc process may be applied for all types of repair on propellers. Argon-shielded tungsten welding is to be used with care on cast copper alloy propellers.

~~Metal arc welding is recommended for all types of repair on bronze propellers.~~

~~Gas welding may be applied for repair of defects on Cu1 and Cu2 copper alloy propellers, provided that the application is limited to a distance of 1/3 radius of the propeller from its outside edge and material thickness less than 30 mm.~~

8.4.5.11 To minimize the risk of distortion and cracking, interpass temperatures are to be kept low. This is especially the case with C~~u~~U3 alloys.

8.4.6 Straightening

8.4.6.1 Minor distortions of propellers may be straightened with or without heating. Weld repaired areas may be subject to hot straightening, provided it can be demonstrated that weld properties are not impaired by the hot straightening operations. Cold straightening is to be used for minor repairs of tips and edges only. For hot and cold straightening purposes, only static loading is to be used.

8.4.7 Heat treatment

8.4.7.1 Unless demonstrated by the manufacturer as not necessary, all cold straightening or weld repairs of C~~u~~U1, C~~u~~U2 and C~~u~~U4 copper alloy propellers are to be stress relief heat treated. Stress relief heat treatment of alloy C~~u~~U3 propeller castings may be required after repairs in zone B (and specially approved welding in zone A) or if a welding consumable susceptible to stress corrosion cracking is used.

8.4.7.3 The recommended stress relief heat treatment temperatures for copper alloy propellers are listed in Table 8.4.7.3. Soaking times are to be in accordance with Table 9.1.4.4 in Chapter 9 of PART ONE of the Rules.

Recommended Filler Metals, Preheating and Heat Treatment Temperatures **Table 8.4.7.3**

Alloy type	Filler metal	Min preheating temperature ℃	Max. interpass temperature ℃	Stress relief temperature ℃	Hot straightening temperature ℃
C~~u~~U1	Al-bronze① Mn-bronze	150	300	350 ~ 500	500 ~ 800
C~~u~~U2	Al-bronze Ni-Mn-bronze	150	300	350 ~ 550	500 ~ 800
C~~u~~U3	Al-bronze Ni-Al-bronze② Mn-Al-bronze	100	250	450 ~ 500	700 ~ 900
C~~u~~U4	Mn-Al-bronze	100	300	450 ~ 600	700 ~ 850

Notes: ① Ni-Al-bronze and Mn-Al-bronze are acceptable.

② Stress relieving not required, if filler metal Ni-Al-bronze is used.

A new appendix is added as follows:

APPENDIX 2 ADVANCED NON-DESTRUCTIVE TESTING OF MATERIALS AND WELDS [5]

1 General

1.1 This Appendix gives minimum requirements on the methods and quality levels that are to be adopted for the advanced non-destructive testing (ANDT) of materials and welds during new building of ships. The advanced methods intended for use under this Appendix are listed in Section 2.

1.2 The ANDT is to be performed by the shipbuilder, manufacturer or its subcontractors in accordance with the requirements of this Appendix. CCS surveyor may require witnessing testing.

1.3 It is the shipbuilder's or manufacturer's responsibility to ensure that testing specifications and procedures are adhered to during the construction, and the report is to be made available to CCS on the findings made by the ANDT.

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5 This content will take effect on 1 July 2020..

1.4 The extent and method of testing, and the number of checkpoints are normally agreed between the shipyard and CCS.

1.5 Terms and definitions

The following terms and definitions apply for this document.

ANDT Advanced non-destructive testing

RT-D Digital Radiography

RT-S Radioscopic testing with digital image acquisition (dynamic≥12bit)

RT-CR Testing with computed radiography using storage phosphor imaging plates

PAUT Phased Array Ultrasonic Testing

TOFD Time of Flight Diffraction

AUT Automated Ultrasonic Examinations. A technique of ultrasonic examination performed with equipment and search units that are mechanically mounted and guided, remotely operated, and motor-controlled (driven) without adjustments by the technician. The equipment used to perform the examinations is capable of recording the ultrasonic response data, including the scanning positions, by means of integral encoding devices such that imaging of the acquired data can be performed.

