Amendments to the “Rules for Carrying out Non-Destructive Examinations of Welding”

RFP/018/AMN/01

Effective from 1/7/2021

Reasons of the amendments:

Chapter/Paragraph amended	Reason
Ch 1, Ch 2, App A, App B and App C deleted and replaced by new Ch 1	to introduce **IACS UR W33** (new Dec 2019 and Rev.1, May 2020) "Non-destructive testing of ship hull steel welds"
Ch 3 (renumbered as Ch 2)	to modify acronyms in line with **IACS UR W33** (new Dec 2019 and Rev.1, May 2020) "Non-destructive testing of ship hull steel welds" and to improve two existing references
Ch 3 (new)	to introduce **IACS UR W34** (new Dec 2019) "Advanced non-destructive testing of materials and welds"

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1 - FIELD OF APPLICATION

1.1

These Rules provide requirements for carrying out non-destructive examinations (NDE) of welding of hull structures and ship arrangements and systems.

They apply to:

- normal and higher strength **C** and **C-Mn** steels and low-alloy steels, foreseen by Part D of the Rules for the Classification of Ships
- butt-joints and T- and corner joints, with and without full penetration, performed by electric-arc, electroslag or electrogas welding using the welding consumables foreseen in Part D of the Rules for the Classification of Ships.

Moreover, at the discretion of Tasneef, the Rules may also be applied, in whole or in part, to structures, systems and materials other than those above, such as offshore installations, as well as to other industrial sectors with the agreement of the interested parties.

Appendix A provides general criteria defining the limits for discontinuities in accordance with normal good welding practice as found satisfactory by years of experience in shipbuilding. These limits constitute quality levels appropriate for such applications for the purpose of the inspections required in surveys of ships and units intended for classification or classified by Tasneef.

The following non-destructive examinations are considered in these Rules:

(a) For the detection of **surface** discontinuities:
- visual examination **(VE)**,
- magnetic particle examination **(ME)**,
- liquid penetrant examination **(PE)**.

(b) For the detection of **embedded** discontinuities:
- radiographic examination **(RE)**,
- ultrasonic examination **(UE)**.

The **UE** method is particularly appropriate for the detection of bidimensional discontinuities.

Other methods of examination may be taken into consideration for specific applications. The relevant requirements in such cases are specially stipulated by Tasneef.

2 - SUITABILITY OF THE METHODS OF EXAMINATION

2.1

For the purpose of the suitability of the **UE** and **RE** methods in the detection of embedded discontinuities, the different types of weldments have been divided into the following groups and the more reliable NDE is shown for each group:

V1 full penetration butt-welded joints of members having thickness ≥ 10 mm: **UE** and **RE** methods.

V0 full penetration butt-welded joints of members having thickness < 10 mm, or partial penetration butt-welded joints, irrespective of thickness: **RE** method.

T1 full penetration T-joints, corner joints and cruciform joints of members having thickness ≥ 10 mm: **UE** method.

T0 joints as in T1 but relevant to members having thickness < 10 mm as well as partial penetration of any thickness and fillet welds: neither **UE** nor **RE** suitable.

2.2

The general capability of the different methods to detect weld discontinuities is summarized in Table 1 for the different types of joint.

3 - OPERATORS

3.1

Operators are to have adequate experience and be qualified according to a national 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. Non-destructive examination is to be performed using calibrated equipment of suitable type and according to approved procedures, recognised standards and Tasneef requirements. Personnel responsible for the preparation and approval of NDT procedures are to be qualified to a grade equivalent to level III of ISO 9712, SNT-TC-1A, EN 473, ACCP or ASNT. The Manufacturer's laboratory or other organisation responsible for the non-destructive examination is required to issue, on its own responsibility, a certificate illustrating the results and, where requested, an opinion concerning the acceptability of the product; in the latter case, the certificate is to be countersigned by the qualified operator. Personnel qualifications are to be verified by certification. Personnel certificates are to be issued by Tasneef, by other IACS Society or by a recognised third part body. The occasional use of operators not certified but deemed qualified for specific applications may be allowed at the discretion of Tasneef.

3.2

Operators are to be familiar with the equipment used and the relevant calibration, and are to have adequate operating experience for the task at hand. Irrespective of the checks performed by the Surveyors, it is the Manufacturer's responsibility to ensure that the choice of the operators is such as to meet these needs.

3.3

Furthermore, the Manufacturer is to keep up-to-date records concerning the operators, the expiry of certificates and the results of any checks carried out.

The Surveyors are to have access to such records.

4 - DOCUMENTATION

4.1

The final reports regarding the **ND** examinations carried out are to be signed by the operator and contain adequate information concerning:

- examination techniques and procedures,
- equipment and relevant details of the validity of the calibration,
- positions examined,
- results,
- conclusions.

Such information is to enable judgement in relation to the requirements applicable to the examinations themselves.

Any defects found are to be clearly identified in relation to their position and dimensions so as to verify compliance with the set limits.

The **ND** examination report is to be drafted on a special form.

In any event, it is understood that the exam documentation is issued by the Manufacturer on his own responsibility; it is therefore to be signed by his authorized representative.

TABLE 1

CAPABILITY OF DETECTION OF DISCONTINUITIES [1]

Type of joint [4]	Methods for surface or sub-surface discontinuities [2] [3]		Methods for embedded discontinuities [2]	
	VS	**MF/LP**	**UE**	**RE**
Group A (butt welds of $t \geq 10$ mm)	porosity undercut underfill (overlap) (cracks) (lack of fusion) incomplete penetration	undercut overlap cracks lack of fusion incomplete penetration porosity ----	porosity slag inclusions cracks lack of fusion incomplete penetration lamellar tears ----	porosity slag inclusions undercut underfill (cracks) (lack of fusion) incomplete penetration
Group B (butt welds of $t < 10$ mm)	porosity undercut underfill (overlap) (cracks) (lack of fusion) incomplete penetration	undercut overlap cracks lack of fusion incomplete penetration porosity ----	not applicable not applicable not applicable not applicable not applicable not applicable not applicable	porosity slag inclusions undercut underfill (cracks) (lack of fusion) incomplete penetration
Group C (T-joints or similar of $t \geq$ 10 mm)	porosity undercut underfill (overlap) (cracks) ----	undercut overlap cracks porosity ---- ----	porosity slag inclusions cracks lack of fusion incomplete penetration lamellar tears	not applicable not applicable not applicable not applicable not applicable not applicable
Group D (T-joints and similar of $t <$ 10 mm or partial penetration)	porosity undercut underfill (overlap) (cracks)	undercut overlap cracks porosity ----	not applicable not applicable not applicable not applicable not applicable	not applicable not applicable not applicable not applicable not applicable

NOTES:
[1] The table is given for general information.
[2] The capability for discontinuities in brackets is marginal.
[3] **VE** and **PE** only detect surface discontinuities and imperfections; **ME** may also detect discontinuities just below the surface.
[4] t = thickness.

