



RULES

PUBLICATION 71/P

NON-DESTRUCTIVE TESTING OF HULL MARINE STEEL CASTINGS

January
2022

Publications P (Additional Rule Requirements) issued by Polski Rejestr Statków complete or extend the Rules and are mandatory where applicable.

GDAŃSK

Publication 71/P – Non-Destructive Testing of Hull Marine Steel Castings – January 2022, based on the IACS Guidelines (Recommendation No. 69 (Rev. 1, May 2004)), is an extension of the requirements contained in *Part IX – Materials and Welding* of the *Rules for the Classification and Construction of Sea-going Ships*.

This Publication was approved by PRS Board on 21 December 2021 and enters into force on 1 January 2022.

This Publication also applies to other PRS regulations if it is mentioned there.

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1 GENERAL

1.1 This *Publication* contains guidelines on the extent, methods and recommended quality levels applicable to the non-destructive testing of marine steel castings, except in those cases where alternative criteria have been otherwise approved or specified.

1.2 This *Publication* contains guidelines on surface inspections by visual testing, magnetic particle testing and liquid penetrant testing as well as volumetric inspection by radiographic testing and ultrasonic testing.

1.3 Although no detailed guidelines are given for machinery components, the requirements in these guidelines may apply correspondingly considering their materials, kinds, shapes and stress conditions to which such components will be subjected.

1.4 Castings intending to be examined by NDT methods are identified in Annex 1. The list of castings is not definitive. Criteria for the inspection of other castings not listed in Annex 1 will be subject to agreement with PRS.

1.5 PRS Rules Part IX or this *Publication* do not include every cast component type that may be subject to classification. In such cases where the particular component or type is not included, appropriate national or international standards may be applied, to determine the appropriate testing regime and defect acceptance criteria.

1.6 These guidelines complement and reference the requirements of the PRS Rules and contain general guidance for the non-destructive testing methods, the extent of testing and the minimum recommended quality levels that shall be complied with unless otherwise approved or specified.

1.7 Castings shall be examined in the final delivery condition.

1.8 Where intermediate inspections have been performed the manufacturer shall provide reports of the results upon the request of PRS surveyor.

1.9 Where a casting is supplied in semi-finished condition, the manufacturer shall take into account the quality level of final finished machined components.

1.10 Where advanced ultrasonic testing methods are applied, e.g. PAUT or TOFD, reference is made to *Publication No. 80/P*, for general approach in adopting and application of these advanced methods. Acceptance levels regarding accept/reject criteria are specified in the applicable section in this *Publication*.

2 PERSONNEL QUALIFICATION

2.1 Personnel carrying out non-destructive testing shall be certified to ISO 9712 or equivalent national or international standard. Qualifications issued in compliance with other schemes, including employer-based schemes, are subject to PRS acceptance in each particular case).

2.2 Personnel responsible for the NDT activity including approval of procedures should be qualified and certified to level 3.

2.3 The NDT personnel's certificates and competence should comprise all industrial sectors and techniques being applied by the manufacturer or its subcontractors.

2.4 Certificates shall be made available to PRS for verification, when requested.

2.5 The operator carrying out the NDT and interpreting indications, should as a minimum, be qualified and certified to level 2 in the NDT method(s) concerned. 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 shall have adequate knowledge of material, weld, structures or components, NDT equipment and limitations that are sufficient to apply the relevant NDT method for each application appropriately.

3 CASTING CONDITION

3.1 Heat Treatment

3.1.1 Non-destructive testing applied for acceptance purposes to support final casting certification shall be conducted after the final heat treatment of the casting. For detailed requirements see paragraphs 3.2.1 and 3.2.2.

3.1.2 Where intermediate inspections have been performed, the manufacturer shall provide reports of the results upon PRS Surveyor's request.

3.2 Surface Condition

3.2.1 Castings shall be tested in the final delivery condition free from any material such as scale, dirt, grease, paint and other impurities that might affect the effectiveness of the inspection and interpretation of indications. A thin coating of contrast paint is permissible when using magnetic particle techniques. For surface inspection NDT methods, the surface quality shall be a minimum value of $R_a \leq 6.3 \mu\text{m}$.

