
No.20 Non-destructive testing of ship hull steel welds

(1988)
(Rev.1
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1. General

1.1 This document is intended to give guidance on the minimum requirements on the methods and quality levels that may be adopted for the non-destructive testing (NDT) of ship hull steel welds during new building and ship repair.

1.2 The quality levels given in this document refer to production quality and not to fitness-for-purpose of the welds examined.

1.3 The non-destructive testing is normally to be performed by the Shipbuilder or its subcontractors in accordance with these requirements. The Classification Society's surveyor may require to witness some testing.

1.4 It should be the Shipbuilder's responsibility to assure that testing specifications and procedures are adhered to during the construction and the report is made available to the Classification Society on the findings made by the NDT.

1.5 The extent of testing and the number of checkpoints are normally agreed between the ship yard and the Classification Society.

2. Limitations

2.1 Materials

2.1.1 This document applies to fusion welds made in normal and higher strength hull structural steels in accordance with UR W11, high strength quenched and tempered steels in accordance with UR W16 and connections welds with hull steel forgings in accordance with UR W7 and hull steel castings in accordance with UR W8.

2.2 Welding processes

2.2.1 This document applies to fusion welds made using shielded metal arc welding, flux cored arc welding, gas metal arc welding, gas tungsten arc welding, submerged arc welding, electro-slag welding and electro-gas welding processes.

2.3 Weld joints

2.3.1 This document applies to butt welds with full penetration, tee, corner and cruciform joints with or without full penetration, and fillet welds.

2.4 Timing of NDT

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

2.4.2 For steels with specified minimum yield stress of 420 N/mm² and above, NDT should not be carried out before 48 hours after completion of welding. Where post weld heat treatment (PWHT) is carried out the requirement for testing after 48 hours may be relaxed.

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2.5 Testing methods

2.5.1 The methods mentioned in this document for detection of surface imperfections are visual testing (VT), liquid penetrant testing (PT) and magnetic particle testing (MT). The methods mentioned for detection of internal imperfections are ultrasonic testing (UT) and radiographic testing (RT).

2.5.2 Applicable methods for testing of the different types of weld joints are given in Table 1.

Table 1: Applicable methods for testing of weld joints

| WELD JOINT | PARENT MATERIAL THICKNESS | APPLICABLE TESTING METHODS |
|--|---------------------------|-----------------------------|
| Butt welds with full penetration | thickness \leq 10mm | VT, PT, MT, RT |
| | thickness $>$ 10mm | VT, PT, MT, UT, RT |
| Tee joints, corner joints and cruciform joints with full penetration | thickness \leq 10mm | VT, PT, MT |
| | thickness $>$ 10mm | VT, PT, MT, UT |
| Tee joints, corner joints and cruciform joints without full penetration and fillet welds | All | VT, PT, MT, UT ¹ |

Note:

- 1) UT can be used to monitor the extent of penetration in tee, corner and cruciform joints.

3. Qualification of personnel involved in NDT

3.1 For each inspection method, operators should be qualified according to a nationally recognised scheme with a grade equivalent to level II qualification of ISO 9712, SNT-TC-1A, EN 473 or ASNT Central Certification Program (ACCP). Operators qualified to level I may be engaged in the tests under the supervision of personnel qualified to level II or III.

3.2 Personnel responsible for the preparation and approval of NDT procedures should be qualified according to a nationally recognised scheme with a grade equivalent to level III qualification of ISO 9712, SNT-TC-1A, EN 473 or ASNT Central Certification Program (ACCP).

3.3 Personnel qualifications should be verified by certification.

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(cont)**4. Surface condition**

4.1 Zones to be examined should be free from scale, loose rust, weld spatter, oil, grease, dirt or paint that might affect the sensitivity of the testing method.

5. General method of testing

5.1 The extent of testing should be planned by the Shipbuilder according to the ship design, ship type and welding processes used. Particular attention should be paid to highly stressed areas.

5.2 For each construction, the Shipbuilder should submit a plan for approval by the Classification Society, specifying the areas to be examined and the extent of testing with reference to the NDT procedures to be used. The plan should only be released to the personnel in charge of the NDT and its supervision.

5.3 The identification system should identify the exact locations of the lengths of weld examined.

5.4 All welds should be subject to visual testing by personnel designated by the Shipyard.

5.5 As far as practicable, magnetic particle testing should be preferred over liquid penetrant testing and should cover a minimum weld length of 500mm.

5.6 Welded connections of large cast or forged components (stern frame, stern boss, rudder parts, shaft brackets...) should be tested over their full length using MT or PT and at agreed locations using RT or UT.