~~1 - EXAMINATION TECHNIQUES - GENERAL~~

~~1.1~~

~~The examination techniques and procedures are to be in compliance with recognized standards or are to be recognized suitable by Tasneef in each single case.~~

~~1.2~~

~~The individual NDE applications are to be governed by an adequate procedure specification submitted by the Manufacturer and accepted by Tasneef.~~

~~The specifications are to contain the following general information in addition to that relevant to each individual method as stated below:~~

- ~~surface requirements, cleaning and preparation,~~
- ~~location, reference, identification and marking,~~
- ~~evaluation of findings,~~
- ~~reporting.~~

~~Specific requirements for the different methods are given in 2 to 6.~~

~~1.3~~

~~The procedural conditions generally accepted by Tasneef are provided in Appendix B for the different methods; these may be adopted by the interested parties with reference to these Rules in lieu of submitting their own specifications.~~

~~2 - VISUAL EXAMINATION~~

~~2.1~~

~~This examination is suitable for revealing weld surface discontinuities and irregularities like undercut, surface porosity, and irregular shape of beads and of weld reinforcements.~~

~~2.2~~

~~The examination is to be carried out, where necessary, with the aid of additional means of lighting and measuring instruments to assess and size the discontinuities.~~

~~2.3~~

~~The welds are to be presented clean and without paint.~~

~~3 - MAGNETIC PARTICLE EXAMINATION~~

~~3.1~~

~~This examination is suitable for detecting surface discontinuities and sub-surface discontinuities within certain limits.~~

~~3.2~~

~~The following items are, in particular, to appear in the procedure specification for evaluation, where appropriate:~~

~~(a) magnetising procedure and equipment~~
~~(b) detection media~~
~~(c) field strength measurement/verification~~
~~(d) detection media application~~
~~(e) viewing conditions~~
~~(f) demagnetization~~
~~(g) precautions against arcing.~~

3.3

As regards the examination procedure, the following generally applies.

(a) The surface to be examined may be as welded, except that noticeable irregularities are to be smoothed by grinding; the surface is to be clean and dry.
(b) The peak value of the tangential magnetic field strength in the area to be examined is to be between 2,4 and 4,0 kA/m.
(c) Magnetization by **AC** (i.e. alternating current) or **HWDC** (half wave rectified direct current), particularly suitable for defects below the surface, is to be used.
(d) Fluorescent or non-fluorescent magnetic inks may be applied.
(e) The preparation and illumination (by visible or ultraviolet light, depending on the means of detection used) of the surface under examination are to be sufficient.

4 - DYE PENETRANT EXAMINATION

4.1

This examination is suitable for detecting surface open discontinuities.

4.2

The following elements are, in particular, to appear in the procedure specification for evaluation, where appropriate:

- reference specimens
- surface cleaning and preparation
- object temperature
- type of penetrant and developer
- penetrant application and removal; penetration time
- developer application and development time.

4.3

As regards the examination procedure, the following generally applies.

(a) The surface to be examined may be as welded.
It is, however, to be clean (free from any surface impediments which may impair the action of the penetrant), dry and without noticeable irregularities. Any grinding of the surfaces is to be applied with considerable care in order to avoid masking of discontinuities.
(b) The penetrant may be visible or fluorescent, water washable, solvent removable or post-emulsified; the developer may be aqueous, non-aqueous wet or dry powder.
(c) Outside the temperature range 5-50°C for the parts to be examined, reference comparator blocks are to be used.
(d) The penetration and development times are to be suitable for the type of penetrant, the material and the temperature (for steel welds with water or solvent penetrant, the penetration time should typically be between 20 and 60 minutes, the development time between 5 and 30 minutes or, if the temperature is below 15°C, 30 minutes).
(e) Regardless of the development times given above, it is advisable to watch for the building up of indications in the first few minutes.
(f) The illumination of the surface under examination (by visible or ultraviolet light, depending on the developer used) is to be sufficient.

5 - ULTRASONIC EXAMINATION

5.1

This examination is suitable for revealing internal discontinuities, including those of the bidimensional type.

As a check of welds, it is to be directed towards the detection of longitudinal and transverse discontinuities of the welded joint.

The technique to be used is the ultrasonic pulse echo technique applying angle and/or normal probes.

The examination may be carried out manually or by means of mechanized or automatic equipment.

5.2

The following elements are, in particular, to appear in the procedure specification for evaluation, where appropriate:

(a) equipment type
(b) probe type(s), frequencies and angles
(c) calibration and reference blocks
(d) couplant

~~(e) equipment calibration and checks (linearity, resolution, wear)~~
~~(f) sensitivity setting~~
~~(g) examination of parent material~~
~~(h) scanning techniques~~
~~(i) evaluating and sizing techniques.~~

~~**5.3**~~

~~As regards the examination procedure, the following generally applies.~~

~~(a) One angle probe is to be used from each side of the welded joint, except where the type and shape of the joint also require, in addition or as an alternative, the use of a normal non-angle probe.~~
~~(b) The examination of welded joints is to be performed using as reference the echo given by a transversal hole, perpendicular to the ultrasonic beam, having diameter equal to 1,5 mm; such Echo defines the Reference Level (ERL).~~
~~(c) Alternative examination methods other than the above, which use as reference other types of reflectors, such as flat-bottom holes or rectangular or V-notches, may be used provided the same sensitivity is achieved. In this connection, for example, the DGS (Distance Gain Sensitivity) method is mentioned.~~

~~6 - RADIOGRAPHIC EXAMINATION~~

~~**6.1**~~

~~This examination is suitable for revealing internal discontinuities.~~

~~The technique is projective imaging using X- or gamma-rays with film as the permanent recording and displaying medium.~~

~~For members of thickness less than 15 mm, X-rays are to be preferred.~~

~~Special techniques, such as the use of fluoroscopic screens, may be adopted provided that the basic requirements concerning the quality of the image are satisfied.~~

~~**6.2**~~

~~The following elements are, in particular, to appear in the procedure specification for evaluation, where appropriate:~~

~~(a) radiation source; type and focal spot size~~
~~(b) geometry of radiographic setup~~
~~(c) film type and relevant features; film density~~
~~(d) film identification marking~~
~~(e) intensifying screens~~
~~(f) image quality indicators~~
~~(g) exposure conditions~~
~~(h) film processing.~~

~~**6.3**~~

~~Where wire image quality indicators are used, the following sensitivities are required:~~

~~Thickness t, in mm, of the member~~	~~IQI Wire Sensitivity~~
~~≤ 10~~	~~2,0%~~
~~80~~	~~1,0%~~
~~> 80~~	~~0,8/t~~

~~For thicknesses between 10 and 80 mm the sensitivity required is found by linear interpolation.~~

~~In the case of the use of other types of IQI, the sensitivity values are to be equivalent to those specified above for wire IQIs.~~

CHAPTER 1 NON-DESTRUCTIVE TESTING OF SHIP HULL STEEL WELDS

1 General

1.1 Application

1.1.1 These Rules give 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 building ("hull structure" as defined in Pt A, Ch 3, Sec 1, [1.2.1] of the Rules for the Classification of Ships).