SAUT Semi-Automated Ultrasonic Examinations. A technique of ultrasonic examination performed with equipment and search units that are mechanically mounted and guided, manually assisted (driven), and which may be manually adjusted by the technician. The equipment used to perform the examinations is capable of recording the ultrasonic response data, including the scanning positions, by means of integral encoding devices such that imaging of the acquired data can be performed.

2 Applicability

2.1 Materials

2.1.1 This Appendix applies to the following materials and manufactured products:

(1) Material and welding for gas tankers in accordance with Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk

(2) Normal and higher strength hull structural steels in accordance with CCS Rules for Materials and Welding, PART ONE, Chapter 3

(3) High strength steels for welded structures in accordance with CCS Rules for Materials and Welding, PART ONE, Chapter 3

(4) Hull steel forgings in accordance with CCS Rules for Materials and Welding, PART ONE, Chapter 5

(5) Hull and machinery steel castings in accordance with CCS Rules for Materials and Welding, PART ONE, Chapter 6

(6) Extremely Thick Steel Plates in Container Ships in accordance with CCS Guidelines for Inspection of Thick Higher Strength Steel Plates for Ships

(7) Aluminium Alloys in accordance with CCS Rules for Materials and Welding, PART ONE, Chapter 8

(8) Copper Propellers in accordance with CCS Rules for Materials and Welding, PART ONE, Chapter 9

(9) Cast Steel Propellers in accordance with CCS Rules for Materials and Welding, PART ONE, Chapter 6

(10) EH47 Steels and Brittle Crack Arrest Steels in accordance with CCS Guidelines for Inspection of Thick Higher Strength Steel Plates for Ships

(11) Hull and machinery steel forgings in accordance with CCS Guidelines for Inspection of Hull Welds, Appendix 7A

(12) Hull and machinery steel castings in accordance with Guidelines for Inspection of Hull Welds, Appendix 7B

2.2 Welding processes

2.2.1 This Appendix applies to welding processes specified in Table 2.2.1. ANDT of welding process unspecified in the Table is to be to the satisfaction of CCS.

Applicable welding process **Table 2.2.1**

Welding process		ISO 4063:2009
Manual welding	Shield Metal Arc Welding(SMAW)	111

Resistance welding	Flash welding(FW)	24
Semi-automatic welding	(1) Metal Inert Gas welding(MIG) (2) Metal Active Gas welding(MAG) (3) Flux Cored Arc Welding(FCAW)	131 135, 138 136
TIG welding	Gas Tungsten Arc Welding(GTAW)	141
Automatic welding	(1) Submerged Arc Welding(SAW) (2) Electro-gas Welding(EGW) (3) Electro-slag Welding(ESW)	12 73 72

2.3 Weld joints

2.3.1 This Appendix applies to butt welds with full penetration. Variations of joint design, for example, tee, corner and cruciform joints (with or without full penetration) can be tested using PAUT. The constraints of joint design with respect to testing are to be recognized, documented, and agreed with the Society before application.

2.4 Timing of ANDT

2.4.1 ANDT are to be conducted after welds have cooled to ambient temperature and after post weld heat treatment where applicable.

2.4.2 Timing of ANDT on ship hull welds on steels with specified minimum yield stress in the range of 420 N/mm^2 to 690 N/mm^2 shall be in accordance with 2.4.2 of Appendix 1 Non-destructive testing of ship hull steel welds of PART Three of CCS Rules for Materials and Weldings.

2.5 Testing methods

2.5.1 The methods mentioned in this Appendix for detection of imperfections are PAUT (only automated / semi-automated PAUT), TOFD, RT-D.

