

**INDIAN REGISTER OF SHIPPING**

# **CLASSIFICATION NOTES**

## **Requirements for Non-Destructive Testing**

*July 2021*



**IRCLASS**  
Indian Register of Shipping

## **CLASSIFICATION NOTES**

### **Requirements for Non-Destructive Testing**

**July 2021**

#### **Contents**

#### **Section**

#### **1 Non-destructive testing of ship hull steel welds**

- 1.1 General
- 1.2 Application
- 1.3 Qualification of personnel involved in NDT
- 1.4 Surface condition
- 1.5 General plan of testing: NDT method selection
- 1.6 Testing
- 1.7 Acceptance Levels (criteria)
- 1.8 Reporting
- 1.9 Unacceptable indications and repairs

#### **2 Advanced non-destructive testing of material and welds**

- 2.1 General
- 2.2 Applicability
- 2.3 Qualification of personnel involved in ANDT
- 2.4 Technique and procedure qualification
- 2.5 Surface condition
- 2.6 General plan of testing: ANDT method selection
- 2.7 Testing requirements
- 2.8 Acceptance Levels
- 2.9 Reporting
- 2.10 Unacceptable indications and repairs

## Section 1

### Non-destructive testing of ship hull steel welds

#### 1.1 General

1.1.1 This document gives minimum requirements on the methods and quality levels that are to be adopted for the non-destructive testing (NDT) of ship hull structure steel welds during new construction. The “hull structure” is defined as follows:

- a) hull envelope including all internal and external structures;
- b) superstructures, deckhouses and casings;
- c) welded foundations, e.g. main engine seatings;
- d) hatch coamings, bulwarks;
- e) all penetrations fitted and welded into bulkheads, decks and shell;
- f) the fittings of all connections to decks, bulkheads and shell, such as air pipes and ship side valves – all ILLC 1966, as amended, items;
- g) welded attachments to shell, decks and primary members, e.g. crane pedestals, bitts and bollards, but only as regards their interaction on the hull structure.

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

1.1.3 The NDT is normally to be performed by the Shipbuilder or its subcontractors in accordance with these requirements. IRS Surveyor may require witnessing of the testing.

1.1.4 It is the Shipbuilder’s responsibility to assure that testing specifications and procedures are adhered to during the construction and the reports are made available to IRS on the findings made by the NDT.

1.1.5 The extent of testing and the number of checkpoints are to be agreed between the Shipbuilder and IRS. For criticality of structure, reference is to be made to Part 3, Ch.2 of IRS Rules and Regulations for the Construction and Classification of Steel Ships and Vol 2 of IRS Rules for Bulk Carriers and Oil Tankers (i.e. IACS CSR for Bulk Carriers and Oil Tankers)

1.1.6 This Section covers conventional NDT methods. Advanced non-destructive testing (ANDT) methods such as phased array ultrasonic testing (PAUT), time of flight diffraction (TOFD), digital radiography (RT-D), radiosopic testing (RT-S), and computed radiography (RT-CR) are covered in Section 2.

### **1.1.7 Terms and definitions**

The following terms and definitions are applicable to this section.

NDT Non-Destructive Testing - the development and application of technical methods to examine materials or components in ways that do not impair their future usefulness and serviceability, in order to measure geometrical characteristics and to detect, locate, measure and evaluate flaws. NDT is also known as non-destructive examination (NDE), non-destructive inspection (NDI) and non-destructive evaluation (NDE).

RT - Radiographic Testing

UT - Ultrasonic Testing

MT - Magnetic Particle Testing

PT - Dye or Liquid Penetrant Testing

PWHT - Post Weld Heat Treatment

VT - Visual Testing

## **1.2 Application**

### **1.2.1 Base Metals**

1.2.1.1 This Section applies to the following base metals:

- fusion welds made in normal and higher strength hull structural steels in accordance with Pt.2, Ch.3, Sec 2 & 3 of IRS Rules and Regulations for the Construction and Classification of Steel Ships(herein after referred to as “the Rules”),
- high strength steels for welded structures in accordance with Pt.2, Ch.3, Sec 4 of the Rules,
- connection welds with hull steel forgings in accordance with Pt.2, Ch.5, Sec.2 of the Rules and
- hull steel castings in accordance with Pt.2, Ch.4, Sec.2 of the Rules.

Base metal other than the above may be specially considered.

## 1.2.2 Welding processes

1.2.2.1 This Section applies to the following welding processes:

- fusion welds made using manual metal arc welding (shielded metal arc welding, 111),
- gas-shielded metal arc welding (gas metal arc welding, including flux cored arc welding, 13x),
- gas-shielded arc welding with non-consumable tungsten electrode (gas tungsten arc welding, 14x),
- submerged arc welding (12x),
- electro-slag welding (72x) and
- electro-gas welding processes (73).

Terms and numbers according to ISO 4063:2009 ("x" indicates that relevant subgroups are included). This Section may also be applied to welding processes other than the above at the discretion of IRS.

## 1.2.3 Weld joints

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

## 1.2.4 Timing of NDT

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

1.2.4.2 For high strength steels for welded structure with specified minimum yield stress in the range of 420 N/mm<sup>2</sup> to 690 N/mm<sup>2</sup>, NDT is not to be carried out before 48 hours after completion of welding. For steel with specified minimum yield greater than 690 N/mm<sup>2</sup>, NDT is not to be carried out before 72 hours after completion of welding. Regardless of yield strength consideration is to be given to requiring a delayed inspection where evidence of delayed cracking has been observed in production welds.

