W27 Cast Steel Propellers

(May 2000) (Rev.1 May 2004) (Rev.2 July 2020) (Corr.1 Sep 2020)

1. Scope

1.1 These unified requirements are applicable to the manufacture, inspection and repair procedures of cast steel propellers, blades and bosses.

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

1.3 These requirements may also be used for the repair of propellers damaged in service, subject to prior agreement with the Classification Society.

Notes:

1. Changes introduced in Rev.2 are to be uniformly implemented by IACS Societies on ships contracted for construction on or after 1 July 2021, or when the application for certification of cast ~~copper alloy~~ steel propellers is dated on or after 1 July 2021, or the application for certification of manufacturer approval is dated on or after 1 July 2021.

2. The “contracted for construction” date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of “contract for construction”, refer to IACS Procedural Requirement (PR) No.29

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2. Foundry approval

2.1 All propellers, blades and bosses are to be manufactured by foundries approved by the Classification Society.The castings are to be manufactured and tested in accordance with the requirements of these rules.

2.2 Application for approval

It is the manufacturer's responsibility to assure that effective quality, process and production controls during manufacturing are adhered to within the manufacturing specification. The manufacturing specification shall be submitted to the Classification Society at the time of initial approval, and shall at least include the following particulars: description of the foundry facilities, steel material specification, runner and feeder arrangements, manufacturing procedures, non-destructive testing and repair procedures.

2.3 Scope of the approval test

The scope of the approval test is to be agreed with the Classification Society. This should include the presentation of cast test coupons of the propeller materials in question for approval testing in order to verify that the chemical composition and the mechanical properties of these materials comply with these rules.

2.4 Inspection facilities

The foundry is to have an adequately equipped laboratory, manned by experienced personnel, for the testing of moulding materials chemical analyses, mechanical testing, microstructural testing of metallic materials and non-destructive testing. Where testing activities are assigned to other companies or other laboratory, additional information required by the Society is to be included.

3. Quality of castings

3.1 Freedom from defects

All castings are to have a workmanlike finish and are to be free from imperfections defects which would be prejudicial to their proper application in service.

Minor casting defects which may still be visible after machining such as small sand and slag inclusions, small cold shuts and scabs shall be trimmed off by the manufacturer in accordance with W27.11.

3.2 Removal of defects

Casting defects which may impair the serviceability of the castings, e.g. major non-metallic inclusions, shrinkage cavities, blow holes and cracks, are not permitted. They may be removed by one of the methods described in W27.11 and repaired within the limits and restrictions for the severity zones. Full description and documentation must be available for the surveyor.

4. Dimensions, dimensional and geometrical tolerances

4.1 The verification of dimensions, the dimensional and geometrical tolerances is the responsibility of the manufacturer.

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The report on the relevant examinations is to be submitted to the Surveyor, who may require checks to be made in his presence.

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

5. Chemical composition

5.1 Typical cast steel propeller alloys are grouped into four types depending on their chemical composition as given in Table 1. Cast steel whose chemical composition deviate from the typical values of Table 1 must be specially approved by the Classification Society.

Table 1 - Typical chemical composition for steel propeller castings

Alloy type	C Max. (%)	Mn Max. (%)	Cr (%)	Mo[1)] Max. (%)	Ni (%)
Martensitic (12 Cr 1 Ni)	0,15	2,0	11,5-17,0	0,5	Max. 2,0
Martensitic (13 Cr 4 Ni)	0,06	2,0	11,5-17,0	1,0	3,5-5,0
Martensitic (16 Cr 5 Ni)	0,06	2,0	15,0-17,5	1,5	3,5-6,0
Austenitic (19 Cr 1 1 Ni)	0,12	1,6	16,0-21,0	4,0	8,0-13,0

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

5.2 The manufacturer is to maintain records of the chemical analyses of the production casts, which are to be made available to the Surveyor so that he can satisfy himself that the chemical composition of each casting is within the specified limits.

6. Heat treatment

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

7. Mechanical properties

7.1 The mechanical properties are to comply with values given in Table 2. These values refer to the test specimens machined from integrally cast test coupons attached to the hub or on the blade. The thickness of test coupon is to be in accordance with a recognized standard.