3.2.2 Ultrasonic testing shall be carried out after the castings have been ground, machined or shot blasted to a suitable condition, with a minimum value surface quality of $R_a \leq 12.5 \mu\text{m}$. The surfaces of castings to be tested shall be such that adequate coupling can be established between the probe and the casting and that excessive wear of the probe is avoided.

4 EXTENT OF INSPECTIONS

4.1 Zones to be Tested

4.1.1 Zones to be examined in nominated castings are identified in Annex 1. Testing shall be made in accordance with an inspection plan approved by PRS. The plan shall specify the extent of the testing, the testing procedure, the quality level or, if necessary, the level for different locations of the castings.

4.1.2 In addition to the areas identified in Annex 1, surface inspections shall be carried out in the following locations:

- at all accessible fillets and changes of section,
- in way of fabrication weld preparation, for a band width of 30 mm,
- in way of chaplets,
- in way of weld repairs,
- at positions where surplus metal has been removed by flame cutting, scarifying or arc-air gouging.

4.1.3 Ultrasonic testing shall be carried out in the zones indicated in Figures 1 to 6 and also in the following locations:

- in way of all accessible fillets and at pronounced changes of section,
- in way of fabrication weld preparations for a distance of 50 mm from the edge,
- in way of weld repairs where the original defect was detected by ultrasonic testing,

- in way of riser positions,
- in way of machined areas particularly those subject to further machining such as bolt hole positions.

In the case of castings such as rudder horns, which may have a large surface area still untested after the inspections specified in paragraphs 4.1.1 to 4.1.3 have been applied, an additional ultrasonic testing of the untested areas shall be made along continuous perpendicular grid lines on nominal 225 mm centres, scanning from one surface only.

5 TESTING PROCEDURES

5.1 Visual Testing

Steel castings covered by this Publication shall be subjected to a 100% visual testing of all accessible surfaces by the **manufacturer and made available to the** PRS Surveyor. **Viewing** conditions at the inspected surfaces shall fulfil the requirements specified in the relevant national or international standard (e.g. EN 13018¹).

Unless otherwise agreed, the visual, magnetic particle and liquid penetrant testing shall be carried out in the presence of PRS Surveyor.

5.2 Surface Inspection

5.2.1 The testing procedures, apparatus, conditions and test media used for magnetic particle testing and penetrant testing shall fulfil the requirements specified in the relevant national or international standards (e.g. **EN ISO 3452-1**, EN 1369).

Magnetic particle testing shall be carried out in preference to penetrant testing except in the following cases:

- austenitic stainless steels,
- interpretation of open visual or magnetic particle indications,
- at the instruction of PRS Surveyor, **when a particular need for penetrant testing has been identified.**

5.2.2 For magnetic particle testing attention shall be paid to the contact between the casting and the clamping devices of stationary magnetisation benches in order to avoid local overheating or burning damage in its surface. Prods are permitted on finished machined items provided they are applied with special care. Note that the use of solid copper at the prod tips must be avoided due to the risk of copper **contamination into casting. The pole of the magnets shall have close contact with the component.**

5.2.3 **AC magnetisation method shall normally be used, as it is more sensitive for detecting surface indications. Where DC magnetisation method is used, this shall be in agreement with PRS, and the reason for use clearly stated.**

5.2.4 When indications have been detected as a result of the surface inspection, acceptance or rejection shall be decided by PRS Surveyor in accordance with the requirements specified in Chapter 6.

¹ EN 13018:2016 – Non-destructive testing. Visual testing. General principles.

5.3 Ultrasonic Testing

5.3.1 Ultrasonic testing shall be carried out using the contact method with **normal (0°)** beam and/or angle beam technique. The testing procedures, apparatus and conditions of ultrasonic testing shall fulfil the requirements specified in the relevant national or international standards (e.g. **EN ISO 16810**).

5.3.2 In some cases, due to the shape, nature, complexity of casting, or defect type or orientation, there may be a need for radiographic testing. In such cases, radiographic testing may be carried out on the basis of prior agreement with PRS. Where radiographic testing is to be applied, national or international standards (e.g. ISO 4993) for both the testing method, and the quality or severity level to be applied, shall be agreed with PRS.

A suitable quality level for marine castings would normally be severity level 2 or 3 of the above standard, depending on the location zone and the type of casting. Other severity levels may be applied, and should be agreed with PRS.