At the discretion of the surveyor, a longer interval and/or additional random inspection at a later period may be required, (for example in case of high thickness welds).

At the discretion of the surveyor, the 72 hour interval may be reduced to 48 hours for RT or UT inspection, provided there is no indication of delayed cracking, and a complete visual and random MT or PT inspection to the satisfaction of the surveyor is conducted 72 hours after welds have been completed and cooled to ambient temperature.

Where PWHT is carried out the requirement for testing after a delay period may be relaxed, at the discretion of the surveyor.

### 1.2.5 Applicable methods for testing of weld joints

1.2.5.1 The methods mentioned in this document for detection of surface imperfections are VT, PT and MT. The methods mentioned for detection of internal imperfections are UT and RT.

1.2.5.2 Applicable methods for testing of the different types of weld joints are given in Table 1.2.5.2.

<b>Table 1.2.5.2: Applicable methods for testing of weld joints</b>		
<b>Weld Joint</b>	<b>Parent Material Thickness</b>	<b>Applicable Test Methods</b>
Butt welds with full penetration	thickness < 8mm <sup>1</sup>	VT, PT, MT, RT
	thickness ≥ 8mm	VT, PT, MT, UT, RT
Tee joints, corner joints and cruciform joints with full penetration	thickness < 8mm <sup>1</sup>	VT, PT, MT, RT <sup>3</sup>
	thickness ≥ 8mm	VT, PT, MT, UT, RT <sup>3</sup>
Tee joints, corner joints and cruciform joints without full penetration and fillet welds	All	VT, PT, MT, UT <sup>2</sup> , RT <sup>3</sup>
Notes:		
1) In cases of thickness below 8mm, IRS may consider application of an appropriate advanced UT method.		
2) UT may be used to check the extent of penetration in tee, corner and cruciform joints. This requirement is to be agreed with IRS.		
3) RT may be applied however there will be limitations		

### 1.3 Qualification of personnel involved in NDT

1.3.1 The Shipbuilder 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 such as SNT-TC-1A, 2016 or ANSI/ASNT CP-189, 2016 may be accepted if the Shipbuilder or its subcontractors written practice is reviewed and found acceptable by IRS. The Shipbuilder or its subcontractors written practice, except for the impartiality requirements of a certification body and/or authorised body, as a minimum are to 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 an accredited certification body.

1.3.2 The Shipbuilder 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 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 1.3.1. It is not permissible to appoint Level 3 personnel; they must be certified by an accredited certification body. It is recognised that a Shipbuilder 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 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, on behalf of the Shipbuilder or its subcontractors is to re-evaluate the qualification of the operators annually.

1.3.3 The operator carrying out the NDT and interpreting indications, as a minimum, are to be qualified and certified to Level 2 in the NDT method(s) concerned and as described in 1.3.1.

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, welding, structures or components, NDT equipment and limitations that are sufficient to apply the relevant NDT method for each application appropriately.

#### **1.4 Surface condition**

1.4.1 Areas to be examined are to be free from scale, slag, loose rust, weld spatter, oil, grease, dirt or paint that might affect the sensitivity of the testing method.

Preparation and cleaning of welds for subsequent NDT are to be in accordance with the accepted NDT procedures, and are to be to the satisfaction of the surveyor. Surface conditions that prevent proper interpretation may be cause for rejection of the weld area of interest.

#### **1.5 General plan of testing: NDT method selection**

1.5.1 The extent of testing and the associated quality levels are to be planned by the Shipbuilder according to the ship design, ship type and welding processes used. For new construction survey reference is to be made to the NDT requirements of IACS UR Z23 and the applicable parts of the UR Z23 enclosures Table 1 and Appendices.

1.5.2 For each construction, the Shipbuilder is to submit a plan for approval, specifying the areas to be examined and the extent of testing and the quality levels, with reference to the NDT procedures to be used. Particular attention is to be paid to inspecting welds in highly stressed areas and welds in primary and special structure indicated in Part 3 Chapter 2 of the Rules. The NDT

procedure(s) are to meet the requirement stated in 1.6. The plan is to be only released to the personnel in charge of the NDT and its supervision.

In selecting checkpoints, emphasis is to be given to the following inspection locations:

- Welds in high stressed areas
- Fatigue sensitive areas
- Other important structural elements
- Welds which are inaccessible or very difficult to inspect in service
- Field erected welds
- Suspected problem areas

Block construction welds performed in the yards, or at subcontracted yards/facilities, are to be considered in selecting checkpoints.

For other marine and offshore structures the extent is to be agreed with IRS.

If an unacceptable level of indications are found, the NDT extent is to be increased.

1.5.3 The identification system is to identify the exact locations of the lengths of weld examined.

1.5.4 All welds over their full length are to be subject to VT by personnel designated by the Shipbuilder, who may be exempted from the qualification requirements defined in 1.3.

1.5.5 As far as practicable, PT or MT are to be used when investigating the outer surface of welds, checking the intermediate weld passes and back-gouged joints prior to subsequent passes deposition. MT is to be performed in ferromagnetic materials welds unless otherwise agreed with IRS. Surface inspection of important tee or corner joints, using an approved MT or PT method, is to be conducted to the satisfaction of the surveyor.