2.5.2 Applicable methods for testing of the different types of materials and weld joints are given in Table 2.5.2.

Applicable methods for testing of materials and weld joints Table 2.5.2

Materials and Weld Joints	Parent Material Thickness	Applicable Methods
Ferritic butt welds with full penetration	Thickness <6mm	RT-D
	6 mm ≤Thickness ≤ 40 mm	PAUT, TOFD, RT-D
	Thickness >40mm	PAUT, TOFD, RT-D*
Ferritic tee joints and corner joints with full penetration	Thickness≥6mm	PAUT, RT-D*
Ferritic cruciform joints with full penetration	Thickness≥6mm	PAUT*
Austenitic stainless steel butt welds with full penetration	Thickness <6mm	RT-D
	6 mm ≤Thickness≤ 40 mm	RT-D, PAUT*
	Thickness >40mm	PAUT*, RT-D*
Austenitic stainless steel tee joints, corner joints with full penetration ①	Thickness≥6mm	PAUT*, RT-D*
Aluminum tee joints and corner joints with full penetration	Thickness≥6mm	PAUT*, RT-D*
Aluminum cruciform joints with full penetration	Thickness≥6mm	PAUT*
Aluminum butt welds with full penetration	Thickness <6mm	RT-D
	6 mm ≤Thickness ≤ 40 mm	RT-D, TOFD, PAUT
	Thickness >40mm	TOFD, PAUT, RT-D*
Cast Copper Alloy	All	PAUT, RT-D*
Steel forgings	All	PAUT, RT-D*
Steel castings	All	PAUT, RT-D*

Materials and Weld Joints	Parent Material Thickness	Applicable Methods
Base materials/Rolled steels, Wrought Aluminum Alloys	Thickness <6mm	RT-D
	6 mm ≤Thickness ≤ 40 mm	PAUT, TOFD, RT-D
	Thickness >40 mm	PAUT, TOFD, RT-D*
* Only applicable with limitations, need special qualification subject to acceptance by CCS.		

Note: ① The ultrasonic testing of anisotropic material using advanced methods will require specific procedures and techniques. Additionally, the use of complementary techniques and equipment may also be required, e.g. using angle compression waves, and/or creep wave probes for detecting defects close to the surface.

3 **Qualification of personnel involved in ANDT**

3.1 The Shipbuilder, manufacturer or its subcontractors is responsible for the qualification and preferably 3rd party certification of its supervisors and operators to a recognised certification scheme based on ISO 9712:2012.

Personnel qualification to an employer based qualification scheme as e.g. SNT-TC-1A, 2016 or ANSI/ASNT CP-189, 2016 may be accepted if the Shipbuilder, manufacturer or its subcontractors written practice is reviewed and found acceptable by the CCS. The Shipbuilder, manufacturer or its subcontractors written practice are to as a minimum, except for the impartiality requirements of a certification body and/or authorised body, comply with ISO 9712:2012.

The supervisors' and operators' certificates and competence are to comprise all industrial sectors and techniques being applied by the Shipbuilder or its subcontractors.

Level 3 personnel are to be certified by a certification body accredited by CCS.

3.2 The Shipbuilder, manufacturer or its subcontractors are to have a supervisor or supervisors, responsible for the appropriate execution of NDT operations and for the professional standard of the operators and their equipment, including the professional administration of the working procedures. The Shipbuilder, manufacturer or its subcontractors are to employ, on a full-time basis, at least one supervisor independently certified to Level 3 in the method(s) concerned as per the requirements of item 3.1. It is not permissible to appoint Level 3 personnel; they must be certified by an accredited certification body. It is recognised that a Shipbuilder, manufacturer or its subcontractors may not directly employ a Level 3 in all the stated methods practiced. In such cases, it is permissible to employ an external, independently certified, Level 3 in those methods not held by the full-time Level 3(s) of the Shipbuilder, manufacturer or its subcontractors.

The supervisor is to be directly involved in review and acceptance of NDT Procedures, NDT reports, calibration of NDT equipment and tools. The supervisor is, on behalf of the Shipbuilder, manufacturer or its subcontractors, to re-evaluate the qualification of the operators annually.

3.3 The operator carrying out the NDT and interpreting indications, is to, as a minimum, be qualified and certified to Level 2 in the NDT method(s) concerned and as described in item 3.1.

However, operators only undertaking the gathering of data using any NDT method and not performing data interpretation or data analysis may be qualified and certified as appropriate, at level 1.

The operator is to have adequate knowledge of materials, weld, structures or components, NDT equipment and limitations that are sufficient to apply the relevant NDT method for each application appropriately.

4 Technique and procedure qualification

4.1 General

The shipbuilder or manufacturer has to submit to CCS the following documentation for review:

(1) The technical documentation of the ANDT.