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Table 2 – Mechanical Properties for steel propeller castings

Alloy type	Proof stress Rp0.2 min. (N/mm²)	Tensile strength Rm min. (N/mm²)	Elongation A5 min. (%)	Red. of area Z min. (%)	Charpy V-notch[1] Energy min. (J)
12 Cr 1Ni	440	590	15	30	20
13 Cr 4Ni	550	750	15	35	30
16 Cr 5Ni	540	760	15	35	30
19 Cr 11Ni	180[2]	440	30	40	-

[1] Not required for general service and the lowest Ice class notations. For other Ice class notations, tests are to be made at -10°C.

[2] Rp1,0 value is 205 N/mm².

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

7.3 The test bars are not to be detached from the casting until the final heat treatment has been carried out. Removal is to be by non-thermal procedures.

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

7.5 At least one set of mechanical tests is to be made on material representing each casting in accordance with UR W2.

7.6 As an alternative to 7.5, where a number of small propellers of about the same size, and less than 1m in diameter, are made from one cast and heat treated in the same furnace charge, a batch testing procedure may be adopted using separately cast test samples of suitable dimensions. At least one set of mechanical tests is to be provided for each multiple of five castings in the batch.

8. Definition of skew, severity zones

8.1 In order to relate the degree of inspection to the criticality of imperfections in propeller blades and to help reduce the risk of failure by fatigue cracking after repair, propeller blades are divided into three severity zones designated A, B and C. Definition of skew, and, severity zones are given in UR W24.

9. Non-destructive testing

9.1 Qualification of personnel involved in NDT

Refer to UR W35 Requirements for NDT Suppliers, sections 2.3, 2.4 and, 2.5.

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9.2 Visual testing

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 Surveyor.

9.3 Liquid penetrant testing

Liquid penetrant testing procedure is to be submitted to the Classification Society and is to be in accordance with ISO 3452-1:2013 or a recognized standard. The acceptance criteria are specified in W27.10.

For all propellers, separately cast blades and hubs, the surfaces covered by severity zones A, B and C are to be liquid penetrant tested. Testing of zone A is to be undertaken in the presence of the Surveyor, whilst testing of zone B and C may be witnessed by the Surveyor upon his request.

If repairs have been made either by grinding or by welding, the repaired areas are additionally to be subjected to the liquid penetrant testing independent of their location and/or severity zone. Weld repairs are, independent of their location, always to be assessed according to zone A.

9.4 Magnetic particle testing

Magnetic particle testing may be used in lieu of liquid penetrant testing for examination of martensitic stainless steels castings.

Magnetic particle testing procedure is to be submitted to the Classification Society and is to be in accordance with ISO 9934-1:2016 or a recognized standard.

9.5 Radiographic and ultrasonic testing

When required by the Classification Society or when deemed necessary by the manufacturer, further non-destructive testing (e.g. radiographic and/or ultrasonic testing) are to be carried out. The acceptance criteria or applied quality levels are then to be agreed between the manufacturer and the Classification Society in accordance with a recognized standard.

Note: due to the attenuating effect of ultrasound within 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.

10. Acceptance criteria for liquid penetrant testing and magnetic particle testing

10.1 Definitions of liquid penetrant indications

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 (i.e. $l < 3\ w$).

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Linear indication: an indication with a largest dimension three or more times its smallest dimension (i.e. l ≥ 3 w).

Aligned indications:

a) Non-linear indications form an alignment when the distance between indications is less than 2mm and at least three indications are aligned. An alignment of indications is considered to be a unique indication and its length is equal to the overall length of the alignment.

b) Linear indications form an alignment when the distance between two indications is smaller than the length of the longest indication.

Illustration of liquid penetrant indications is given in Fig. 1.