1.5.6 Welded connections of large cast or forged components (e.g. stern frame, stern boss, rudder parts, shaft brackets...) are to be tested over their full length using MT (MT is the preferred method) or PT, (PT is to be applied for non-ferrous metals) and at agreed locations using RT or UT.

1.5.7 As given in Table 1.2.5.2, UT or RT or a combination of UT and RT may be used for testing of butt welds with full penetration of 8 mm or greater. Methods to be used are to be agreed with IRS. The method used is to be suited for the detection of particular types and orientations of discontinuities. RT and UT are used for detection of internal discontinuities, and in essence they supplement and complement each other. RT is generally most effective in detecting volumetric discontinuities (e.g. porosity and slag) whilst UT is more effective for detecting planar discontinuities (e.g. laminations, lack of fusion and

cracks). Although one method may not be directly relatable to the other, either one would indicate conditions of inadequate control of the welding process.

1.5.8 In general start/stop points in welds made using automatic (mechanized) welding processes are to be examined using RT or UT, except for internal members where the extent of testing is to be agreed with the attending Surveyor.

1.5.9 Where the Surveyor becomes aware that an NDT location has been repaired without a record of the original defect, the shipyard is to carry out additional examinations on adjacent areas to the repaired area to the satisfaction of the attending surveyor. Reference is to be made to UR Z23.

1.5.10 Welds in thick steels (>50mm) used in container ships, deck and hatch coaming areas are to be inspected in accordance with the additional requirements in Pt.5, Ch.5, of the Rules.

## **1.6 Testing**

### **1.6.1 General**

1.6.1.1 The testing method, equipment and conditions are to comply with recognized National or International standards.

1.6.1.2 Sufficient details are to be given in a written procedure for each NDT technique submitted to IRS for acceptance.

1.6.1.3 The testing volume is to be the zone which include the weld and parent material for at least 10mm on each side of the weld, or the width of the heat affected zone (HAZ), whichever is greater. In all cases inspection is to cover the whole testing volume.

1.6.1.4 Provision is to be made for the Surveyor to verify the inspection, reports and records (e.g. radiographs) on request.

### **1.6.2 Visual testing (VT)**

1.6.2.1 The personnel in charge of VT are to confirm that the surface condition is acceptable prior to carrying out the inspection. VT is to be carried out in accordance with standards agreed between the Shipbuilder and IRS.

### **1.6.3 Liquid penetrant testing (PT)**

1.6.3.1 PT is to be carried out in accordance to ISO 3452-1:2013 or a recognized accepted standard.

1.6.3.2 The extent of PT is to be in accordance to the plans agreed with the attending surveyor and to the satisfaction of the surveyor.

1.6.3.3 The surface to be examined is to be clean and free from scale, oil, grease, dirt or paint so there are not contaminants and entrapped material that may impede penetration of the inspection media.

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

#### **1.6.4 Magnetic particle testing (MT)**

1.6.4.1 MT is to be carried out in accordance to ISO 17638:2016 or a recognized accepted standard.

1.6.4.2 The extent of MT is to be in accordance to the plans agreed with the attending surveyor and to the satisfaction of the surveyor.

1.6.4.3 The surface to be examined is to be free from scale, weld spatter, oil, grease, dirt or paint and is to be clean and dry. In general, the inside and outside of the welds to be inspected need to be sufficiently free from irregularities that may mask or interfere with interpretation.

#### **1.6.5 Radiographic testing (RT)**

1.6.5.1 RT is to be carried out in accordance to ISO 17636-1:2013 or an accepted recognized standard.

1.6.5.2 The minimum inspected weld length for each checkpoint is to be specified in the approved NDT plan (see 1.5.2) and is to follow the requirements of IRS. For hull welds, the minimum length inspected by RT is typically 300mm.

The extent of RT is to be in accordance to the approved plans and to the satisfaction of the surveyor.

Consideration may be given for reduction of inspection frequency for automated welds where quality assurance techniques indicate consistent satisfactory quality.

The number of checkpoints is to be increased if the proportion of non-conforming indications is abnormally high.

1.6.5.3 The inside and outside surfaces of the welds to be radiographed are to be sufficiently free from irregularities that may mask or interfere with interpretation. Surface conditions that prevent proper interpretation of radiographs may be cause for rejection of the weld area of interest.

### 1.6.6 Ultrasonic testing (UT)

1.6.6.1 UT is to be carried out according to procedure based on ISO 17640:2018 (testing procedure), ISO 23279:2017 (characterization) and ISO 11666:2018 (acceptance levels) or other accepted standards.

1.6.6.2 The minimum inspected weld length for each checkpoint is to be specified in the approved NDT plan (see 1.5.2).

The extent of UT is to be in accordance to the approved plans and to the satisfaction of the surveyor.

A checkpoint is to consist of the entire weld length or a length agreed with IRS.

### 1.7 Acceptance Levels (criteria)

#### 1.7.1 General

1.7.1.1 This section details the acceptance levels (criteria) followed for the assessment of the NDT results. Techniques include but are not limited to: VT, MT, PT, RT and UT.

1.7.1.2 As far as necessary, testing techniques are to be combined to facilitate the assessment of indications against the acceptance criteria.

1.7.1.3 The assessment of indications not covered by this Section is to be made in accordance with a standard agreed with IRS. Alternative acceptance criteria can be agreed with IRS, provided equivalency is established.

The general accepted methods for testing of welds are provided in Table 1.7.1.3(a) and Table 1.7.1.3(b) for surface and embedded discontinuities respectively. Refer to ISO 17635:2016.