1.1.2 The quality levels given in these Rules 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. The 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 the Society 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 the Society taking into consideration the requirements in Ch 2. For criticality of structure, reference is also to be made to Pt B, Ch 4, Sec 1, [2] and IACS CSR for Bulk Carriers and Oil Tankers.

1.1.6 Advanced non-destructive testing (ANDT) methods such as phased array ultrasonic testing (PAUT), time of flight diffraction (TOFD), digital radiography (RT-D), radioscopic testing (RT-S), and computed radiography (RT-CR) are covered by Chapter 3.

1.2 Terms and definitions

1.2.1 The following terms and definitions apply:

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

2 Application

2.1 Base Metals

2.1.1 These Rules apply to:

- fusion welds made in normal and higher strength hull structural steels in accordance with Pt D, Ch 2, Sec 1, [2] and [11] of the Rules for the Classification of Ships;
- high strength steels for welded structures in accordance with Pt D, Ch 2, Sec 1, [3] of the Rules for the Classification of Ships;
- connections welds with hull steel forgings in accordance with Pt D, Ch 2, Sec 3, [1] to [5] of the Rules for the Classification of Ships;
- hull steel castings in accordance with Pt D, Ch 2, Sec 4, [1] to [4] of the Rules for the Classification of Ships.

Base metal other than the above may be applied by the Society.

2.2 Welding processes

2.2.1 These Rules apply to 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). These Rules may also be applied to welding processes other than the above at the discretion of the Society.

2.3 Weld joints

2.3.1 These Rules apply 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 is to be conducted after welds have cooled to ambient temperature and after post weld heat treatment where applicable.

2.4.2 For high strength steels for welded structure with specified minimum yield stress in the range of 420 N/mm² to 690 N/mm², NDT is not to be carried out before 48 hours after completion of welding. For steel with specified minimum yield greater than 690 N/mm² 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.

2.5 Applicable methods for testing of weld joints

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.

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

Table 1 Applicable methods for testing of weld joints

WELD JOINT	PARENT MATERIAL THICKNESS	APPLICABLE TEST METHODS
Butt welds with full penetration	thickness < 8mm[1]	VT, PT, MT, RT
	thickness ≥ 8mm	VT, PT, MT, UT, RT
Tee joints, corner joints and cruciform joints with full penetration	thickness < 8mm[1]	VT, PT, MT, RT[3]
	thickness ≥ 8mm	VT, PT, MT, UT, RT[3]
Tee joints, corner joints and cruciform joints without full penetration and fillet welds	All	VT, PT, MT, UT[2], RT[3]
Notes: 1) In cases of thickness below 8mm the Society 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 the Society. 3) RT may be applied however there will be limitations		

3 Qualification of personnel involved in NDT

3.1

3.1.1 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 as e.g. 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 the Society. The Shipbuilder or its subcontractors written practice is to as a minimum, except for the impartiality requirements of a certification body and/or authorised body, comply with ISO 9712:2012.

The supervisors' and operators' certificates and competence are to comprise all industrial sectors and techniques being applied by the Shipbuilder or its subcontractors. Level 3 personnel is to be certified by an accredited certification body.

3.2

3.2.1 The Shipbuilder or its subcontractors is 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 is to employ, on a full-time basis, at least one supervisor independently certified to Level 3 in the method(s) concerned as per the requirements of item [3.1]. It is not permissible to appoint Level 3 personnel; they must be certified by an accredited certification body. It is recognised that a Shipbuilder 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 is to on behalf of the Shipbuilder or its subcontractors re-evaluate the qualification of the operators annually.

3.3

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

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

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

4 Surface condition

4.1

4.1.1 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.

5 General plan of testing: NDT method selection

5.1

5.1.1 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 Pt A, Ch 3, Sec 1 of the Rules for the Classification of Ships and the applicable parts of Pt A, Ch 3, Sec 1, Tab 1, [1.8] to [1.11], [2.1], [2.2], [2.3], Tab 2, of the Rules for the Classification of Ships.

5.1.2 For each construction, the Shipbuilder is to submit a plan for approval by the Society, 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 Pt B, Ch 4, Sec 1, [2]. The NDT procedure(s) is to meet the requirement stated in [6] and the specific requirements of the Society. The plan is to only be 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 sub-contracted yards/facilities, are to be considered in selecting checkpoints.

For other marine and offshore structures the extent is to be agreed by the Society.

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

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

5.1.4 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 [3].

5.1.5 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 the Society. 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.

5.1.6 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.

5.1.7 As given in Tab 1, UT or RT or a combination of UT and RT may be used for testing of butt welds with full penetration of 8mm or greater. Methods to be used are to be agreed with the Society. 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.

5.1.8 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.

5.1.9 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 made to Pt A, Ch 3, Sec 1 of the Rules for the Classification of Ships.

5.1.10 Welds in thick steels (>50mm) used in container carrier, deck and hatch coaming areas are to be inspected in accordance with the additional requirements in Pt D, Ch 2, Sec 1, [10].

6 Testing

6.1 General

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

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

6.1.3 The testing volume is to be the zone which include the weld and parent material for at least 10mm 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.

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

6.2 Visual testing (VT)

6.2.1 The personnel in charge of VT is 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 the Society.

6.3 Liquid penetrant testing (PT)

6.3.1 PT is to be carried out in accordance to ISO 3452-1:2013 or a recognized accepted standard and the specific requirement of the Society.

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.

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.

6.3.4 The temperature of parts examined is 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.

6.4 Magnetic particle testing (MT)

6.4.1 MT is to be carried out in accordance to ISO 17638:2016 or a recognized accepted standard and the specific requirement of the Society.

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.

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.