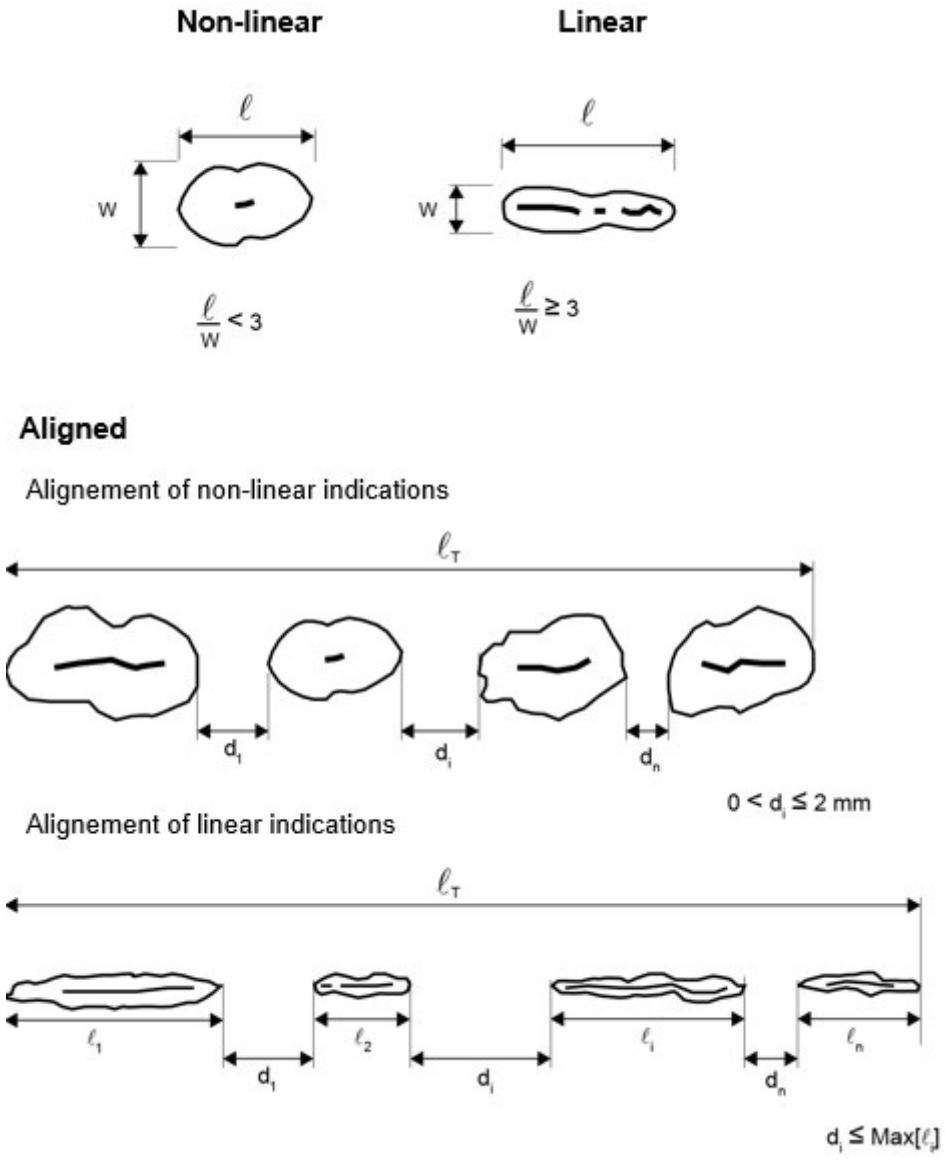

Fig.1 Shape of indications

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10.2 Acceptance standard

The surface to be inspected is to be divided into reference areas of 100 cm^2. Each reference area may be square or rectangular with the major dimension not exceeding 250mm.

The area shall be taken in the most unfavourable location relative to the indication being evaluated.

The relevant indications detected shall with respect to their size and number, not exceed the values given in the Table 3.

Areas which are prepared for welding are independent of their location always to be assessed according to zone A. The same applies to the welded areas after being finished machined and/or grinded.

Table 3 – Allowable number and size of relevant indications in a reference area of 100 cm^2, depending on severity zones[1)]

Severity zones	Max. total number of indications	Type of indication	Max. number for each type [1) 2)]	Max. dimension of indication (mm)
A	7	Non-linear	5	4
		Linear	2	3
		Aligned	2	3
B	14	Non-linear	10	6
		Linear	4	6
		Aligned	4	6
C	20	Non-linear	14	8
		Linear	6	6
		Aligned	6	6

[1)] Single non-linear indications less than 2mm in zone A and less than 3mm ~~in~~ for the other zones are not considered relevant.

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

11. Repair of defects

11.1 Defective castings are to be repaired in accordance with the requirements given in 11.2 to 11.7 and, where applicable, the requirements of W27.12.

11.2 In general the repairs are to be carried out by mechanical means, e.g. by grinding, chipping or milling. The resulting grooves are to be blended into the surrounding surface so as to avoid any sharp contours. Complete elimination of the defective material is to be verified by liquid penetrant testing, or magnetic particle testing if applicable.

11.3 Weld repairs are to be undertaken only when they are considered to be necessary and have prior approval of the Surveyor.

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

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11.5 Grinding in severity zone A may be carried out to an extent that maintains the blade thickness. Repair welding is generally not permitted in severity Zone A and will only be allowed after special consideration by the Classification Society.