5.7 As given in Table 1, UT or RT or a combination of UT and RT can be used for testing of butt welds with full penetration of 10mm thickness or greater. Methods to be used should be agreed with the Classification Society.

5.8 All start/stop points in welds made using automatic (mechanised) welding processes should be examined using RT or UT except for internal members where the extent of testing should be agreed.

5.9 Within the agreed NDT plan, the minimum RT test length should be 300mm and the minimum UT test length should be 500mm.

6. Testing techniques**6.1 General**

6.1.1 The testing method, equipment and conditions should comply with recognised National or International standards, or other documents to the satisfaction of the Classification Society.

6.1.2 Sufficient details should be given in a written procedure for each NDT technique submitted to the Classification Society for acceptance.

6.2 Visual testing

6.2.1 The welds examined should be clean and free from paint.

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(cont)**6.3 Liquid penetrant testing**

6.3.1 The procedure should detail as a minimum the calibration equipment, surface preparation, cleaning and drying prior to testing, temperature range, type of penetrant, cleaner and developer used, penetrant application and removal, penetration time, developer application and development time and lighting conditions during testing.

6.3.2 The surface to be examined should be clean and free from scale, oil, grease, dirt or paint and should include the weld bead and base metal for at least 10mm on each side of the weld, or the width of the heat affected zone, whichever is greater.

6.3.3 The temperature of parts examined should be typically between 5°C and 50°C, outside this temperature range special low/high temperature penetrant and reference comparator blocks should be used.

6.3.4 The penetration time should not be less than 10 minutes and in accordance with the manufacturer's specification. The development time should not be less than 10 minutes and in accordance with the manufacturer's specification, normally between 10-30 minutes.

6.4 Magnetic particle testing

6.4.1 The procedure should detail as a minimum the surface preparation, magnetizing equipment, calibration methods, detection media and application, viewing conditions and post demagnetization.

6.4.2 The surface to be examined should be free from scale, weld spatter, oil, grease, dirt or paint and should be clean and dry.

6.4.3 When using current flow equipment with prods, care shall be taken to avoid local damage to the material. Copper prod tips must not be used. The prod tips should be lead, steel, aluminium or aluminium- copper braid.

6.4.4 To ensure detection of discontinuities of any orientation, the welds are magnetized in two directions approximately perpendicular to each other with a maximum deviation of 30°. Adequate overlapping shall ensure testing of the whole zone.

6.4.5 Continuous wet particle method should be used as far as practicable.

6.5 Radiographic testing

6.5.1 The procedure should detail as a minimum the type of radiation source, considering the thickness to be radiographed, test arrangement and films overlapping, type and position of image quality indicators (IQI), image quality, film system and intensifying screens used if any, exposure conditions, scattered radiation control, film processing, film density and viewing conditions.

6.5.2 Processed films should display hull no., frame no., weld boundary indicators, Port/Starboard, location (or film serial number) and date as radiographic image.

6.5.3 The Classification Society may require to duplicate some radiographs in order that some processed films are handed over to the Society together with testing reports. Alternative method to duplicate the processed film can be agreed with the Society.

6.5.4 The type of source is selected by the shipbuilder in accordance with item 7.2 of ISO 17636.

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6.5.5 Single-wall exposure technique should be used as far as practicable.

6.5.6 The image quality should be verified using an IQI (Image Quality Indicator) in accordance with ISO 19232 or equivalent. In general the IQI is to be placed on the source side of the weld examined. The minimum image quality should be in accordance with Class A of ISO 17636 or equivalent, as given in Table 2 for IQI's of wire type placed on source side.

6.5.7 When using IQI's of wire type, the image of a wire is considered visible on the film if a continuous length of at least 10mm is clearly visible in a section of uniform optical density.

6.5.8 The optical density of the radiographs should be selected by the shipbuilder in accordance with Table 5 of ISO 17636.

6.5.9 Traditional radiographic film may be replaced by digital radiographic techniques where it can be shown, to the satisfaction of the classification society, that the sensitivity of the digital image is better than or equal to the image obtained with traditional radiographic film.