(2) The operating methodology and procedure of the ANDT according to Section 7 of this Appendix.

(3) Result of software simulation, when applicable.

4.2 Software simulation

Software simulation may be required by CCS, when applicable for PAUT or TOFD techniques. The simulation may include initial test set-up, scan plan, volume coverage, result image of artificial flaw etc. In

some circumstances, artificial defect modeling/simulation may be needed or required by the project.

4.3 Procedure qualification test
The procedure qualification for ANDT system is to include the following steps:
(1) Review of available performance data for the inspection system (detection abilities and defect sizing accuracy);
(2) Identification and evaluation of significant parameters and their variability;
(3) Planning and execution of a repeatability and reliability test programme① which including onsite demonstration;
(4) Documentation of results from the repeatability and reliability test programs.
Note: ① The data from the repeatability and reliability test program is to be analyzed with respect to comparative qualification block test report and onsite demonstration. The qualification block is to be in accordance with ASME V Article 14 MANDATORY APPENDIX II UT PERFORMANCE DEMONSTRATION CRITERIA or agreed by CCS, and at least the intermediate level qualification blocks are to be used. The high level qualification blocks are to be used when sizing error distributions and an accurate POD need to be evaluated. The demonstration process onsite is to be witnessed by CCS surveyor.

4.4 Procedure approval
The testing procedure is to be evaluated based upon the qualification results, if satisfactory the procedure can be considered approved.

4.5 Onsite review
4.5.1 For the test welds, supplementary NDT is to be performed on an agreed proportion of welds to be cross checked with other methods. Alternatively, other documented reference techniques may be applied to compare with ANDT results.
4.5.2 Data analyses are to be performed in accordance with the above activities. Probability of Detection (POD) and sizing accuracy are to be established when applicable. When the result of inspection review does not conform to the approved procedure, the inspection is to be suspended immediately. Additional procedure review qualification and demonstration are to be undertaken to account for any nonconformity. When a significant nonconformity is found, CCS has the right to reject the results of such activities.

5 Surface condition
5.1 Area to be examined is to be free from scale, loose rust, weld spatter, oil, grease, dirt or paint that might affect the sensitivity of the testing method.
5.2 Where there is a requirement to carry out PAUT or TOFD through paint, the suitability and sensitivity of the test are to be confirmed through an appropriate transfer correction method defined in the procedure. In all cases, if transfer losses exceed 12 dB, the reason is to be considered and further preparation of the scanning surfaces is to be carried out, if applicable. If testing is done through paint, then the procedure is to be qualified on a painted surface.
5.3 The requirement for acceptable test surface finish is to ensure accurate and reliable detection of defects. For the testing of welds, where the test surface is irregular or has other features likely to interfere with the interpretation of NDT results, the weld is to be ground or machined.

6 General plan of testing: NDT method selection
6.1 The extent of testing is to be planned by the shipbuilder or manufacturer according to the ship design, ship or equipment type and welding processes used. Particular attention is to be paid to highly stressed areas. The extent of testing is to be in accordance with the rules or guidelines applicable with material of weld examined.

7 Testing requirements
7.1 General
7.1.1 The shipyard or manufacturer is to ensure that personnel carrying out NDT or interpreting the results of NDT are qualified to the appropriate level as detailed in section 3.
7.1.2 Procedures
(1) All NDT are to be carried out to a procedure that is representative of the item under inspection.
(2) Procedures are to identify the component to be examined, the NDT method, equipment to be used and the full extent of the examinations including any test restrictions.
(3) Procedures are to include the requirement for components to be positively identified and for a datum