6.5 Radiographic testing (RT)

6.5.1 RT is to be carried out in accordance to ISO 17636-1:2013 or an accepted recognized standard and any specific requirement of the Society

6.5.2 The minimum inspected weld length for each checkpoint is to be specified in the approved NDT plan (see [5.1.2]) and is to follow the requirements of the Society. 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.

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.

6.6 Ultrasonic testing (UT)

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 accepted standards and the specific requirements of the Society.

6.6.2 The minimum inspected weld length for each checkpoint is to be specified in the approved NDT plan (see [5.1.2]) and is to follow the requirements of the Society.

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 the Society.

7 Acceptance Levels (criteria)

7.1 General

7.1.1 This Article 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.

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

7.1.3 The assessment of indications not covered by these Rules is to be made in accordance with a standard agreed with the Society. Alternative acceptance criteria can be agreed with the Society, provided equivalency is established.

The general accepted methods for testing of welds are provided in Tab 2 and Tab 3 for surface and embedded discontinuities respectively. Refer to ISO 17635:2016.

Table 2 Method for detection of surface discontinuities (All type of welds including fillet welds)

Materials	Testing Methods
Ferritic Steel	VT
	VT, MT
	VT, PT

Table 3 NDT for detection of embedded discontinuities (for butt and T joints with full penetration)

Materials and type of joint	Nominal thickness (t) of the parent material to be welded (mm)		
	t < 8	8 ≤ t ≤ 40	t > 40
Ferritic butt-joints	RT or UT[1]	RT or UT	UT or RT[2]
Ferritic T-joints	UT[1] or RT[2]	UT or RT[2]	UT or RT[2]

Notes:
1) Below 8mm the Society may consider application of an appropriate advanced UT method.
2) RT may be applied however there will be limitations.

7.2 Quality Levels

7.2.1 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 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 is to be agreed with the Society. This will determine the quality level required in accordance with the non-destructive technique selected. Refer to Tables 4 to 9.

7.3 Testing Levels

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 the Society. 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.

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

7.4 Acceptance Levels

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 4 to 9 (or any recognized acceptable standard agreed with the Society).

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

7.5 Visual testing (VT)

7.5.1 The acceptance levels and required quality levels for VT are provided in IACS Rec 47 and Tab 4.

Table 4 Visual testing

Quality Levels (ISO 5817:2014 applies)[a]	Testing Techniques/ levels (ISO 17637:2016 applies)[a]	Acceptance levels[b]
B	Level not specified	B
C		C
D		D

Notes:
[a] Or any recognized standard agreed with the Society and demonstrated to be acceptable
[b] The acceptance levels for VT are the same to the quality levels requirements of ISO 5817:2014

7.6 Penetrant testing (PT)

7.6.1 The acceptance levels and required quality levels for PT are provided in Tab 5

Table 5 Penetrant Testing

Quality Levels (ISO 5817:2014 applies)[a]	Testing Techniques/ levels (ISO 3452-1:2013 applies)[a]	Acceptance levels (ISO 23277:2015 applies)[a]
B	Level not specified	2X
C		2X
D		3X

Notes:
[a] Or any recognized standard agreed with the Society and demonstrated to be acceptable

7.7 Magnetic Particle testing (MT)

7.7.1 The acceptance levels and required quality levels for MT are provided in Tab 6

Table 6 Magnetic Particle Testing

Quality Levels (ISO 5817:2014 applies)[a]	Testing Techniques/ levels (ISO 17638:2016 applies)[a]	Acceptance levels (ISO 23278:2015 applies)[a]
B	Level not specified	2X
C		2X
D		3X

Notes:
[a] Or any recognized standard agreed with the Society and demonstrated to be acceptable

7.8 Radiographic testing (RT)

7.8.1 The acceptance levels and required quality levels for RT are provided in Tab 7. Reference radiographs for the assessment of weld imperfections are to be provided in accordance to ISO 5817:2014 or acceptable recognized standard agreed with the Society.

Table 7 Radiographic Testing

Quality Levels (ISO 5817:2014 applies)[a]	Testing Techniques/ levels (ISO 17636-1:2013 applies)[a]	Acceptance levels (ISO 10675-1:2016 applies)[a]
B	B (class)	1
C	B[b] (class)	2
D	At least A (class)	3

Notes:
[a] Or any recognized standard agreed with the Society and demonstrated to be acceptable
[b] For circumferential weld testing, the minimum number of exposures may correspond to the requirements of ISO 17636-1:2013, class A

7.9 Ultrasonic testing (UT)

7.9.1 The acceptance levels and required quality levels for UT are provided in Tables 8 and 9:

Table 8 Ultrasonic Testing

Quality Levels (ISO 5817:2014 applies)[a,b]	Testing Techniques/ levels (ISO 17640:2018 applies)[a,b]	Acceptance levels (ISO 11666:2018 applies)[a,b]
B	at least B	2
C	at least A	3
D	at least A	3[c]

Notes:
[a] Or any recognized standard agreed with the Society and demonstrated to be acceptable
[b] When characterization of indications is required, ISO 23279:2017 is to be applied
[c] UT is not recommended but can be defined in a specification with same requirement as Quality Level C

Table 9 Recommended Testing and Quality Levels (ISO 17640)

Testing Level[a,b,c] (ISO 17640:2018 applies)	Quality Level (ISO 5817:2014 applies)
A	C, D
B	B
C	By agreement
D	Special application

Notes:
[a] POD increases from testing level A to C as testing coverage increases
[b] Testing Level D for special application is to be agreed with Society
[c] Specific requirements for testing levels A to C, are provided for various types of joints in ISO 17460:2018 Annex A

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 the Society.

7.9.3 The acceptance levels for UT of welds are to be defined in accordance to ISO 11666:2018 requirements or any recognized acceptable standard agreed with the Society. The standard specifies acceptance levels 2 and 3 for full penetration welded joints in ferritic steels, corresponding to quality levels B and C (Refer to Tab 8).

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 flatbottom hole (disk shaped reflector)

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

8 Reporting

8.1

8.1.1 Reports of NDT required are to be prepared by the Shipbuilder and are to be made available to the Society.

8.1.2 Reports of NDT 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

8.1.3 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

8.1.4 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

8.1.5 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 is to be included. The control of documentation unprocessed original images and digitally processes images is to be to the satisfaction of the Surveyor.

8.1.6 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.

8.1.7 The shipyard is to keep the inspection records specified in [8.1.2] to [8.1.6] for at least 5 years.

9 Unacceptable indications and repairs

9.1

9.1.1 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.

9.1.2 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.

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

9.1.4 The inspection records specified in [8] are to include the records of repaired welds.

9.1.5 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.