<b>Table 1.7.1.3(a) Method for detection of surface discontinuities (All type of welds including fillet welds)</b>	
<b>Materials</b>	<b>Testing Methods</b>
Ferritic Steel	VT
	VT, MT
	VT, PT

<b>Table 1.7.1.3(b) NDT for detection of embedded discontinuities (for butt and T joints with full penetration)</b>			
<b>Materials and type of joint</b>	<b>Nominal thickness (t) of the parent material to be welded (mm)</b>		
	<b>t &lt; 8</b>	<b>8 ≤ t ≤ 40</b>	<b>t &gt; 40</b>
Ferritic butt-joints	RT or UT <sup>1</sup>	RT or UT	UT or RT <sup>2</sup>
Ferritic T-joints	UT <sup>1</sup> or RT <sup>2</sup>	UT or RT <sup>2</sup>	UT or RT <sup>2</sup>
Notes:			
1) Below 8mm IRS may consider application of an appropriate advanced UT method.			
2) RT may be applied however there will be limitations.			

### 1.7.2 Quality Levels.

Testing requirements follows the designation of a particular quality level of imperfections in fusion-welded joints in accordance with ISO 5817:2014. Three quality levels (B, C and D) are specified.

In general Quality level C is to be applied for hull structure.

Quality level B corresponds to the highest requirement on the finished weld, and may be applied on critical welds.

This standard applies to steel materials with thickness above 0.5 mm. ISO 5817:2014 Table 1.1 provides the requirements on the limits of imperfections for each quality level. ISO 5817:2014 Annex A also provides examples for the determination of percentage of imperfections (number of pores in surface percent).

All levels (B,C and D) refer to production quality and not to the fitness for purpose (ability of product, process or service to serve a defined purpose under specific conditions). The correlation between the quality levels defined in ISO 5817:2014, testing levels/ techniques and acceptance levels (for each NDT technique) will serve to define the purpose under specific conditions. The acceptance level required for examination are to be agreed with IRS. This will determine the quality level required in accordance with the non-destructive technique selected. Refer to Tables 1.7.5 to 1.7.9.

### 1.7.3 Testing Levels.

1.7.3.1 The testing coverage and thus the probability of detection increases from testing level A to testing level C. The testing level is to be agreed with IRS. Testing level D is intended for special applications, this can only be used when defined by specification. ISO 17640:2018 Annex A Tables A.1 to A.7 provide guidance on the selection of testing levels for all type of joints in relation to the thickness of parent material and inspection requirements.

1.7.3.2 The testing technique used for the assessment of indications is also to be specified.

#### 1.7.4 Acceptance Levels.

1.7.4.1 The acceptance levels are specified for each testing technique used for performing the inspection. The criteria applied is to comply with each standard identified in Tables 1.7.5 to 1.7.9 (or any recognized acceptable standard agreed with IRS).

1.7.4.2 Probability of detection (POD) indicates the probability that a testing technique will detect a given flaw.

#### 1.7.5 Visual testing (VT)

1.7.5.1 The acceptance levels and required quality levels for VT are provided in IACS Rec 47 and table below.

<b>Table 1.7.5 Visual testing</b>		
<b>Quality Levels (ISO 5817:2014 applies)<sup>a</sup></b>	<b>Testing Techniques/ levels (ISO 17637:2016 applies)<sup>a</sup></b>	<b>Acceptance levels<sup>b</sup></b>
B	Level not specified	B
C		C
D		D
Notes: <sup>a</sup> Or any recognized standard agreed with IRS and demonstrated to be acceptable <sup>b</sup> The acceptance levels for VT are the same to the quality levels requirements of ISO 5817:2014		

#### 1.7.6 Penetrant testing (PT)

1.7.6.1 The acceptance levels and required quality levels for PT are provided in table below:

<b>Table 1.7.6 Penetrant Testing</b>		
<b>Quality Levels (ISO 5817:2014 applies)<sup>a</sup></b>	<b>Testing Techniques/ levels (ISO 3452-1:2013 applies)<sup>a</sup></b>	<b>Acceptance levels (ISO 23277:2015 applies)<sup>a</sup></b>
B	Level not specified	2X
C		2X
D		3X

Notes:

<sup>a</sup> Or any recognized standard agreed with IRS and demonstrated to be acceptable

### 1.7.7 Magnetic Particle testing (MT)

1.7.7.1 The acceptance levels and required quality levels for MT is provided in table below:

Table 1.7.7 Magnetic Particle Testing		
Quality Levels (ISO 5817:2014 applies) <sup>a</sup>	Testing Techniques/ levels (ISO 17638:2016 applies) <sup>a</sup>	Acceptance levels (ISO 23278:2015 applies) <sup>a</sup>
B	Level not specified	2X
C		2X
D		3X
<sup>a</sup> Or any recognized standard agreed with IRS and demonstrated to be acceptable		

### 1.7.8 Radiographic testing (RT)

1.7.8.1 The acceptance levels and required quality levels for RT are provided in table below. Reference radiographs for the assessment of weld imperfections are to be provided in accordance to ISO 5817:2014 or acceptable recognized standard agreed with IRS.