system or marking system to be applied to ensure repeatability of inspections.
(4) Procedures are to include the method and requirements for equipment calibrations and functional checks, together with specific technique sheets / scan plans, for the component under test.
(5) Procedures are to be approved by personnel qualified to Level III in the appropriate technique in accordance with a recognised standard.
(6) Procedures are to be reviewed by CCS Surveyor.
7.1.3 The methods considered within the application of this Appendix are defined in 2.5.1.
7.1.4 PAUT techniques are to conform as a minimum to section 7.2 of this Appendix. Depending on the complexity of the item under test and the access to surfaces, there may be a requirement for additional scans and/or complementary NDT techniques to ensure that full coverage of the item is achieved.
7.1.4.1 PAUT of welds is to include a linear scan of the fusion face, together with other scans as defined in the specific test technique. Refer to linear scan requirements in 7.2.2.4.
7.1.5 TOFD techniques are to conform as a minimum to 7.3 of this Appendix. Depending on the complexity of the item under test and the access to surfaces, there may be a requirement for additional scans and/or complementary NDT techniques to ensure that full coverage of the item is achieved.
7.1.6 RT-D techniques are to conform as a minimum to 7.4 of this Appendix. For the purpose of this Appendix, RT-D comprises of two main RT methods; RT-S and RT-CR. Other methods may be included (e.g. radioscopy systems), however, then must conform to this Appendix as applicable, and any specific requirements are to demonstrate equivalence to these requirements.
7.1.6.1 In all RT-D methods, in addition to specific requirements, detector output quality control methods are to be described within the procedure.
7.1.6.2 The procedure is to define the level of magnification, post-processing tools, image/data security and storage, for final evaluation and reporting.

7.2 Phased array ultrasonic testing（PAUT)
PAUT is to be carried out according to procedures based on ISO 13588:2019, ISO 18563-1:2015, ISO 18563-2:2017, ISO 18563-3:2015 and ISO 19285:2017 or recognized standards and the specific requirements of CCS.
7.2.1 Information required prior to testing
A procedure is to be written and include the following information as in minimum shown in table 7.2.1. When an essential variable in the Table is to change from the specified value, or range of values, the written procedure shall require requalification. When a nonessential variable is to change from the specified value, or range of values, requalification of the written procedure is not required. All changes of essential or nonessential variables from the value, or range of values, specified by the written procedure shall require revision of, or an addendum to, the written procedure.

Requirements of a PAUT Procedure **Table 7.2.1**

Requirement	Essential Variable	Nonessential Variable
Material types or weld configurations to be examined, including thickness dimensions and material product form (castings, forgings, pipe, plate, etc.)	X	…
The surfaces from which the examination shall be performed	X	…
Technique(s) (straight beam, angle beam, contact, and/or immersion)	X	…
Angle(s) and mode(s) of wave propagation in the material	X	…
Search unit type, frequency, element size and number, pitch and gap dimensions, and shape	X	…
Focal range (identify plane, depth, or sound path)	X	…
Virtual aperture size (i.e., number of elements, effective height①, and element width)	X	…
Focal laws for E-scan and S-scan (i.e., range of element numbers used, angular range used, element or angle increment change)	X	…
Special search units, wedges, shoes, or saddles, when used	X	…
Ultrasonic instrument(s)	X	…
Calibration [calibration block(s) and technique(s)]	X	…
Directions and extent of scanning	X	…
Scanning (manual vs. automatic)	X	…
Method for sizing indications and discriminating geometric from flaw indications	X	…
Computer enhanced data acquisition, when used	X	…
Scan overlap (decrease only)	X	…
Personnel performance requirements, when required	X	…

Requirement	Essential Variable	Nonessential Variable
Testing levels, acceptance levels and/or recording levels	X	…
Personnel qualification requirements	…	X
Surface condition (examination surface, calibration block)	…	X
Couplant (brand name or type)	…	X
Post-examination cleaning technique	…	X
Automatic alarm and/or recording equipment, when applicable	…	X
Records, including minimum calibration data to be recorded (e.g., instrument settings)	…	X
Environmental and safety issues	…	X

Note: ①Effective height is the distance from the outside edge of the first to last element used in the focal law.

7.2.2 Testing

7.2.2.1 Testing levels

The testing levels specified in the testing procedure are to be in accordance with recognized standards accepted by CCS. Four testing levels are specified in ISO 13588:2019, each corresponding to a different probability of detection of imperfections.

7.2.2.2 Weld Examinations

The weld examinations are to be in accordance with ISO 13588:2019 and the additional special requirements of this Appendix.

7.2.2.3 Material Examinations

Material examinations are to conform to 2.1 of this Appendix as a minimum.