5.3.3 Only the areas indicated in the agreed inspection plan shall be tested, however, the inspections may reveal indications that require further evaluation, or an extension of testing. In such cases, this shall be agreed with PRS. The plan shall include those locations nominated in paragraph 4.1.3 together with the scanning zones identified for the relevant casting in Annex 1.

5.3.4 Ultrasonic scans are to be done using a 0° probe of 1 ÷ 4 MHz (usually 2 MHz) frequency, and angle probes, where required. Whenever possible scanning shall be performed from both perpendicular surfaces of the casting.

5.3.5 The back wall echo obtained on parallel sections shall be used to monitor variations in probe coupling and material attenuation. Any reduction in the amplitude of the back wall echo due to material properties shall be corrected. Attenuation in excess of 30 dB/m indicates an unsatisfactory annealing heat treatment, and may render the effectiveness of the testing as unsuitable. In such cases of excessive attenuation, this shall be investigated, and suitable mitigation measures carried out for effective ultrasonic testing to continue, where possible.

5.3.6 Machined surfaces, especially those in the vicinity of riser locations and in the bores of stern boss castings, shall be subjected to a near surface (approximately 25 mm) scan using a twin crystal 0° probe.

Additional scans on machined surfaces are of particular importance in cases where boltholes are to be drilled or where surplus material such as 'padding' has been removed by machining. Additionally, it is good practice to examine the machined bores of castings using circumferential scans with 70° probes in order that axial radial planar flaws such as hot tears can be detected. Fillet radii should be tested using 45°, 60° or 70° probes scanning from the surfaces/direction likely to give the best reflection, primarily to determine the presence of any cracks within the radiused areas, and as an additional scan to confirm any indications that may have been detected with 0° probe(s) within this area.

5.3.7 Before ultrasonic testing the reference sensitivity shall be established against a 6 mm reflector. Sensitivity can be calibrated either against a 6 mm diameter flat bottomed hole(s) in a reference block (or series of blocks) corresponding to the thickness of the casting provided that a transfer correction is made, using the DAC (distance-amplitude-correction) method, or by using the DGS (distance-gain-size) method.

The reference sensitivity of angle probes (where required for testing) shall be established against an appropriate 6 mm reflector (e.g. reference reflectors angled perpendicular to the sound beam) for the DAC method, or equivalent using the DGS method.

The DGS diagrams issued by a probe manufacturer identify the difference in dB between the amplitude of a back wall echo and that expected from a 6 mm diameter disk reflector.

By adding this difference to the sensitivity level initially set by adjusting a back wall echo to a reference height, e.g. 80%, the amended reference level will be representative of a 6 mm diameter disk reflector. Similar calculations can be used for evaluation purposes to establish the difference in dB between a back wall reflector and disk reflectors of other diameters such as 12 or 15 mm.

5.3.8 After any necessary corrections have been made for differences in attenuation or surface condition between the reference block and the casting, any indications received from the nominated zones in the casting that exceed the 6 mm reference level shall be marked for evaluation against the criteria given in paragraph 6.3. Evaluation shall include additional scans with angle probes in order that the full extent of the discontinuity can be plotted.

6 ACCEPTANCE CRITERIA

6.1 Visual Testing

6.1.1 All castings shall be free of cracks, crack-like indications, hot tears, cold shuts or other injurious indications. Thickness of the remains of sprues or risers is to be within the casting dimensional tolerance.

6.1.2 In justified cases additional magnetic particle, penetrant or ultrasonic testing may be required by PRS Surveyor for a more detailed evaluation of surface irregularities.

6.2 Magnetic Particle or Penetrant Testing

6.2.1 The following definitions relevant to indications apply:

Linear indication – an indication with a largest dimension three or more times its smallest dimension (i.e. $l \geq 3 w$).

Non-linear indication – an indication with a largest dimension less than three times its smallest dimension (i.e. $l < 3 w$).

Aligned indication – a) non-linear indications form an alignment when the distance between indications is less than 2 mm 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.

Open indication – an indication visible after removal of the magnetic particles or that can be detected by the use of penetrant testing.

Non-open indication – an indication that is not visually detectable after removal of the magnetic particles or that cannot be detected by the use of penetrant testing.