Table 1.7.8 Radiographic Testing		
Quality Levels (ISO 5817:2014 applies) <sup>a</sup>	Testing Techniques/ levels (ISO 17636-1:2013 applies) <sup>a</sup>	Acceptance levels (ISO 10675-1:2016 applies) <sup>a</sup>
B	B (class)	1
C	B <sup>b</sup> (class)	2
D	At least A (class)	3
Notes:		
<sup>a</sup> Or any recognized standard agreed with IRS and demonstrated to be acceptable		
<sup>b</sup> For circumferential weld testing, the minimum number of exposures may correspond to the requirements of ISO 17636-1:2013, class A		

### 1.7.9 Ultrasonic testing (UT)

1.7.9.1 The acceptance levels and required quality levels for UT are provided in tables below:

<b>Table 1.7.9(a) Ultrasonic Testing</b>		
<b>Quality Levels (ISO 5817:2014 applies)<sup>a, b</sup></b>	<b>Testing Techniques/ Levels (ISO 17640:2018 applies)<sup>a, b</sup></b>	<b>Acceptance Levels (ISO 11666:2018 applies)<sup>a, b</sup></b>
B	at least B	2
C	at least A	3
D	at least A	3 <sup>c</sup>
Notes: <sup>a</sup> Or any recognized standard agreed with IRS and demonstrated to be acceptable <sup>b</sup> When characterization of indications is required, ISO 23279:2017 is to be applied <sup>c</sup> UT is not recommended but can be defined in a specification with same requirement as Quality Level C		

<b>Table 1.7.9(b) Recommended Testing and Quality Levels (ISO 17640)</b>	
<b>Testing Level<sup>a,b,c</sup> (ISO 17640:2018 applies)</b>	<b>Quality Level (ISO 5817:2014 applies)</b>
A	C, D
B	B
C	By agreement
D	Special application
Notes: <sup>a</sup> POD increases from testing level A to C as testing coverage increases <sup>b</sup> Testing Level D for special application is to be agreed with IRS <sup>c</sup> Specific requirements for testing levels A to C, are provided for various types of joints in ISO 17460:2018 Annex A	

1.7.9.2 UT Acceptance Levels apply to the examination of full penetration ferritic steel welds, with thickness from 8 mm to 100mm. The nominal frequency of probes used is to be between 2MHz and 5MHz. Examination procedures for other type of welds, material, thicknesses above 100 mm and examination conditions are to be submitted to the consideration of IRS.

1.7.9.3 The acceptance levels for UT of welds are to be defined in accordance with ISO 11666:2018 requirements or any recognized acceptable standard agreed with IRS. The standard specifies acceptance level 2 and 3 for full penetration welded joints in ferritic steels, corresponding to quality levels B and C (Refer to table 1.7.9(a)).

1.7.9.4 Sensitivity settings and levels. The sensitivity levels are set by the following techniques:

- Technique 1: based on 3mm diameter side- drilled holes
- Technique 2: based on distance gain size (DGS) curves for flat bottom holes (disk-shaped reflectors)
- Technique 3: using a distance-amplitude-corrected (DAC) curve of a rectangular notch of 1mm depth and 1mm width
- Technique 4: using the tandem technique with reference to a 6mm diameter flat-bottom hole (disk shaped reflector)

The evaluation levels (reference, evaluative, recording and acceptance) are specified in ISO 11666:2018 Annex A.

## 1.8 Reporting

1.8.1 NDT reports required are to be prepared by the Shipbuilder and are to be made available to IRS.

1.8.2 NDT reports are to include the following generic items:

- Date of testing
- Hull number, location and length of weld inspected
- Names, qualification level and signature of personnel that have performed the testing
- Identification of the component examined
- Identification of the welds examined
- Steel grade, type of joint, thickness of parent material, welding process
- Acceptance criteria
- Testing standards used
- Testing equipment and arrangement used
- Any test limitations, viewing conditions and temperature
- Results of testing with reference to acceptance criteria, location and size of reportable indications

- Statement of acceptance / non-acceptance, evaluation date, name and signature of evaluator
- Number of repairs if specific area repaired more than twice

1.8.3 In addition to generic items, reports of PT are to include the following specific items:

- Type of penetrant, cleaner and developer used
- Penetration time and development time

1.8.4 In addition to generic items, reports of MT are to include the following specific items:

- Type of magnetization
- Magnetic field strength
- Detection media
- Viewing conditions
- Demagnetization, if required

1.8.5 In addition to generic items, reports of RT are to include the following specific items:

- Type and size of radiation source (width of radiation source), X-ray voltage
- Type of film/designation and number of film in each film holder/cassette
- Number of radiographs (exposures)
- Type of intensifying screens
- Exposure technique, time of exposure and source-to-film distance as per below:
  - Distance from radiation source to weld
  - Distance from source side of the weld to radiographic film
  - Angle of radiation beam through the weld (from normal)
  - Sensitivity, type and position of IQI (source side or film side)
  - Density

- Geometric un-sharpness
- Specific acceptance class criteria for RT

Examinations used for acceptance or rejection of welds are to be recorded in an acceptable medium. A written record providing following information: identification and description of welds, procedures and equipment used, location within recorded medium and results are to be included. The control of documentation unprocessed original images and digitally processes images is to be to the satisfaction of the surveyor.

1.8.6 In addition to generic items, reports of UT are to include the following specific items:

- Type and identification of ultrasonic equipment used (instrument maker, model, series number), probes (instrument maker, serial number), transducer type (angle, serial number and frequency) and type of couplant (brand).
- Sensitivity levels calibrated and applied for each probe
- Transfer loss correction applied Type of reference blocks
- Signal response used for defect detection
- Reflections interpreted as failing to meet acceptance criteria

The method for review and evaluation of UT reports is required for adequate quality control and is to be to the satisfaction of the surveyor.