CHAPTER 2 EXTENT OF NON-DESTRUCTIVE ~~EXAMINATIONS~~TESTING

1 Hull Structures

1.1

1.1.1

With respect to hull structures of new buildings, the non-destructive ~~examinations~~testing (ND~~E~~T) requirements specific to the individual buildings are generally stipulated at the time of approval of the main classification drawings, or by the Surveyors in charge of survey.

1.1.2

As regards the V~~E~~T and M~~E~~T methods, the following generally applies.

The Manufacturer is to carry out and record:

a) V~~E~~T to a full extent

b) M~~E~~T or P~~E~~T where necessary as a complement to V~~E~~T.

The Surveyors may carry out checks and direct examinations as deemed appropriate.

1.1.3

Checks with the R~~E~~T and U~~E~~T methods are required for butt-welded joints of plating and stiffening members.

Such checks are generally to be performed with the RET method, while Tasneef reserves the right to require the UET method in addition to, or to admit it partially or wholly in lieu of, the former.

In particular, additional U~~E~~T may be required where necessary to determine more precisely the position and size of a defect in the section.

The individual checks are to cover weld sections of length not less than 200÷480 mm or approximately 1 m, for the R~~E~~T and U~~E~~T, respectively.

In general, the number "n" of checks to be subjected to the R~~E~~T is to be not less than that resulting from the following formula:

$$n = \frac{L \cdot (B + D)}{46}$$

where L, B and D are the principal dimensions of the ship, in metres, as defined in ~~Part B~~Pt B, Ch 1, Sec 2 of the Rules for the Classification of Ships.

Checks are to be carried out as indicated in the following items a) to e), to the satisfaction of the Surveyors, unless otherwise stated.

Additional checks may be required as deemed necessary by the Surveyors in charge of the survey.

a) Shell and strength deck plating within 0,6 L amidships (including, for the deck and sheerstrake if appropriate, the zone of the break of the poop within 0,35 L aft of amidships):
   - all "4-way" crossings of butt-joints of panels or strakes of strength deck, bottom and bilge, welded practically at the same time (i.e. assembled when all still unwelded), regardless of the type of welding process used
   - a sufficient number of lengths of butts (transverse butt-joints) welded by special welding processes, such as "one side", "single pass" SAW and similar; the lengths are generally to be located on the butt in way of the T-crossing so as to also include the seam (longitudinal butt-joint) for a sufficient length
   - at least one examination in each butt of a round gunwale plate. The locations of the films will be distributed among the various butts such that different positions of the joints are examined, with particular reference to the central curved portion
   - spot examinations on joints of strakes in Class III structures in accordance with Part B, Ch 4, Sec 1 of the Rules for the Classification of Ships or made of steel types E/EH and higher
   - spot examinations of butt-joints, with the purpose of checking the workmanship. Within the scope of these examinations, butts beyond 0,6 L amidships may be required to be examined.

b) Spot examinations of butt-joints of insert plates around openings in the shell and strength deck, with particular regard to the zones including the rounded corners. In the case of inserts at the corners of large openings in the strength deck, at least one examination is required for each insert

c) Spot examinations on highly stressed butt-joints, such as those of the plating of rudder horns, the connection to the hull and adjacent plating, as well as those of cast pieces involved in the construction of sternposts and sternframes (in relation to the thickness of the material to be examined, gamma-ray examination may be substituted for radiographic examination)

d) Spot examinations on butt-joints of longitudinals of the strength deck, bottom and bilge, when realized without doubler

e) Spot examinations on welded joints of the plating of light alloy superstructures.

1.1.4

Tasneef may modify the normal extent of the ~~N~~DET checks, as deemed necessary, taking into account the level of quality of the welds resulting from production, the welding processes in use and the Manufacturer's quality control methods.

1.1.5

The plan of the positions examined, validated by the Manufacturer, is to be enclosed together with the report for first entry survey.

2 Pressure Vessels And Piping

2.1

2.1.1

For welded joints of pressure vessels, boilers and piping, the requirements regarding the extent of the ND~~E~~Ts are given in Part C of the Rules for the Classification of Ships.

In the absence of requirements as to the method to be adopted for internal ND~~E~~Ts, it is understood that the R~~E~~T is to be used while Tasneef reserves the right to require t~~h~~e UET method in addition to, or to admit it partially or wholly in lieu of, the former.

Moreover, specific requirements may be stipulated at the time of approval of the drawings as well as during construction in accordance with the provisions in the recognized standards used for the design and testing of pressure vessel or piping~~1~~.

2.1.2

The plan of the positions examined, validated by the Manufacturer, is to be enclosed together with the test report.

3 Non-Conforming Results

3.1

3.1.1

Where, in a weld area checked with ND~~E~~T by a method which is applied to an extent less than 100%, discontinuities are found exceeding the acceptable limits applicable to the welding concerned, as a rule the procedure is as follows:

a) the defective area is to be repaired

b) contiguous areas are to be suitably examined with the same method or a method of equivalent reliability

c) where the outcome of the extended examination is also negative, the examination is further extended to similar joints (as regards manufacturing conditions, welding time and other circumstances), at the discretion of the Surveyors

d) any further repairs and checks are stipulated by Tasneef depending on the findings

3.1.2

Where there is a recurrence of non-conforming findings, Tasneef may require:

a) modification of the welding procedures prior to proceeding further with production and/or

b) implementation of appropriate ND~~E~~T checks, also to a full extent, until satisfactory results are obtained.

3.1.3

Any repairs judged necessary by the Surveyors are to be carried out with procedures approved by Tasneef.

Parts repaired are to be checked ~~-~~using NDETs appropriate for the evaluation of the repairs, to the satisfaction of Tasneef.

CHAPTER 3 ADVANCED NON-DESTRUCTIVE TESTING OF MATERIALS AND WELDS

1 General

1.1

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

1.1.2 The ANDT is to be performed by the shipbuilder, manufacturer or its subcontractors in accordance with these requirements. The Society's Surveyor may require witnessing testing.

1.1.3 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 the Society on the findings made by the ANDT.

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

1.2 Terms and definitions

1.2.1 The following terms and definitions apply:

ANDT	:	Advanced non-destructive testing
RT-D	:	Digital Radiography
RT-S	:	Radioscopic testing with digital image acquisition (dynamic.12bit)
RT-CR	:	Testing with computed radiography using storage phosphor imaging plates
PAUT	:	Phased Array Ultrasonic Testing
TOFD	:	Time of Flight Diffraction
AUT	:	Automated Ultrasonic Examinations. A technique of ultrasonic examination performed with equipment and search units that are mechanically mounted and guided, remotely operated, and motor-controlled (driven) without adjustments by the technician. The equipment used to perform the examinations is capable of recording the ultrasonic response data, including the scanning positions, by means of integral encoding devices such that imaging of the acquired data can be performed.
SAUT	:	Semi-Automated Ultrasonic Examinations. A technique of ultrasonic examination performed with equipment and search units that are mechanically mounted and guided, manually assisted (driven), and which may be manually adjusted by the technician. The equipment used to perform the examinations is capable of recording the ultrasonic response data, including the scanning positions, by means of integral encoding devices such that imaging of the acquired data can be performed.