Relevant indication – an indication that is caused by a condition or type of discontinuity which requires evaluation. Only indication with any dimension greater than 1.5 mm shall be considered relevant for the categorization of indications.

6.2.2 To evaluate indications, the surface shall be divided into reference band length of 150 mm for level MT1/PT1 and into reference areas of 225 cm² for level MT2/PT2. The band length and/or area shall be taken in the most unfavourable location relative to the indications being evaluated.

6.2.3 For magnetic particle testing (MT) and/or penetrant testing (PT) the following quality levels are required:

Level MT1/PT1 – fabrication weld preparation and weld repairs.

Level MT2/PT2 – other locations indicated in 4.2.2.

The allowable numbers and sizes of indications in the reference band length and/or area are given in Table 6.2.3. The required quality level shall be shown on the manufacturer's inspection plan. Cracks and hot tears **shall not be accepted**.

Table 6.2.3
Allowable number and size of indications in reference band length/area

Quality level	Total maximum number of all indications	Type of indication	Maximum number of each type of indication	Maximum dimension of single indication [mm] ²
MT1/PT1	4 in 150 mm length	non-linear	4 ¹⁾	5
		linear	4 ¹⁾	3
		aligned	4 ¹⁾	3
MT2/PT2	20 in 225 cm ² area	non-linear	10	7
		linear	6	5
		aligned	6	5
Notes:				
1) 30 mm minimum (measured in any direction) between relevant indications.				
2) In weld repairs, the maximum dimension is 2 mm.				

6.3 Ultrasonic Testing

6.3.1 Acceptance criteria for ultrasonic testing are specified in Table 6.3.4. As stated in paragraph 4.2.1, the quality levels applicable to the zones to be tested shall be identified on an inspection plan.

For ultrasonic testing (UT), the following quality levels are required:

Level UT1

- fabrication weld preparations for a distance of 50 mm, from the weld edge,
- 50 mm depth from the final machined surface including boltholes,
- fillet radii to a depth of 50 mm and within distance of 50 mm from the radius end,
- castings subjected to cycling bending stresses e.g. rudder horn, rudder castings and rudder stocks – the outer one third of thickness in the zones nominated for ultrasonic testing according to **Annex 1**,
- discontinuities within the tested zones interpreted to be cracks or hot tears.

Level UT2

- other locations nominated for ultrasonic testing according to **Annex 1** or the inspection plan,
- positions outside the locations nominated for level UT1 testing where feeders and gates have been removed,
- castings subject to cycling bending stresses – at the central one third of thickness in the zones of nominated for ultrasonic testing according to **Annex 1**.

6.3.2 For near surface testing (to an approximate depth of 25 mm) twin crystal 0° (normal beam) probe shall be used, plus a 0° probe (usually single crystal beyond a depth of 25 mm) for the remaining volume.

6.3.3 Ultrasonic testing acceptance criteria for other castings areas not nominated in Annex 1 are subject to PRS approval in each particular case based on the anticipated stress levels and the type, size and position of the discontinuity.

6.3.4 Table 6.3.4 describes the acceptance criteria for both methods of applied sensitivity (DGS and DAC).

Table 6.3.4
Ultrasonic acceptance criteria for steel castings

Quality level	Allowable disc shape according to DGS ¹⁾ or diameter of FBH according to DAC ^{2),3)} curve [mm]	Maximum number of indications to be registered ⁴⁾	Allowable size of all relevant indications ^{5), 6)} [mm]
UT1	>6	0	0
UT2	12-15	5	50
	>15	0	0

Notes:

- 1) DGS – distance-gain-size.
- 2) DAC – distance amplitude correction.
- 3) The corresponding DAC level to each of the FBH reflectors is at 100% DAC.
- 4) Grouped in an area measuring 300 x 300 mm.
- 5) Measured on the scanning surface.
- 6) The measured indication is regarded as the longest dimension, as measured in the scanning process.

6.3.5 DGS and DAC methods may be used for determining sensitivity. The DAC method for normal beam probes may be based on a 6.0 mm diameter reflector or flat bottomed hole (FBH). A DAC curve shall be produced using reference blocks containing 6.0 mm FBH reflectors over a range representative of the inspection thickness, after adjustment for transfer and attenuation losses.