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 the Society.

11.6 Defects in severity zone B that are not deeper than t/40 mm ("t" is the minimum local thickness according to the Rules) or 2mm, whichever is greatest, are to be removed by grinding. Those defects that are deeper may be repaired by welding subject to prior approval from the Classification Society.

11.7 Repair welding is generally permitted in severity zone C.

11.8 Repair documentation

The foundry is to maintain records of inspections, welding, and any subsequent heat treatment, traceable to each casting.

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 the Classification Society for approval.

12. Welding repair procedure

12.1 Before welding is started, manufacturer shall submit to the Classification Society a detailed welding procedure specification covering the weld preparation, welding parameters, filler metals, preheating and post weld heat treatment and inspection procedures.

12.2 All weld repairs are to be carried out in accordance with qualified procedures, and, by welders who are qualified to a recognized standard. Welding Procedure Qualification Tests are to be carried out in accordance with Appendix A and witnessed by the Surveyor.

Defects to be repaired by welding are to be ground to sound material according to W27.10.

The welding grooves are to be prepared in such a manner which will allow a good fusion of the groove bottom.

The resulting ground areas are to be examined in the presence of the Surveyor by liquid penetrant testing in order to verify the complete elimination of defective material.

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

12.4 Metal arc welding with electrodes or filler wire used in the procedure tests is to be used. The welding consumables are to be stored and handled in accordance with the manufacturer s recommendations.

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

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

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12.7 On completion of heat treatment the weld repairs and adjacent material are to be ground smooth. All weld repairs are to be liquid penetrant tested.

13. Identification and marking

13.1 The manufacturer is to adopt a system for the identification of all castings, which enable the material to be traced to its original cast. The Surveyor is to be given full facilities for so tracing the castings when required.

Each finished casting propeller shall be marked by the manufacturer at least with the following particulars:

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

b) Grade of cast material or corresponding abbreviated designation

c) The Society s certificate number;

d) Ice class symbol, where applicable;

e) Skew angle for high skew propellers,

f) Date of final inspection.

13.2 The Society s stamp is to be put on when the casting has been accepted.

14. Document and certification

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

a) Purchaser s name and order number;

b) Vessel identification, where known;

c) Description of the casting with drawing number;

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

e) Skew angle for high skew propellers;

f) Final weight;

g) Alloy type, heat number and chemical composition;

h) Casting identification number;

i) Details of time and temperature of heat treatment,

j) Results of the mechanical tests,

k) Results of non-destructive tests and details of test procedure where applicable.

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Appendix A: Welding procedure qualification tests for repair of cast steel propeller

1. General

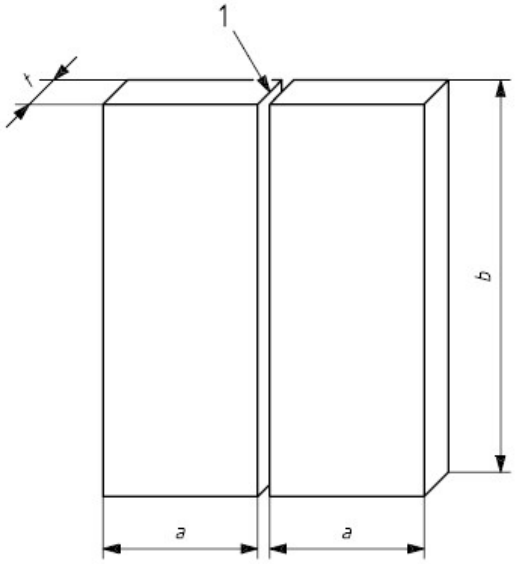
1.1 This document gives requirements for qualification tests of welding procedures intended for the repair of cast steel propellers.

1.2 For the welding procedure approval the welding procedure qualification tests are to be carried out with satisfactory results. The qualification tests are to be carried out with the same welding process, filler metal, preheating and stress-relieving treatment as those intended applied by the actual repair work. Welding procedure specification is to refer to the test results achieved during welding procedure qualification testing.

1.3 Welding procedures qualified at a manufacturer are valid for welding in workshops under the same technical and quality management.

2. Test piece and welding of sample

2.1 The test assembly, consisting of cast samples, is to be of a size sufficient to ensure a reasonable heat distribution and according to Fig.A.1 with the minimum dimensions:



1: Joint preparation and fit-up as detailed in the preliminary Welding Procedure Specification
a: minimum value 150mm
b: minimum value 350mm
t: material thickness

Fig.A.1 Test piece for welding repair procedure

The dimensions and shape of the groove shall be representative of the actual repair work.