Table 2: Minimum image quality using IQI wire type placed on source side with single wall technique

| NOMINAL THICKNESS RANGE | WIRE NUMBER ¹⁾ VISIBLE ON THE FILM (NOMINAL DIAMETER) |
|-------------------------|--|
| 5mm < t ≤ 7mm | W14 (0.16mm) |
| 7mm < t ≤ 10mm | W13 (0.20mm) |
| 10mm < t ≤ 15mm | W12 (0.25mm) |
| 15mm < t ≤ 25mm | W11 (0.32mm) |
| 25mm < t ≤ 32mm | W10 (0.40mm) |
| 32mm < t ≤ 40mm | W9 (0.50mm) |
| 40mm < t ≤ 55mm | W8 (0.63mm) |
| 55mm < t ≤ 85mm | W7 (0.80mm) |
| 85mm < t ≤ 150mm | W6 (1.0mm) |

Note:

- 1) When using Iridium 192 sources, lower values can be accepted:
 - up to 2 values for 10mm < t ≤ 24mm
 - up to one value for 24mm < t ≤ 30mm

6.6 Ultrasonic testing

6.6.1 The procedure should detail the equipment, type of probes (frequency, angle of incidence), coupling media, type of reference blocks, method for range and sensitivity setting, method for transfer corrections, scanning technique, sizing technique and intervals for calibration checks during testing.

6.6.2 The equipment (instrument and probes) should be verified by the use of appropriate standard calibration blocks at suitable time intervals.

6.6.3 The range and sensitivity should be set prior to each testing and checked at regular intervals as per the procedure and whenever needed.

6.6.4 The scanning surfaces should be sufficiently clean and free from irregularities like rust, loose scale, paint (excluding primer), weld spatter or grooves which may interfere with probe coupling.

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- 6.6.5 The surface profile should be such to avoid loss of probe contact by rocking.
- 6.6.6 The scanning technique should be determined to allow the testing of the entire volume of the weld bead and base metal for at least 10mm on each side of the weld, or the width of the heat affected zone, whichever is greater.
- 6.6.7 The probe frequency should be within the range 2 MHz to 5 MHz.
- 6.6.8 The reference level for testing should be set using a Distance-Amplitude-Corrected curve (DAC curve) for a series of 3mm diameter side-drilled holes in a reference block or other methods like the Distance-Gain-Size (DGS) system based on a disc shaped reflector provided the same sensitivity is achieved. The reference block used should be made in a material giving equivalent ultrasonic response to that of the material to be tested.
- 6.6.9 The indications with an echo height below 33% of DAC curve (DAC minus 10 dB) should be disregarded. The indications with an echo height equal to or exceeding 33% of DAC curve (DAC minus 10 dB) should be evaluated.
- 6.6.10 Base material in the scanning zone should be examined with a straight beam technique to check the absence of imperfections which would interfere with the angle beam technique, unless already demonstrated at a previous fabrication stage.
- 6.6.11 Angle beam technique should be used to search for longitudinal and transverse weld discontinuities. An angle probe with an incident angle of the sound wave equal to that of the weld preparation should be used as a minimum.

7. Acceptance criteria**7.1 General**

- 7.1.1 This section details the acceptance criteria for assessment of the NDT results.
- 7.1.2 As far as necessary, testing techniques should be combined to facilitate the assessment of indications against the acceptance criteria.
- 7.1.3 The assessment of indications not covered by this document should be made in accordance with a standard agreed with the Classification Society.

7.2 Visual testing

- 7.2.1 Acceptance criteria are given in Table 3.

7.3 Liquid penetrant and magnetic particle testing

- 7.3.1 Only the indications which have any dimension greater than 2mm should require evaluation.
- 7.3.2 Welds examined using liquid penetrant or magnetic particle technique should be evaluated on the basis of the criteria for visual testing.

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7.4 Radiographic testing

7.4.1 Acceptance criteria are given in Table 4.

7.4.2 When discontinuities like undercut or incomplete filled groove are detected on a radiograph, additional testing is recommended to state their acceptance. Criteria for visual testing apply.

7.5 Ultrasonic testing

7.5.1 Acceptance criteria are given in Table 5.

7.5.2 The length of the indication should be determined using a suitable technique (like 6dB drop tip location technique).

8. Reporting

8.1 Reports of non-destructive testing required should be prepared by the Shipbuilder and should be made available to the Classification Society.

8.2 Reports of non-destructive testing should include the following generic items:

- (1) date of testing
- (2) names, qualification level and signature of personnel that have performed the testing
- (3) identification of the component examined
- (4) identification of the welds examined
- (5) steel grade, type of joint, thickness of parent material, welding process
- (6) acceptance criteria
- (7) testing standards used
- (8) testing equipment and arrangement used
- (9) any test limitations, viewing conditions and temperature
- (10) results of testing with reference to acceptance criteria, location and size of reportable indications
- (11) statement of acceptance / non-acceptance
- (12) number of repairs if specific area repaired more than twice

8.3 In addition to generic items, reports of liquid penetrant testing should include the following specific items:

- type of penetrant, cleaner and developer used
- penetration time and development time

8.4 In addition to generic items, reports of magnetic particle testing should include the following specific items:

- type of magnetization
- magnetic field strength
- detection media
- viewing conditions
- demagnetization, if required