6.3.6 For quality level UT1, any discontinuity producing a signal amplitude in excess of the 6.0 mm DAC curve is unacceptable.

6.3.7 For quality level UT2, the sensitivity may be base on actual size FBH (of 12 and 15 mm) or based on equivalent 6 mm FBH, and the sensitivity adjusted to obtain equivalent amplitudes, as described in 6.3.8.

6.3.8 For use of FBH of 6 mm for setting sensitivity, adjustment of signal amplitudes (measured in dB above 6 mm DAC) can be determined for 12 mm and 15 mm FBH reflectors: to be DAC+12 dB and DAC+16 dB (plus any compensation for transfer and attenuation losses). This is illustrated in Figure 6.3.8. The increase in dB to the indicated levels represent the equivalent FBH sizes (for 12 mm and 15 mm), and their respective corresponding ultrasonic response amplitudes.

6.3.9 The maximum number of indications to be registered and the maximum length of indications permissible for quality level 2 (as stated in Table 6.3.4) apply to normal probes.

6.3.10 For quality level UT2, any discontinuity producing a signal amplitude in excess of the 15.0 mm DAC curve shall be regarded as unacceptable.

6.3.11 Any signal between DAC+12 dB and DAC+15 dB curves shall be evaluated for length of defect, and referred to Table 6.3.4 for acceptance.

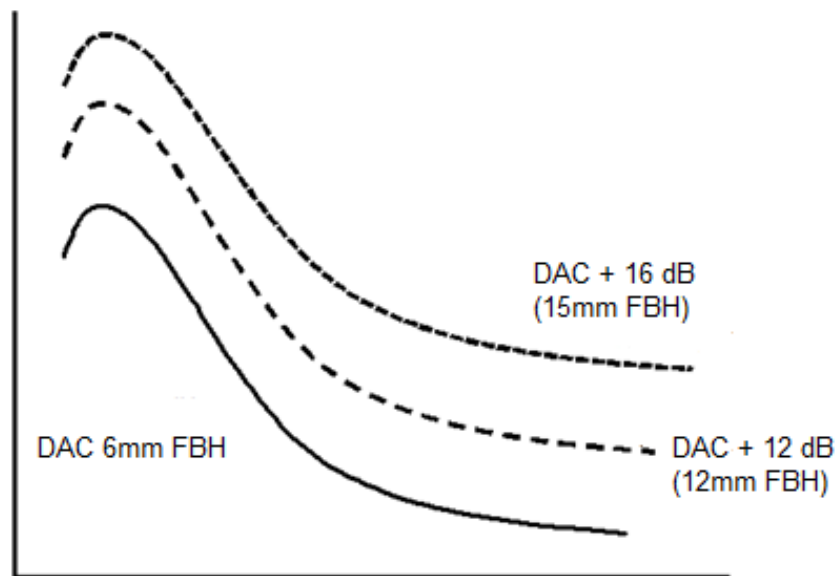


Fig. 6.3.8 – DAC curve produced from 6.0 mm FBH reflector and DAC curves adjusted to represent equivalent 12.0 mm and 15.0 mm FBH reflectors.

NOTE: The bottom curve (DAC) represents a sensitivity based on 6 mm FBH, and the two additional curves (DAC+12 dB and DAC+16 dB) above this represent the equivalent sensitivities converted for larger FBH's (12 mm and 15 mm). When scanning using these curves, and applying Table 6.3.4 acceptance criteria for UT2, any indication below DAC+12 dB shall be disregarded, and any indication above DAC+16 dB shall be rejected. Any indication between these two curves shall be evaluated according to its size, as per Table 6.3.4.

7 REPORTING

7.1 Reports of non-destructive testing shall include at least the following items:

- .1 date of testing,
- .2 names, signatures and qualification level of inspection personnel,
- .3 type of casting,
- .4 unique product identification, e.g. number,
- .5 grade of steel,
- .6 heat treatment,
- .7 stage of testing,
- .8 locations and zones for testing,
- .9 surface condition,
- .10 test standards and/or instructions used, including reference to the appropriate tables for acceptance purposes,
- .11 results, including documentation regarding the repair and testing history (as appropriate),
- .12 statement of acceptance/non-acceptance,
- .13 locations of reportable indications,
- .14 details of weld repairs including sketches (where applicable).