1.8.7 The shipyard is to keep the inspection records specified in 1.8.2 to 1.8.6 of this Section for at least 5 years.

## **1.9 Unacceptable indications and repairs**

1.9.1 Unacceptable indications are to be eliminated and repaired where necessary. The repair welds are to be examined on their full length using appropriate NDT method at the discretion of the Surveyor.

1.9.2 When unacceptable indications are found, additional areas of the same weld length are to be examined unless it is agreed with the surveyor and fabricator that the indication is isolated without any doubt. In case of automatic welded joints, additional NDT is to be extended to all areas of the same weld length.

All radiographs exhibiting non-conforming indications are to be brought to the attention of the Surveyor. Such welds are to be repaired and inspected as required by the Surveyor. When non-conforming indications are observed at the end of a radiograph, additional RT is generally required to determine their extent. As an alternative, the extent of non-conforming welds may be ascertained by excavation, when approved by the Surveyor.

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

1.9.4 The inspection records specified in 1.8 are to include the records of repaired welds.

1.9.5 The Shipbuilder is to take appropriate actions to monitor and improve the quality of welds to the required level. The repair rate is to be recorded by the shipyard and any necessary corrective actions are to be identified in the builder's QA system.

## Section 2

### Advanced non-destructive testing of materials and welds

#### 2.1 General

2.1.1 This Section 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 in this Section are listed in 2.2.

2.1.2 The ANDT is to be performed by the Shipbuilder, manufacturer or its subcontractors in accordance with these requirements. IRS' surveyor may require witnessing testing.

2.1.3 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 IRS on the ANDT findings.

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

#### 2.1.5 Terms and definitions

The following terms and definitions apply for this section

ANDT	Advanced non-destructive testing
RT-D	Digital Radiography
RT-S	Radioscopic testing with digital image acquisition(dynamic $\geq$ 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

## **2.2 Applicability**

### **2.2.1 Materials**

2.2.1.1 This section applies to the following materials and manufactured products:

- Material and welding for gas tankers in accordance with Pt.5, Ch.4, of the Rules
- Normal and higher strength hull structural steels in accordance with Pt.2, Ch.3, Sec.2 and 3 of the Rules
- High strength steels for welded structures in accordance with Pt.2, Ch.3, Sec.4 of the Rules
- Hull steel forgings in accordance with Pt.2, Ch.5, Sec.2 of the Rules
- Hull and machinery steel castings in accordance with Pt.2, Ch.4, Sec.2 of the Rules
- Extremely Thick Steel Plates in Container Ships in accordance with Pt.5, Ch.5 the Rules
- Cast Copper Alloy propellers in accordance with Pt.2, Ch.8, Sec.3 of the Rules
- Aluminium alloys for hull construction in accordance with Pt.2, Ch.9, of the Rules
- Cast Steel Propellers in accordance with Pt.2, Ch.4, Sec.4 of the Rules
- YP47 Steels and Brittle Crack Arrest Steels in accordance with Pt.5, Ch.5, of the Rules
- Hull and machinery steel forgings in accordance with IRS Classification Notes “Guidelines for non-destructive examination of hull and machinery steel forgings”.
- Marine steel castings in accordance with IRS Classification Notes “Guidelines for non-destructive examination of steel casting for marine application”

### **2.2.2 Welding processes**

2.2.2.1 This Section is applicable to welding processes specified in Table 2.2.2. ANDT of welding process unspecified in Table 2.2.2 is to be to the satisfaction of IRS.

<b>Table 2.2.2 Applicable welding process</b>		
<b>Welding process</b>		<b>ISO 4063:2009</b>
Manual welding	Shield Metal Arc Welding(SMAW)	111
Resistance welding	Flash welding(FW)	24
Semi-automatic welding	(1) Metal Inert Gas welding(MIG)	131
	(2) Metal Active Gas welding(MAG)	135, 138
	(3) Flux Cored Arc Welding(FCAW)	136
TIG welding	Gas Tungsten Arc Welding(GTAW)	141
Automatic welding	(1) Submerged Arc Welding(SAW)	12
	(2) Electro-gas Welding(EGW)	73
	(3) Electro-slag Welding(ESW)	72

### 2.2.3 Weld joints

2.2.3.1 This Section is applicable 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 IRS before application.

### 2.2.4 Timing of ANDT

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

2.2.4.2 Timing of ANDT on ship hull welds on steels with specified minimum yield stress in the range of 420 N/mm<sup>2</sup> to 690 N/mm<sup>2</sup> is to be in accordance with 1.2.4.2.

### 2.2.5 Testing methods

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

2.2.5.2 Applicable methods for testing of the different types of materials and weld joints are given in Table 2.2.5.

<b>Table 2.2.5 Applicable methods for testing of materials and weld joints</b>		
<b>Materials and Weld Joints</b>	<b>Parent Material Thickness</b>	<b>Applicable methods</b>
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 <sup>1</sup>	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 <sup>1</sup>	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*
Base materials/Rolled steels, Wrought Aluminum Alloys	thickness < 6mm	RT-D
	6 mm ≤ thickness ≤ 40 mm	PAUT, TOFD, RT-D
	thickness > 40mm	PAUT, TOFD, RT-D*
<p>Note:</p> <p>*Only applicable with limitations, need special qualification subject to acceptance by IRS.</p> <p>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.</p>		

## 2.3 Qualification of personnel involved in ANDT

2.3.1 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 IRS. The Shipbuilder, manufacturer or its subcontractors written practice, as a minimum, is to, 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 is to be certified by an accredited certification body.