7.2.2.4 Volume to be inspected

The purpose of the testing is to be defined by the testing procedure. Based on this, the volume to be inspected is to be determined.

A scan plan shall be provided. The scan plan is to show the beam coverage, the weld thickness and the weld geometry. If the evaluation of the indications is based on amplitude only, it is a requirement that an 'E' scan (or linear scan) is to be utilized to scan the fusion faces of welds, so that the sound beam is perpendicular to the fusion face ± 5º. This requirement may be omitted if an 'S' (or sectorial) scan can be demonstrated to verify that discontinuities at the fusion face can be detected and sized, using the stated procedure (note, this demonstration is to utilize reference blocks containing suitable reflectors in location of fusion zone).

7.2.2.5 Reference blocks

Depending on the testing level, a reference block is to be used to determine the adequacy of the testing (e.g. coverage, sensitivity setting). The design and manufacture of reference blocks are to be in accordance with ISO 13588:2019 or recognized equivalent standards and the specific requirements of CCS.

7.2.2.6 Indication assessment

Indications detected when applying testing procedure are to be evaluated either by length and height or by length and maximum amplitude. Indication assessment is to be in accordance with ISO 19285:2017 or recognized standards and the specific requirements of CCS. The sizing techniques include reference levels, Time Corrected Gain (TCG), Distance Gain Size (DGS) and 6 dB drop. 6 dB drop method is only to be used for measuring the indications larger than the beam width.

7.3 Time of flight diffraction (TOFD)

TOFD is to be carried out according to procedure based on ISO 10863:2011, and ISO 15626:2018 or recognized standards and the specific requirements of CCS.

7.3.1 Information required prior to testing

A procedure is to be written and include the following information as shown in Table 7.3.1. When an essential variable in the table is to change from the specified value, or range of values, the written procedure is to require requalification. When a nonessential variable is to change from the specified value, or range of values, requalification of the written procedure is not required. All changes of essential or nonessential variables from the value, or range of values, specified by the written procedure are to require revision of, or an addendum to, the written procedure.

Requirements of a TOFD Procedure **Table 7.3.1**

Requirement	**Essential Variable**	**Nonessential Variable**
Weld configurations to be examined, including thickness dimensions and material product form (castings, forgings, pipe, plate, etc.)	X	…

Requirement	Essential Variable	Nonessential Variable
The surfaces from which the examination shall be performed	X	…
Angle(s) of wave propagation in the material	X	…
Search unit type(s), frequency(ies), and element size(s)/shape(s)	X	…
Special search units, wedges, shoes, or saddles, when used	X	…
Ultrasonic instrument(s) and software(s)	X	…
Calibration [calibration block(s) and technique(s)]	X	…
Directions and extent of scanning	X	…
Scanning (manual vs. automatic)	X	…
Data sampling spacing (increase only)	X	…
Method for sizing indications and discriminating geometric from flaw indications	X	…
Computer enhanced data acquisition, when used	X	…
Scan overlap (decrease only)	X	…
Personnel performance requirements, when required	X	…
Testing levels, acceptance levels and/or recording levels	X	…
Personnel qualification requirements	…	X
Surface condition (examination surface, calibration block)	…	X
Couplant (brand name or type)	…	X
Post-examination cleaning technique	…	X
Automatic alarm and/or recording equipment, when applicable	…	X
Records, including minimum calibration data to be recorded (e.g., instrument settings)	…	X
environmental and safety issues	…	X

7.3.2 Testing

7.3.2.1 Testing levels

The testing levels specified in the testing procedure are to be in accordance with recognized standards accepted by CCS. Four testing levels are specified in ISO 10863:2011, each corresponding to a different probability of detection of imperfections.

7.3.2.2 Volume to be inspected

The purpose of the testing is to be defined by the testing procedure. Based on this, the volume to be inspected is to be determined.

A scan plan is to be provided. The scan plan is to show the locations of the probes, beam coverage, the weld thickness and the weld geometry.

7.3.2.3 Due to the nature of the TOFD method, there is a possibility that the scan plan may reveal weld volume zones that will not receive full TOFD coverage (commonly known as dead zones, either in the lateral wave, back wall, or both). If the scan plan reveals that these dead zones are not adequately inspected, then further TOFD scans and/or complementary NDT methods are to be applied to ensure full inspection coverage.