7.2 In addition to the items listed in 7.1, reports of surface inspections shall include at least the following items:

- for penetrant testing: the penetrant system used,

- for magnetic particle testing: method of magnetising, test media, magnetic field strength and magnetic flux indicators (where appropriate),
- viewing condition (as appropriate to the penetrant or magnetic technique and media used),
- testing details and procedure number,
- details of any test restrictions.

7.3 In addition to the items listed in 7.1, reports of ultrasonic inspection shall include at least the following items:

- flaw detector, probe type, size, angle and frequency (and any adaptations to probes for curved surfaces), calibration and reference blocks, sensitivity method (including reflector size, transfer correction), maximum scanning rate (mm/s) and couplant.

8 RECTIFICATION OF DEFECTS

8.1 Indications that exceed the requirements of Tables 6.2.3 and 6.3.4 shall be classed as defects, and shall be repaired or rejected as appropriate, according to the requirements of PRS Rules.

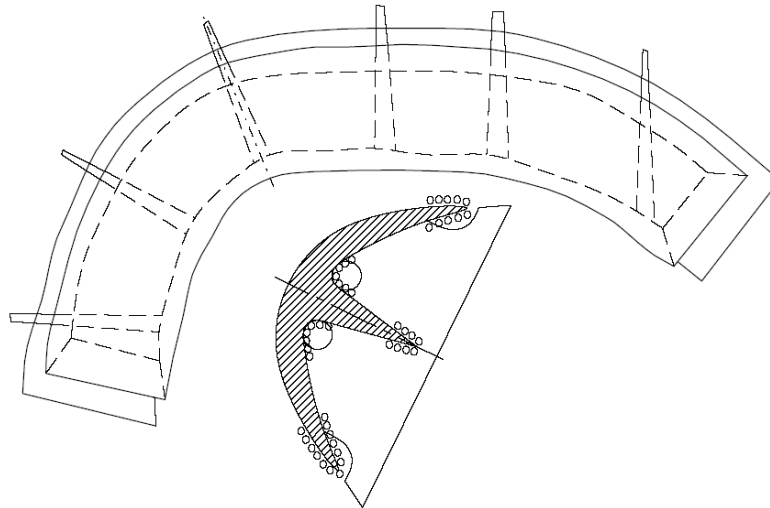
8.2 Generally it may be permissible to remove shallow indications by light grinding where it is acceptable by PRS Rules.

8.3 Complete removal of the defect shall be proved by magnetic particle testing or penetrant testing, as appropriate.

8.4 Castings which are repaired shall be tested by the same method as at initial inspection as well as by additional methods required by PRS Surveyor.

ANNEX 1

Extent and methods of non-destructive testing that shall be applied to typical hull steel castings.

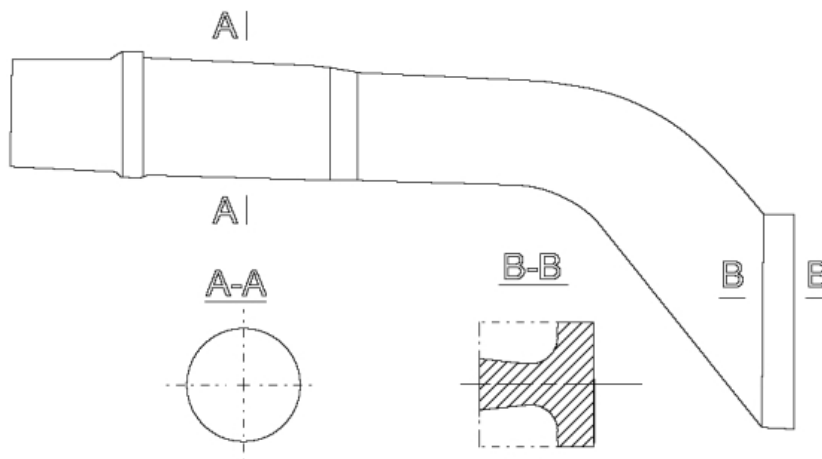


Notes:

Location of non-destructive testing:

1. All surfaces – visual testing.
2. Locations indicated with (0000) – magnetic particle and ultrasonic testing.
3. The detailed extents of testings and quality levels are given in Chapters 4 and 6.