2 Applicability

2.1 Materials

2.1.1 The requirements in this Chapter apply to the following materials and manufactured products:

- Material and welding for gas tankers in accordance with Pt D and Pt E, Ch 9, Sec 6 of the Rules for the Classification of Ships
- Normal and higher strength hull structural steels in accordance with Pt D, Ch 2, Sec 1, [2] of the Rules for the Classification of Ships
- High strength steels for welded structures in accordance with Pt D, Ch 2, Sec 1, [3] of the Rules for the Classification of Ships
- Hull and machinery steel forgings in accordance with Pt D, Ch 2, Sec 3, [1] to [5] of the Rules for the Classification of Ships
- Hull and machinery steel castings in accordance with Pt D, Ch 2, Sec 4, [1] to [4] of the Rules for the Classification of Ships
- Extremely Thick Steel Plates in Container Ships in accordance with Pt D, Ch 2, Sec 1, [10] of the Rules for the Classification of Ships
- Cast Copper Alloy propellers in accordance with Pt D, Ch 4, Sec 2, [1] of the Rules for the Classification of Ships
- Aluminium alloys for hull construction in accordance with Pt D, Ch 3, Sec 2 of the Rules for the Classification of Ships
- Cast Steel Propellers in accordance with Pt D, Ch 4, Sec 2, [3] of the Rules for the Classification of Ships
- YP47 Steels and Brittle Crack Arrest Steels in accordance with Pt D, Ch 2, Sec 1, [11] of the Rules for the Classification of Ships
- Marine steel castings in accordance with IACS Rec 69

2.2 Welding processes

2.2.1 The requirements in this Chapter apply to welding processes specified in Tab 1. ANDT of welding process unspecified in Tab 1 is to be to the satisfaction of the Society.

Table 1 Applicable welding process

Welding process		ISO 4063:2009
Manual welding	Shield Metal Arc Welding (SMAW)	111
Resistance welding	Flash welding (FW)	24
Semi-automatic welding	(1) Metal Inert Gas welding (MIG)	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

2.3 Weld joints

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

2.4 Timing of ANDT

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

2.4.2 Timing of ANDT on ship hull welds on steels with specified minimum yield stress in the range of 420 N/mm^2 to 690 N/mm^2 is to be in accordance with Ch 1, [2.4.2].

2.5 Testing methods

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

2.5.2 Applicable methods for testing of the different types of materials and weld joints are given in Tab 2.

Table 2 Applicable methods for testing of materials and weld joints

MATERIALS AND WELD JOINTS	PARENT MATERIAL THICKNESS	APPLICABLE METHODS
Ferritic butt welds with full penetration	thickness < 6mm	RT-D
	6 mm ≤ thickness ≤ 40 mm	PAUT, TOFD, RT-D
	thickness > 40mm	PAUT, TOFD, RT-D*
Ferritic tee joints and corner joints with full penetration	thickness ≥ 6mm	PAUT, RT-D*
Ferritic cruciform joints with full penetration	thickness ≥ 6mm	PAUT*
Austenitic stainless steel butt welds with full penetration[1]	thickness < 6mm	RT-D
	6 mm ≤ thickness ≤ 40 mm	RT-D, PAUT*
	thickness > 40mm	PAUT*, RT-D*
Austenitic stainless steel tee joints, corner joints with full penetration[1]	thickness ≥ 6mm	PAUT*, RT-D*
Aluminum tee joints and corner joints with full penetration	thickness ≥ 6mm	PAUT*, RT-D*
Aluminum cruciform joints with full penetration	thickness ≥ 6mm	PAUT*
Aluminum butt welds with full penetration	thickness < 6mm	RT-D
	6 mm ≤ thickness ≤ 40 mm	RT-D, TOFD, PAUT
	thickness > 40mm	TOFD, PAUT, RT-D*
Cast Copper Alloy	All	PAUT, RT-D*
Steel forgings	All	PAUT, RT-D*
Steel castings	All	PAUT, RT-D*
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*

Notes:
* Only applicable with limitations, need special qualification subject to acceptance by the Society.
[1] The ultrasonic testing of anisotropic material using advanced methods will require specific procedures and techniques. Additionally, the use of complementary techniques and equipment may also be required, e.g. using angle compression waves, and/or creep wave probes for detecting defects close to the surface.

3 Qualification of personnel involved in ANDT

3.1

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

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

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

Level 3 personnel is to be certified by an accredited certification body.

3.1.2 The Shipbuilder, manufacturer or its subcontractors is 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 is 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 in [3.1.1]. It is not permissible to appoint Level 3 personnel; they must be certified by an accredited certification body. It is recognised that a Shipbuilder, manufacturer or its subcontractors may not directly employ a Level 3 in all the stated methods practiced. In such cases, it is permissible to employ an external, independently certified, Level 3 in those methods not held by the full-time Level 3(s) of the Shipbuilder, manufacturer or its subcontractors.

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

3.1.3 The operator carrying out the NDT and interpreting indications, is to as a minimum, be qualified and certified to Level 2 in the NDT method(s) concerned and as described in [3.1.1].

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

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

4 Technique and procedure qualification

4.1

4.1.1 General

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

- The technical documentation of the ANDT
- The operating methodology and procedure of the ANDT according to [7].
- Result of software simulation, when applicable.

4.1.2 Software simulation

Software simulation may be required by the Society, when applicable for PAUT or TOFD techniques. The simulation may include initial test set-up, scan plan, volume coverage, result image of artificial flaw etc.. In some circumstances, artificial defect modeling/simulation may be needed or required by the project.

4.1.3 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[1] 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 the Society, and at least the intermediate level qualification blocks is to be used. The high level qualification blocks is 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 Society's Surveyor.

4.1.4 Procedure approval

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

4.1.5 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 are 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, the Society has the right to reject the results of such activities.

5 Surface condition

5.1

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

5.1.2 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.

5.1.3 The requirement for acceptable test surface finish is to ensure accurate and reliable detection of defects. For the testing of welds, where the test surface is irregular or has other features likely to interfere with the interpretation of NDT results, the weld is to be ground or machined.