7.4 Digital radiography (RT-D)

Digital radiography is to be performed per procedure(s) based on ISO 17636-2:2013 and standards referenced therein, or recognized standards and additional specific requirements of CCS.

Any variation to applying the standard (e.g. IQI placement) is to be agreed with CCS.

A procedure is to be written and include the following information as shown in Table 7.4.

Requirements of a Digital radiography Procedure Table 7.4

Requirement
Material types or weld configurations to be examined, including thickness dimensions and material product form (castings, forgings, pipe, plate, etc.)
Digitizing System Description:
Manufacturer and model no. of digitizing system
Physical size of the usable area of the image monitor
Film size capacity of the scanning device
Spot size(s) of the film scanning system
Image display pixel size as defined by the vertical/horizontal resolution limit of the monitor
Illuminance of the video display
Data storage medium
Digitizing Technique:
Digitizer spot size (in microns) to be used

Loss-less data compression technique, if used
Method of image capture verification
Image processing operations
Time period for system verification
Spatial resolution used:
Contrast sensitivity (density range obtained)
Dynamic range used
Spatial linearity of the system
Material type and thickness range
Source type or maximum X-ray voltage used
Detector type
Detector calibration
Minimum source-to-object distance
Distance between the test object and the detector
Source size
Test object scan plan (if applicable)
Image Quality Measurement Tools
Image Quality Indicator (IQI)
Wire Image Quality Indicator
Duplex Image Quality Indicator
Image Identification Indicator
Testing levels, acceptance levels and/or recording levels
Personnel qualification requirements
Surface condition
Records, including minimum calibration data to be recorded
Environmental and Safety issues

7.4.1 Testing levels

Regarding choice of testing level per ISO 17636-2:2013 this is referred to in 8.4 of this Appendix.

8 Acceptance Levels

8.1 General

8.1.1 This Appendix details the acceptance levels followed for the assessment of the NDT results. Methods include but are not limited to: Phased array ultrasonic testing (PAUT), Time of flight diffraction (TOFD), Digital radiography (RT-D).

8.1.2 It may be necessary to combine testing methods to facilitate the assessment of indications against the acceptance criteria.

8.1.3 Acceptance criteria for each material and weld joint are to be in accordance with relevant rules and guidelines in 2.1.1.

8.2 Phased array ultrasonic testing

8.2.1 Weld Examinations

The relationship between acceptance levels, testing levels and quality levels is given in Table 8.2.1.

Quality levels and acceptance levels for PAUT of welds are to be in accordance with ISO 19285:2017 or recognized standard agreed with CCS.

Acceptance levels for PAUT Table 8.2.1

Quality levels according to ISO 5817:2014	Testing level according to ISO 13588:2019	Acceptance levels according to ISO 19285:2017
C, D	A	3
B	B	2
By agreement	C	1
Special application	D	By agreement

8.2.2 Material Examinations

Quality levels and acceptance levels for PAUT of material testing are to be in accordance to recognized standard agreed with CCS.

The acceptance levels for material examinations are to conform as a minimum to the appropriate IACS Resolutions, including UR and Recommendations.

8.3 Time of flight diffraction

The relationship between acceptance levels, testing levels and quality levels is given in Table 8.3.

Quality levels and acceptance levels for TOFD of welds are to be in accordance to ISO 15626:2018 or recognized standard agreed with CCS.

Acceptance levels for TOFD Table 8.3

Quality levels according to ISO 5817:2014	Testing level according to ISO 10863:2011	Acceptance level according to ISO 15626:2018
B (Stringent)	C	1
C (Intermediate)	At least B	2
D (Moderate)	At least A	3

8.4 Digital radiography

The relationship between acceptance levels, testing levels and quality levels is given in Table 8.4.

Quality levels and acceptance levels for Digital Radiography of welds are to be in accordance with ISO 10675 or standard agreed with CCS.