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8.5 In addition to generic items, reports of radiographic testing should include the following specific items:

- type and size of radiation source
- type of film
- type of intensifying screens
- exposure technique, time of exposure and source-to-film distance
- sensitivity, type and position of IQI
- density
- geometric un-sharpness

8.6 Reports of ultrasonic testing should include the following specific items:

- type and identification of ultrasonic equipment used, probes and couplant
- sensitivity levels calibrated and applied for each probe
- transfer loss correction applied
- type of reference blocks
- signal response used for defect detection

9. Unacceptable indications and repairs

9.1 Unacceptable indications should be eliminated and repaired where necessary. The repair welds should be examined on their full length using magnetic particle and ultrasonic or radiographic testing method.

9.2 When unacceptable indications are found, additional areas of the same weld length should be examined unless the indication is judged isolated without any doubt. In case of automatic welded joints, additional NDT should be extended to all areas of the same weld length.

9.3 The extent of testing can be extended at the surveyor's discretion when repeated non-acceptable discontinuities are found.

9.4 The Shipbuilder should take appropriate actions to monitor and improve the quality of welds to the required level. The repair rate at which corrective action is to be instigated should be identified in the builder's QA system.

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Table 3: Acceptance criteria for visual testing, magnetic particle and liquid penetrant testing

| SURFACE DISCONTINUITY | CLASSIFICATION ACCORDING TO ISO 6520-1 | ACCEPTANCE CRITERIA FOR VISUAL TESTING |
|---|---|---|
| Crack | 100 | not accepted |
| Lack of fusion | 401 | not accepted |
| Incomplete root penetration in butt joints welded from one side | 4021 | not accepted |
| Surface pore | 2017 | Single pore diameter $d \leq 0.25t^{1)}$ for butt welds ($d \leq 0.25a^{1)}$ for fillet welds) with maximum diameter 3mm; 2.5d as minimum distance to adjacent pore. |
| Undercut in butt welds | 501 | depth $\leq 0.5\text{mm}$ whatever is the length depth $\leq 0.8\text{mm}$ with a maximum continuous ²⁾ length of 90mm |
| Undercut in fillet welds | 501 | depth $\leq 0.8\text{mm}$ whatever is the length |

Note:

- 1) "t" is the plate thickness of the thinnest plate and "a" is the throat of the fillet weld.
- 2) Adjacent undercuts separated by a distance shorter than the shortest undercut should be regarded as a single continuous undercut.

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Table 4: Acceptance criteria for radiographic testing

| DISCONTINUITY | CLASSIFICATION ACCORDING TO ISO 6520-1 | ACCEPTANCE CRITERIA FOR RADIOGRAPHIC TESTING ¹⁾ |
|-----------------------------|--|---|
| Crack | 100 | not accepted |
| Lack of fusion | 401 | continuous ²⁾ maximum length $t/2$ or 25mm whichever is the less intermittent cumulative ³⁾ length maximum t or 50mm |
| Incomplete root penetration | 4021 | not accepted in butt joint welded from one side |
| | | continuous ²⁾ maximum length $t/2$ or 25mm whichever is the less intermittent cumulative ³⁾ length maximum t or 50mm |
| Slag inclusion | 301 | continuous ²⁾ maximum length t or 50mm whichever is the less intermittent cumulative ³⁾⁴⁾ length maximum $2t$ or 100mm |

Note:

- 1) "t" is the plate thickness of the thinnest plate.
- 2) Two adjacent individual discontinuities of length L1 and L2 situated on a line and where the distance L between them is shorter than the shortest discontinuity should be regarded as a continuous discontinuity of length L1+L+L2.
- 3) Sum of the length of individual continuous discontinuities.
- 4) Parallel inclusions not separated by more than 3 times the width of the largest inclusion should be regarded as one continuous discontinuity.

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Table 5: Acceptance criteria for ultrasonic testing

| ECHO HEIGHT | ACCEPTANCE CRITERIA FOR ULTRASONIC TESTING¹⁾ |
|--|--|
| Greater than 100% of DAC curve | maximum length t/2 or 25mm whichever is the less |
| Greater than 50% of DAC curve but less than 100% of DAC curve | maximum length t or 50mm whichever is the less |
| Indications evaluated to be cracks are unacceptable regardless of echo height; Indications evaluated to be lack of penetration in joints welded from one side are unacceptable regardless of echo height. | |

Note:

- 1) Two adjacent individual discontinuities of length L1 and L2 situated on a line and where the distance L between them is shorter than the shortest discontinuity should be regarded as a continuous discontinuity of length L1+L+L2.

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