6 General plan of testing: NDT method selection

6.1

6.1.1 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 UR or REC applicable with material of weld examined.

7 Testing requirements

7.1 General

7.1.1 The shipyard or manufacturer is to ensure that personnel carrying out NDT or interpreting the results of NDT are qualified to the appropriate level as detailed in [3].

7.1.2 Procedures

a) All NDT are to be carried out to a procedure that is representative of the item under inspection.

b) 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.

c) 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.

d) 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

e) Procedures are to be approved by personnel qualified to Level III in the appropriate technique in accordance with a recognised standard

f) Procedures are to be reviewed by the Society's Surveyor.

7.1.3 The methods considered within the application of this Chapter are defined in [2.5.1].

7.1.4 PAUT techniques are to conform as a minimum to [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.

7.1.5 PAUT of welds is to include a linear scan of the fusion face, together with other scans as defined in the specific test technique. Refer to linear scan requirements in [7.2.6].

7.1.6 TOFD techniques are to conform as a minimum to [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.

7.1.7 RT-D techniques are to conform as a minimum to [7.4]. For the purpose of this UR, RT-D comprises of two main RT methods; RT-S and RT-CR. Other methods may be included (e.g. radioscopy systems), however, then must conform to this Chapter as applicable, and any specific requirements is to demonstrate equivalence to these requirements.

7.1.8 In all RT-D methods, in addition to specific requirements, detector output quality control methods are to be described within the procedure. The procedure is to define the level of magnification, post-processing tools, image/data security and storage, for final evaluation and reporting.

7.2 Phased array ultrasonic testing

7.2.1 PAUT is to be carried out according to procedures based on ISO 13588:2019, ISO 18563-1:2015, ISO 18563-2:2017, ISO 18563-3:2015 and ISO 19285:2017 or recognized standards and the specific requirements of the Society.

7.2.2 Information required prior to testing

A procedure is to be written and include the following information as in minimum shown in Tab 3. When an essential variable in Tab 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 are to require revision of, or an addendum to, the written procedure.

Table 3 Requirements of a PAUT Procedure

Requirement	Essential Variable	Nonessential Variable
Material types or weld configurations to be examined, including thickness dimensions and material product form (castings, forgings, pipe, plate, etc.)	X	…
The surfaces from which the examination 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[1], 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
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.		

7.2.3 Testing levels

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

7.2.4 Weld Examinations

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

7.2.5 Material Examinations

Material examinations are to conform to [2.1] as a minimum.

7.2.6 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 ± 5º. This requirement may be omitted if an 'S' (or sectorial) scan can be demonstrated to verify that discontinuities at the fusion face can be detected and sized, using the stated procedure (note, this demonstration is to utilize reference blocks containing suitable reflectors in location of fusion zone).

7.2.7 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 is to be in accordance with ISO 13588:2019 or recognized equivalent standards and the specific requirements of the Society.

7.2.8 Indication assessment

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

7.3 Time of flight diffraction

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

7.3.2 Information required prior to testing

A procedure is to be written and include the following information as shown in Tab 4. When an essential variable in Tab 4 is to change from the specified value, or range of values, the written procedure is to require requalification. When a nonessential variable is to change from the specified value, or range of values, requalification of the written procedure is not required. All changes of essential or nonessential variables from the value, or range of values, specified by the written procedure are to require revision of, or an addendum to, the written procedure.

Table 4 Requirements of a TOFD Procedure

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

7.3.3 Testing levels

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

7.3.4 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 locations of the probes, beam coverage, the weld thickness and the weld geometry.

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

7.4 Digital radiography

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

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

A procedure is to be written and include the following information as shown in Tab 5.

Table 5 Requirements of a Digital radiography Procedure

Requirement
Material types or weld configurations to be examined, including thickness dimensions and material product form (castings, forgings, pipe, plate, etc.)
Digitizing System Description:
Manufacturer and model no. of digitizing system
Physical size of the usable area of the image monitor
Film size capacity of the scanning device
Spot size(s) of the film scanning system
Image display pixel size as defined by the vertical/horizontal resolution limit of the monitor
Illuminance of the video display
Data storage medium
Digitizing Technique:
Digitizer spot size (in microns) to be used
Loss-less data compression technique, if used
Method of image capture verification
Image processing operations
Time period for system verification
Spatial resolution used:
Contrast sensitivity (density range obtained)
Dynamic range used
Spatial linearity of the system
Material type and thickness range
Source type or maximum X-ray voltage used
Detector type
Detector calibration
Minimum source-to-object distance
Distance between the test object and the detector
Source size
Test object scan plan (if applicable)
Image Quality Measurement Tools
Image Quality Indicator (IQI)
Wire Image Quality Indicator
Duplex Image Quality Indicator
Image Identification Indicator
Testing levels, acceptance levels and/or recording levels
Personnel qualification requirements
Surface condition
Records, including minimum calibration data to be recorded
Environmental and Safety issues

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

8 Acceptance Levels

8.1 General

8.1.1 This 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).

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

8.1.3 Acceptance criteria for each material and weld joint are to be in accordance with [2.1.1].

8.2 Phased array ultrasonic testing

8.2.1 Weld Examinations

The relationship between acceptance levels, testing levels and quality levels is given in Tab 6.

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

Table 6 Acceptance levels for PAUT

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

8.2.2 Material Examinations

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

The acceptance levels for material examinations are to conform as a minimum to the requirements of the Tasneef Rules applicable to the material.

8.3 Time of flight diffraction

8.3.1 The relationship between acceptance levels, testing levels and quality levels is given in Tab 7. Quality levels and acceptance levels for TOFD of welds are to be in accordance to ISO 15626:2018 or recognized standard agreed with the Society.

Table 7 Acceptance levels for TOFD

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

8.4 Digital radiography

8.4.1 The relationship between acceptance levels, testing levels and quality levels is given in Tab 8. Quality levels and acceptance levels for Digital Radiography of welds are to be in accordance with ISO 10675 or standard agreed with the Society.