2.3.2 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 2.3.1. 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, on behalf of the Shipbuilder, manufacturer or its subcontractors is to re-evaluate the qualification of the operators annually.

2.3.3 The operator carrying out the NDT and interpreting indications, as a minimum, is to be qualified and certified to Level 2 in the NDT method(s) concerned and as described in 2.3.1.

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.

## **2.4 Technique and procedure qualification**

### **2.4.1 General**

The shipbuilder or manufacturer is to submit to IRS the following documentation for review:

- The technical documentation of the ANDT.
- The operating methodology and procedure of the ANDT according to 2.7.
- Result of software simulation, when applicable.

### **2.4.2 Software simulation**

Software simulation may be required by IRS, 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.

### **2.4.3 Procedure qualification test**

The procedure qualification for ANDT system is to include the following steps:

- Review of available performance data for the inspection system (detection abilities and defect sizing accuracy).
- Identification and evaluation of significant parameters and their variability.
- Planning and execution of a repeatability and reliability test programme<sup>1</sup> which including onsite demonstration.
- 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 IRS, 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 the Surveyor.

#### **2.4.4 Procedure approval**

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

#### **2.4.5 Onsite review**

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.

Data analyses is to be performed in accordance with the above activities. Probability of Detection (PoD) and sizing accuracy is 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 is to be undertaken to account for any nonconformity.

When a significant nonconformity is found, IRS has the right to reject the results of such activities.

### **2.5. Surface condition**

2.5.1 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.

2.5.2 Where there is a requirement to carry out PAUT or TOFD through paint, the suitability and sensitivity of the test is 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.

2.5.3 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.

### **2.6. General plan of testing: ANDT method selection**

2.6.1 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 requirements applicable with material of weld examined.

## 2.7 Testing requirements

### 2.7.1 General

2.7.1.1 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 2.3.

#### 2.7.1.2 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 3 in the appropriate technique in accordance with a recognised standard.
- (6) Procedures are to be reviewed by the IRS' Surveyor.

2.7.1.3 The methods considered within the application of this Section are defined in 2.2.5.1

2.7.1.4 PAUT techniques are to conform as a minimum to 2.7.2. 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.

.1 PAUT of welds are 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 2.7.2.2.4

2.7.1.5 TOFD techniques are to conform as a minimum to 2.7.3. 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.

2.7.1.6 RT-D techniques are to conform as a minimum to 2.7.4. For the purpose of this section, RT-D comprises of two main RT methods; RT-S and RT-CR. Other methods may be included (e.g. radiology systems), however, then must conform to this section as applicable, and any specific requirements are to demonstrate equivalence to these requirements.

.1 In all RT-D methods, in addition to specific requirements, detector output quality control methods are to be described within the procedure.

.2 The procedure is to define the level of magnification, post-processing tools, image/data security and storage, for final evaluation and reporting.

### **2.7.2 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.

#### 2.7.2.1 Information required prior to testing

A procedure is to be written and include the following information as in minimum shown in Table 2.7.2. When an essential variable in Table 2.3 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 is to require revision of, or an addendum to, the written procedure.

<b>Table 2.7.2 Requirements of a PAUT Procedure</b>		
<b>Requirement</b>	<b>Essential Variable</b>	<b>Nonessential Variable</b>
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 is to 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 height <sup>1</sup> , 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	...
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

<b>Table 2.7.2 Requirements of a PAUT Procedure</b>		
<b>Requirement</b>	<b>Essential Variable</b>	<b>Nonessential Variable</b>
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:  1) Effective height is the distance from the outside edge of the first to last element used in the focal law.		

### 2.7.2.2 Testing

#### .1 Testing levels

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

#### .2 Weld Examinations

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

#### .3 Material Examinations

Material examinations are to conform to 2.2.1 as a minimum.

#### .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 is to 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  $\pm 5^\circ$ . 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).

### .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.

### .6 Indication assessment

Indications detected when applying testing procedure is 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. 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.

## 2.7.3 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.

### 2.7.3.1 Information required prior to testing

A procedure is to be written and include the following information as shown in Table 2.7.3. When an essential variable in Table 2.7.3 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 is to require revision of, or an addendum to, the written procedure.

<b>Requirement</b>	<b>Essential Variable</b>	<b>Nonessential Variable</b>
Weld configurations to be examined, including thickness dimensions and material product form (castings, forgings, pipe, plate, etc.)	X	...
The surfaces from which the examination is to 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	...

<b>Table 2.7.3 Requirements of a TOFD Procedure</b>		
<b>Requirement</b>	<b>Essential Variable</b>	<b>Nonessential Variable</b>
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

### 2.7.3.2 Testing

#### .1 Testing levels

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

#### .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.

.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.

#### 2.7.4 Digital Radiography (RT-D)

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

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

A procedure is to be written and include the following information as shown in Table 2.7.4.