2.2 Preparation and welding of test pieces are to be carried out in accordance with the general condition of repair welding work which it represents.

2.3 Welding of the test assemblies and testing of test specimens are to be witnessed by the Surveyor.

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3. Examinations and tests

3.1 Test assembly is are to be examined non-destructively and destructively in accordance with Table A.1 and Fig.A.2:

Table A.1 Type of tests and extent of testing

Type of test	Extent of testing
Visual testing	100% as per article 3.2
Liquid penetrant testing (1)	100% as per article 3.2
Transverse tensile test	Two specimens as per article 3.3
Bend test (2)	Two root and two face specimens as per article 3.4
Macro examination	Three specimens as per article 3.5
Impact test	Two sets of three specimens as per article 3.6
Hardness test	As per article 3.7
(1) Magnetic particle testing may be used in lieu of liquid penetrant testing for martensitic stainless steels. (2) For t≥12mm, the face and root bend may be substituted by 4 side bend test specimens.	

3.2 Non-destructive testing

Test assembly is to be examined by visual and liquid penetrant testing, or magnetic particle testing if applicable, 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.

No cracks are permitted. Imperfections detected by liquid penetrant testing, or magnetic particle testing if applicable, are to be assessed in accordance with W27.10.

3.3 Tensile test

Two flat transverse tensile test specimens shall be prepared. Testing procedures shall be in accordance with IACS UR W2 2.4.2.8 b). Alternatively tensile test specimens according to recognized standards acceptable to the Classification Society may be used.
The tensile strength shall meet the specified minimum value of the base material. The location of fracture is to be reported, i.e. weld metal, HAZ or base material.

3.4 Bend test

Transverse bend tests for butt joints are to be in accordance with UR W2 Rev.02-2003 2.6, or, according to a recognized standard. The mandrel diameter shall be 4 x thickness except for austenitic steels, in which case the mandrel diameter shall be 3 x thickness.

The bending angle is to be 180°. After testing, the test specimens are not to reveal any open defects in any direction greater than 3 mm. Defects appearing at the corners of a test specimen during testing are to be investigated case by case.

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Two root and two face bend specimens are to be tested. For thickness 12 mm and over, four side bend specimens may alternatively be tested.

3.5 Macro-examination

Two macro-sections shall be prepared and etched on one side to clearly reveal the weld metal, the fusion line, and the heat affected zone. Cracks and lack of fusion are not permitted. Imperfections such as slag inclusions, and pores greater than 3mm are not permitted.

3.6 Impact test

Impact test is required, where the base material is impact tested. Charpy V-notch test specimens shall be in accordance with IACS UR W2. Two sets shall be taken, one set with the notch positioned in the center of the weld and one set with the notch positioned in the HAZ (i.e. the mid-point of the notch shall be at 1mm to 2mm from the fusion line), respectively.

The test temperature, and impact energy shall comply with the requirement specified for the base material.

3.7 Hardness test

The macro-section representing the start of welding shall be used for HV 10 hardness testing. Indentations shall traverse 2mm below the surface. At least three individual indentations are to be made in the weld metal, the HAZ (both sides) and in the base metal (both sides). The values are to be reported for information.

3.8 Re-testing

If the test piece fails to comply with any of the requirements of this Appendix, reference is made to re-test procedures given in UR W28.