Acceptance levels for Digital radiography Table 8.4

Quality levels according to ISO 5817:2014 or ISO 10042:2018	Testing techniques/level(class) according to ISO 17636-2:2013	Acceptance level according to ISO 10675-1:2016 & ISO 10675-2:2017
B (Stringent)	B (class)	1
C (Intermediate)	B* (class)	2
D (Moderate)	A (class)	3
* For circumferential weld testing, the minimum number of exposures may correspond to the requirements of ISO 17636-2:2013, class A		

9 Reporting

9.1 The test report is to include at least the following information:

(1) a reference to standards of compliance;

(2) information relating to the object under test:

①identification of the object under test;

②dimensions including wall thickness;

③material type and product form;

④ geometrical configuration;

⑤ location of welded joint(s) examined;

⑥ reference to welding process and heat treatment;

⑦ surface condition and temperature;

⑧ stage of manufacture;

(3) information relating to equipment:

Information relating to equipment Table 9.1(3)

Method	Information
All	manufacturer and type of instrument, including with identification numbers if required.
PAUT	① manufacturer, type, frequency of phased array probes including number and size of elements, material and angle(s) of wedges with identification numbers if required; ② details of reference block(s) with identification numbers if required, ③ type of couplant used.
TOFD	① manufacturer, type, frequency, element size and beam angle(s) of probes with identification numbers if required; ② details of reference block(s) with identification numbers if required; ③ type of couplant used.

RT-D	① system of marking used; ② radiation source, type and size of focal spot and identification of equipment used; ③ detector, screens and filters and detector basic spatial resolution.

(4) information relating to test technology:

Information relating to test technology Table 9.1(4)

Method	Information
All	①testing level and reference to a written test procedure; ②purpose and extent of test; ③ details of datum and coordinate systems; ④ method and values used for range and sensitivity settings; ⑤details of signal processing and scan increment setting; ⑥ access limitations and deviations from standards, if any.
PAUT	① increment (E-scans) or angular increment (S-scans); ② element pitch and gap dimensions; ③ focus (calibration should be the same as scanning); ④ virtual aperture size, i.e. number of elements and element width; ⑤ element numbers used for focal laws; ⑥ documentation on permitted wedge angular range from manufacturer; ⑦ documented calibration, TCG and angle gain compensation; ⑧ scan plan.
TOFD	① details of TOFD setups ② details of offset scans, if required.
RT-D	① detector position plan; ② tube voltage used and current or source type and activity; ③ time of exposure and source-to-detector distance; ④ type and position of image quality indicators; ⑤ achieved and required SNRN for RT-S or achieved and required grey values and/or SNRN for RT-CR; ⑥ for RT-S: type and parameters such as gain, frame time, frame number, pixel size, calibration procedure; ⑦ for RT-CR: scanner type and parameters such as pixel size, scan speed, gain, laser intensity, laser spot size; ⑧ image-processing parameters used, e.g. of the digital filters.

(5) information relating to test results:

Information relating to test results Table 9.1(5)

Method	Information
All	① acceptance criteria applied; ② tabulated data recording the classification, location and size of relevant indications and results of evaluation; ③ results of examination including data on software used; ④ date of test; ⑤ reference to the raw data file(s); ⑥ date(s) of scan or exposure and test report; ⑦ names, signatures and certification of personnel.
PAUT	① phased array images of at least those locations where relevant indications have been detected on hard copy, all images or data available in soft format; ② reference points and details of the coordinate system.
TOFD	TOFD images of at least those locations where relevant TOFD indications have been detected.

9.2 Results of NDT are to be recorded and evaluated by the shipbuilder or manufacturer on a continual basis. These records are to be available to the Surveyor.

9.3 The shipbuilder or manufacturer is to be responsible for the review, interpretation, evaluation and acceptance of the results of NDT. Reports stating compliance or otherwise with the criteria established in the inspection procedure are to be issued.

9.4 In addition to the above general reporting requirements, all specified NDT methods will have particular requirements and details that are to be listed in the report. Refer to the applicable method standards for specific requirements.

9.5 The shipbuilder or manufacturer is to keep the inspection records for the appropriate period deemed by Classification Societies.

10 Unacceptable indications and repairs

All indications (discontinuities) exceeding the applicable acceptance criteria are to be classed as defects, and are to be eliminated and repaired as per applicable IACS requirements, including UR and Recommendations.