<b>Table 2.7.4 Requirements of a Digital radiography Procedure</b>
<b>Requirement</b>
Material types or weld configurations to be examined, including thickness dimensions and material product form (castings, forgings, pipe, plate, etc.)
<b>Digitizing System Description:</b>
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
<b>Digitizing Technique:</b>
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
<b>Spatial resolution used:</b>
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

#### 2.7.4.1 Testing levels

Testing levels as per ISO 17636-2:2013 are specified in 2.8.4.

## 2.8 Acceptance Levels

### 2.8.1 General

2.8.1.1 This sub-section 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).

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

2.8.1.3 Acceptance criteria for each material and weld joint is to be in accordance with each rules and Classification Notes in 2.2.1.1.

### 2.8.2 Phased array ultrasonic testing(PAUT)

#### 2.8.2.1 Weld Examinations

The relationship between acceptance levels, testing levels and quality levels is given in Table 2.8.2.

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

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

### 2.8.2.2 Material Examinations

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

The acceptance levels for material examinations are to conform as a minimum to the relevant requirements in the Rules and Classification Notes.

### 2.8.3 Time of flight diffraction (TOFD)

The relationship between acceptance levels, testing levels and quality levels is given in Table 2.8.3.

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

<b>Table 2.8.3 Acceptance levels for TOFD</b>		
<b>Quality levels according to ISO 5817:2014</b>	<b>Testing level according to ISO 10863:2011</b>	<b>Acceptance level according to ISO 15626:2018</b>
B (Stringent)	C	1
C (Intermediate)	At least B	2
D (Moderate)	At least A	3

### 2.8.4 Digital radiography (RT-D)

The relationship between acceptance levels, testing levels and quality levels is given in Table 2.8.4.

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

<b>Table 2.8.4 Acceptance levels for Digital radiography</b>		
<b>Quality levels according to ISO 5817:2014 or ISO 10042:2018</b>	<b>Testing techniques/level(class) according to ISO 17636-2:2013</b>	<b>Acceptance level according to ISO 10675-1:2016 &amp; ISO 10675-2:2017</b>
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		

## 2.9 Reporting

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

- a) a reference to standards of compliance;
- b) information relating to the object under test:
  - i. identification of the object under test,
  - ii. dimensions including wall thickness,
  - iii. material type and product form,
  - iv. geometrical configuration,
  - v. location of welded joint(s) examined,
  - vi. reference to welding process and heat treatment,
  - vii. surface condition and temperature,
  - viii. stage of manufacture;
- c) information relating to equipment:

<b>Table 2.9.1(a) Information relating to equipment</b>	
<b>Method</b>	<b>Information</b>
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.

d) information relating to test technology:

<b>Table 2.9.1(b) Information relating to test technology</b>	
<b>Method</b>	<b>Information</b>
All	<ol style="list-style-type: none"> <li>1) testing level and reference to a written test procedure,</li> <li>2) purpose and extent of test,</li> <li>3) details of datum and coordinate systems,</li> <li>4) method and values used for range and sensitivity settings,</li> <li>5) details of signal processing and scan increment setting,</li> <li>6) access limitations and deviations from standards, if any.</li> </ol>
PAUT	<ol style="list-style-type: none"> <li>1) increment (E-scans) or angular increment (S-scans),</li> <li>2) element pitch and gap dimensions,</li> <li>3) focus (calibration should be the same as scanning),</li> <li>4) virtual aperture size, i.e. number of elements and element width,</li> <li>5) element numbers used for focal laws,</li> <li>6) documentation on permitted wedge angular range from manufacturer,</li> <li>7) documented calibration, TCG and angle gain compensation,</li> <li>8) scan plan.</li> </ol>
TOFD	<ol style="list-style-type: none"> <li>1) details of TOFD setups,</li> <li>2) details of offset scans, if required.</li> </ol>
RT-D	<ol style="list-style-type: none"> <li>1) detector position plan,</li> <li>2) tube voltage used and current or source type and activity,</li> <li>3) time of exposure and source-to-detector distance,</li> <li>4) type and position of image quality indicators,</li> <li>5) achieved and required <math>SNR_N</math> for RT-S or achieved and required grey values and/or <math>SNR_N</math> for RT-CR,</li> <li>6) for RT-S: type and parameters such as gain, frame time, frame number, pixel size, calibration procedure,</li> <li>7) for RT-CR: scanner type and parameters such as pixel size, scan speed, gain, laser intensity, laser spot size,</li> <li>8) image-processing parameters used, e.g. of the digital filters.</li> </ol>

e) information relating to test results:

<b>Table 2.9.1(c) Information relating to test results</b>	
<b>Method</b>	<b>Information</b>
All	<ol style="list-style-type: none"> <li>1) acceptance criteria applied,</li> <li>2) tabulated data recording the classification, location and size of relevant indications and results of evaluation,</li> <li>3) results of examination including data on software used,</li> <li>4) date of test,</li> <li>5) reference to the raw data file(s),</li> <li>6) date(s) of scan or exposure and test report,</li> <li>7) names, signatures and certification of personnel.</li> </ol>
PAUT	<ol style="list-style-type: none"> <li>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,</li> <li>2) reference points and details of the coordinate system.</li> </ol>
TOFD	TOFD images of at least those locations where relevant TOFD indications have been detected.

2.9.2 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.

2.9.3 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

2.9.4 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.

2.9.5 The shipbuilder or manufacturer is to keep the inspection records for the appropriate period deemed by IRS.

## **2.10 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 requirements in the Rules and Classification Notes.

**End of the Classification Note**