Fig. A1 – Stern frame

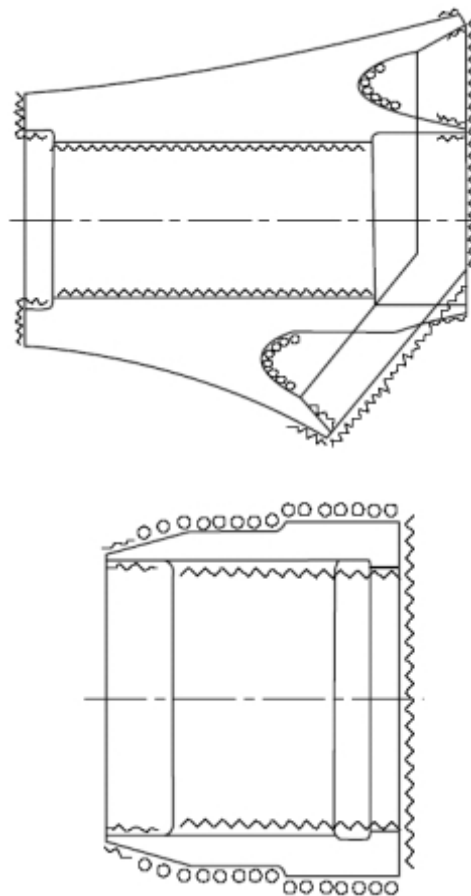


Notes:

Location of non-destructive testing:

1. All surfaces – visual testing, magnetic particle and ultrasonic testing.
2. The detailed extents of testings and quality levels are given in Chapters 4 and 6.

Fig. A2 – Rudder stock

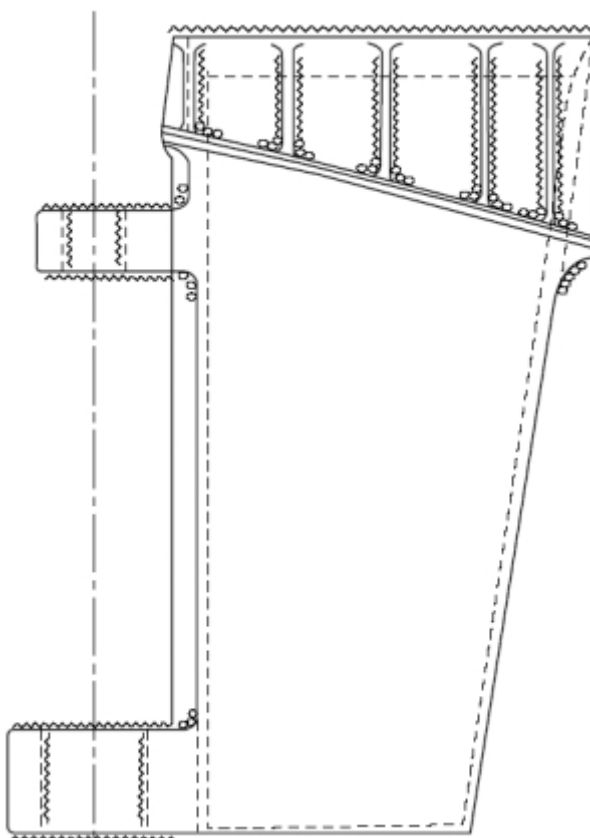


Notes:

Location of non-destructive testing:

1. All surfaces – visual testing.
2. Locations indicated with (O000) – magnetic particle and ultrasonic testing.
3. Locations indicated with (^ ^ ^ ^ ^) – ultrasonic testing.
4. The detailed extents of testings and quality levels are given in Chapters 4 and 6.

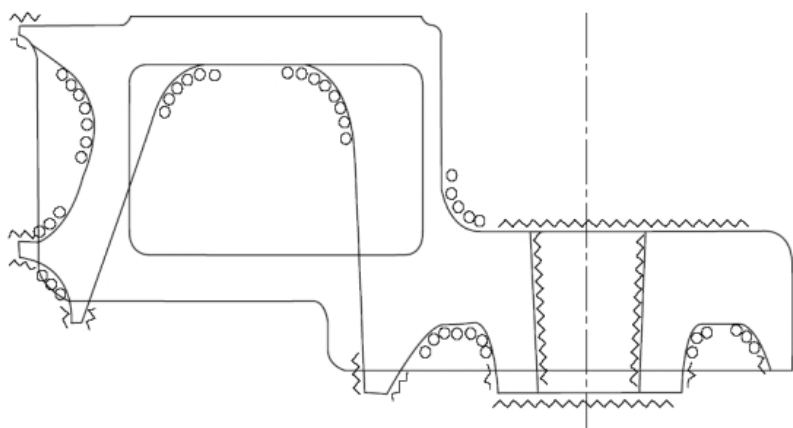
Fig. A3 – Stern boss

**Notes:**

Location of non-destructive testing:

1. All surfaces – visual testing.
2. Locations indicated with (0000) – magnetic particle and ultrasonic testing.
3. Locations indicated with (^ ^ ^ ^ ^) – ultrasonic testing.
4. The detailed extents of testings and quality levels are given in Chapters 4 and 6.

Fig. A4 – Rudder hangings

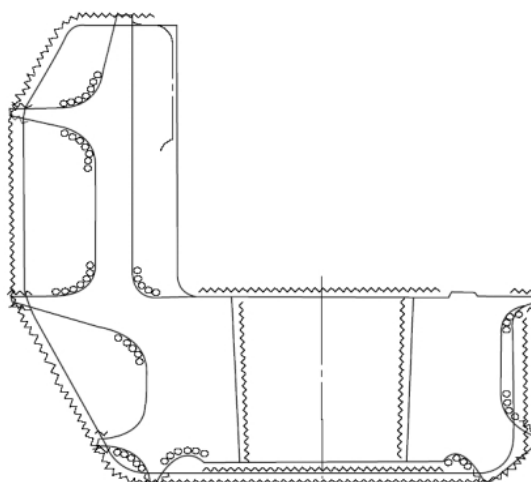


Notes:

Location of non-destructive testing:

1. All surfaces – visual testing.
2. Locations indicated with (0000) – magnetic particle and ultrasonic testing.
3. Locations indicated with (^^^^) – magnetic particle and ultrasonic testing.
4. The detailed extents of testings and quality levels are given in Chapters 4 and 6.

Fig. A5 – Rudder (upper part)



Notes:

Location of non-destructive testing:

1. All surfaces – visual testing.
2. Locations indicated with (0000) – magnetic particle and ultrasonic testing.
3. Locations indicated with (^^^^) – ultrasonic testing.
4. The detailed extents of testings and quality levels are given in Chapters 4 and 6.

Fig. A6 – Rudder (lower part)

List of amendments effective as of 1 January 2022

<i>Item</i>	<i>Title/Subject</i>	<i>Source</i>
5.2.1	Surface Inspection	update of standard
5.3.1	Ultrasonic Testing	update of standard
1.4 – 1.10	General	IACS Rec. 69 (Rev. 2 Oct 2020)
2.1, 2.3, 2.4, 2.5	Personnel Qualification	IACS Rec. 69 (Rev. 2 Oct 2020)
3.1.1, 3.1.2	Heat Treatment	IACS Rec. 69 (Rev. 2 Oct 2020)
3.2.1, 3.2.2	Surface Condition	IACS Rec. 69 (Rev. 2 Oct 2020)
4	Extent of Inspections – revision of section title	IACS Rec. 69 (Rev. 2 Oct 2020)
4.1.1, 4.1.2	Zones to be Tested	IACS Rec. 69 (Rev. 2 Oct 2020)
5.1, 5.2, 5.3	Testing Procedures	IACS Rec. 69 (Rev. 2 Oct 2020)
6.2.1	Definitions	IACS Rec. 69 (Rev. 2 Oct 2020)
6.2.3, Table 6.2.3	Magnetic Testing or Penetrant Testing	IACS Rec. 69 (Rev. 2 Oct 2020)
6.3, Table 6.3.4, Fig. 6.3.8	Ultrasonic Testing	IACS Rec. 69 (Rev. 2 Oct 2020)
7.1, 7.2, 7.3	Reporting	IACS Rec. 69 (Rev. 2 Oct 2020)
8	Rectification of Defects	IACS Rec. 69 (Rev. 2 Oct 2020)
Annex 1	Extent and methods of NDT	IACS Rec. 69 (Rev. 2 Oct 2020)