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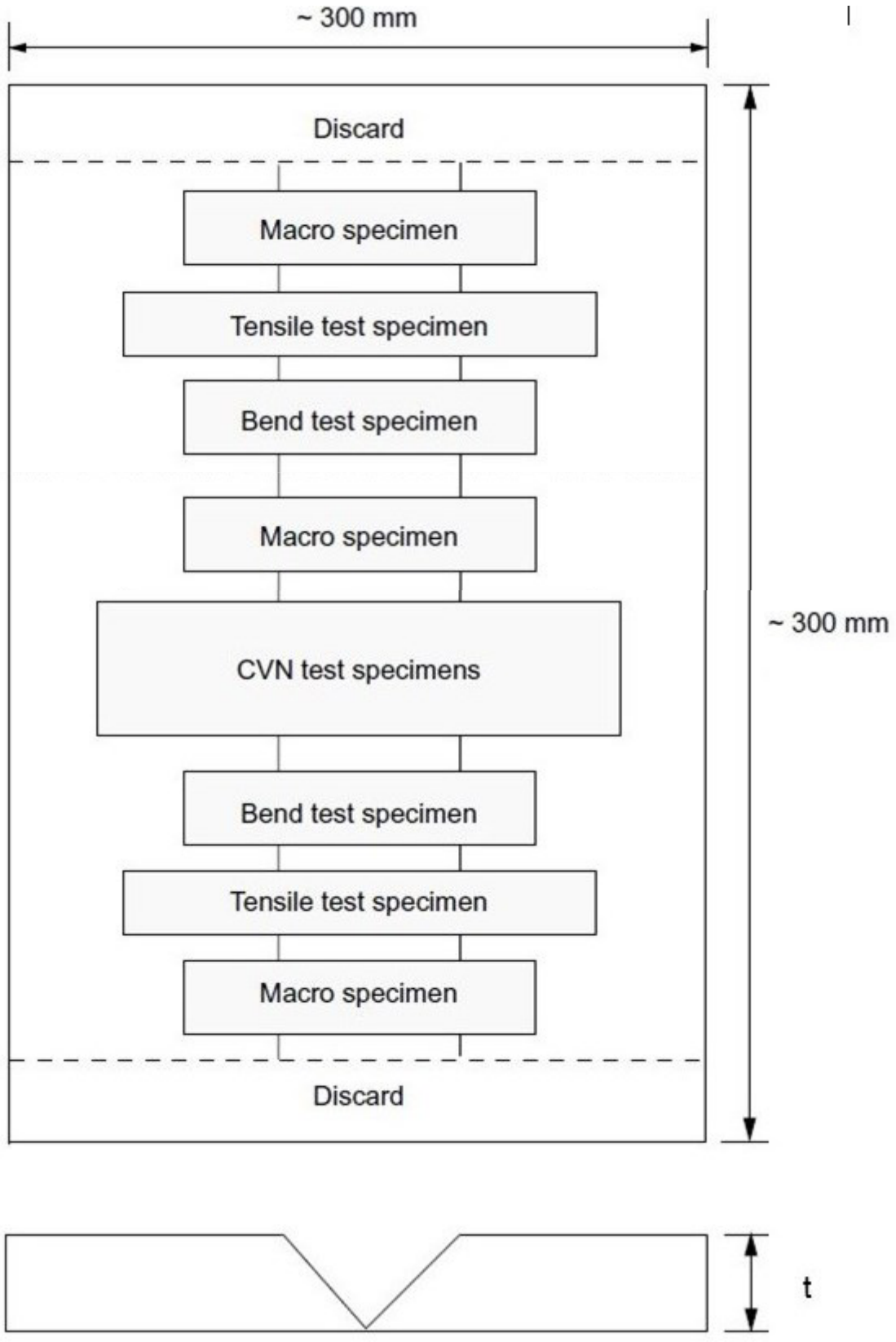

Fig.A.2 Weld test assembly

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4. Test record

4.1 Welding conditions for test assemblies and test results are to be recorded in welding procedure qualification. Forms of welding procedure qualification records can be taken from the Society's rules or from relevant standards.

4.2 A statement of the results of assessing each test piece, including repeat tests, is to be made for each welding procedure qualification records. The relevant items listed for the WPS are to be included.

4.3 The welding procedure qualification record is to be signed by the Surveyor witnessing the test and is to include the Society´s identification.

5. Range of approval

5.1 General

All the conditions of validity stated below are to be met independently of each other. Changes outside of the ranges specified are to require a new welding procedure test.

A qualification of a WPS obtained by a manufacturer is valid for welding in workshops or sites under the same technical and quality control of that manufacturer.

5.2 Base metal

Range of approval for steel cast propeller is limited to steel grade tested.

5.3 Thickness

The qualification of a WPS carried out on a weld assembly of thickness t is valid for the thickness range given in Table A.2.

Table A.2 Range of qualification for thickness

Thickness of the test piece, t (mm)	Range of approval
15<t≤30	3mm to 2t
t>30	0,5t to 2t or 200mm, whichever is the greater

5.4 Welding position

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

5.5 Welding process

5.5.1 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 used in this UR.

5.6 Filler metal

The approval is only valid for the filler metal used in the welding procedure test.

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5.7 Heat input

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.

5.8 Preheating and 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.

5.9 Post-weld heat treatment

The heat treatment used in the qualification test is to be specified in pWPS. Holding time may be adjusted as a function of thickness.

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