Table 8 Acceptance levels for Digital radiography

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

9 Reporting

9.1

9.1.1 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:

1) identification of the object under test
2) dimensions including wall thickness
3) material type and product form
4) geometrical configuration
5) location of welded joint(s) examined
6) reference to welding process and heat treatment
7) surface condition and temperature
8) stage of manufacture

c) information relating to equipment (see Tab 9)

d) information relating to test technology (see Tab 10)

e) information relating to test results (see Tab 11)

Table 9 Information relating to equipment

Method	Information
All	manufacturer and type of instrument, including with identification numbers if required.
PAUT	1) manufacturer, type, frequency of phased array probes including number and size of elements, material and angle(s) of wedges with identification numbers if required 2) details of reference block(s) with identification numbers if required 3) type of couplant used
TOFD	1) manufacturer, type, frequency, element size and beam angle(s) of probes with identification numbers if required 2) details of reference block(s) with identification numbers if required 3) type of couplant used
RT-D	1) system of marking used 2) radiation source, type and size of focal spot and identification of equipment used 3) detector, screens and filters and detector basic spatial resolution

Table 10 Information relating to test technology

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

Table 11 Information relating to test results

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

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

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

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

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

10 Unacceptable indications and repairs

10.1

10.1.1 All indications (discontinuities) exceeding the applicable acceptance criteria are to be classed as defects, and are to be eliminated and repaired according to the applicable Tasneef Rules.

Appendix A - LIMITS FOR DEFECTS - LEVELS

A.1 - GENERAL

A.1.1

The limits for discontinuities and imperfections (also referred to simply as “defects”) stipulated for welded joints in this Appendix are to be considered as limits dictated by normal good practice on the basis of proven experience in shipbuilding and related constructions of structures, boilers and pressure vessels.

Such limits are listed in detail in A.4 and A.5 and the most important are summarized in Tables A.1 and A.2; in addition, Figures A.1, A.2, A.3 and A.4 give the limits for discontinuities of elongated type as a function of the thickness.

Other criteria established by national/international standards may be accepted subject to Tasneef agreement.

A.1.2

The limits as per A.4 represent a **normal quality level** valid for the welded joints in areas considered of primary importance, with internal NDEs (i.e. **RE** and **UE**) required; the level is also applicable, with suitable reductions at the discretion of the Surveyors, in areas of lesser importance.

Examples of items of primary importance for which the normal level is considered appropriate are:

(a) hull structures considered Class II within 0,4 **L** amidships; to be examined for NDE purposes within 0,6 **L** amidships and in other positions deemed important (for example stern area in rudder structures and boss),
(b) Class II pressure vessels,
(c) Class II pipes,
(d) welded members similarly stressed.

A.1.3

For structures and/or items considered of special importance, greater than that in A.1.2, and/or those for which internal NDEs to a full extent are required, a **special quality level** is foreseen, characterized by the limits for defects specified in A.5.

Examples of applications for which the special level is considered appropriate may include:

(a) hull structures considered Class III within 0,4 **L** amidships; to be examined for NDE purposes within 0,6 **L** amidships and in other positions deemed equally important (for example, crossings and insert plates in important plating and of significant thickness even if of Class II, rudder structures and boss of significant thickness),
(b) Class I pressure vessels,
(c) Class I pipes,
(d) welded members which are similarly stressed.

A.1.4

For structures and items other than those in the preceding items, where the degree of importance or the quality level required does not appear in the applicable Rules, this is stipulated by Tasneef in each case, for example at the time of approval of the drawings or the inspection request.

In the absence of specific guidelines, the normal level is considered applicable.

A.1.5

The limits for the individual defects are expressed in terms of their dimensions and are fixed independently of the NDE method used. The sizing of a defect may require the use of more than one method.

For the **UE** method, for which the initial criterion is the "go-no go" check, defects having an echo less than 100% of the echo reference (**ERL**) which come within the stipulated limits for length do not normally require further dimensional checks. Such limits are specified in A.6.

A.1.6

A.1.6.1

The occurrence of minor non-conformities in respect of the limits which characterize the quality levels does not mean that the defective area is to be necessarily repaired.

In fact, such limits define a quality level deemed appropriate but do not constitute acceptance limits. The latter will be stipulated by Tasneef on a case-by-case basis taking into account, in particular, the importance of the type of defect and the local state of stresses.

Subject to the above condition, the acceptance limits given in A.1.6.2, A.1.6.3 and A.1.6.4 may nevertheless be taken as guidance.

If not sporadic, the occurrence of defects exceeding the quality limits requires:

- an extension of the checks to adjacent areas and to welds similar as regards procedures and welding time, in order to identify the extent of the non-conforming weldments,
- an interpretation of the causes,
- adequate provision for the elimination of such causes,
- more stringent checks as deemed necessary by the Surveyors.

A.1.6.2

The normal acceptance limits (**NAL**) for welding of primary structural members are fixed, in relation to the corresponding limit values of the normal quality level (**NQL**), as follows and may be applied if not otherwise required:

- elongated internal defects (**MP** all, **SCall**) and non-elongated **SC**:
  L,**A**,**S** = 1,5 **NQL**
  D,**Dz** = **NQL**
- volumetric internal defects (**SOF**, **GR**, **T** and similar):
  At = 2 **NQL**
  L,**S** = 3 **NQL**; **N** = 2 **NQL**
  D,**Dz** = 0,5 **NQL**
- external defects such as **IM**, **IV**, **IR**, **OV**:
  L = 2,5 **NQL**
  D = 0,5 **NQL**
- external defects such as **IS**, **SL**, **SV**:
  L,**S** = 2 **NQL**
  D = 5 **NQL**.

In all cases above where **D** is less than the limit shown, as a rule the two contiguous defects are regarded as one continuous defect.

A.1.6.3

The special acceptance limits (**SAL**) for welding of structural members of special importance, excluding the welding specified in A.1.6.4, are identified by the quality limits (**NQL**) specified for the normal level.

A.1.6.4

The acceptance limits (**SAL**) for welding of structural members of special importance are identified by the quality limits (**SQL**) applicable to the special level in the following cases:

- when subject to NDE to a full extent, and
- crossings of joints, as defined in A.1.5.1, also when relative to joints not subject to 100% NDE.

A.1.7

A.1.7.1

The lengths of joint presenting NDE lengths $\mathbf{L_{sr}}$ with defects exceeding the limits of acceptability are to be adequately repaired and re-examined as required in item 3 of Chapter 3, except as provided for in A.1.7.2.

A.1.7.2

Where the **RE** reveals defects of the volumetric type, including slag inclusions **SC** and **SCall** (therefore excluding bidimensional defects and incomplete penetration) which exceed the acceptance limits as per A.1.6, the following procedure may be followed at the discretion of the Surveyors in relation to the type and magnitude of the defects.

The defective areas may be examined with the **UE** method.

Repair may be omitted for those defects which, during this additional examination, reveal an echo not greater than 50% of the reference echo (**ERL**) and are therefore acceptable for the **UE**.

~~A.1.7.3~~

~~In addition to the provisions above, and to item 3 of Chapter 3 relevant to non-conforming defects, the following example of procedure relevant to primary structures may be taken for guidance.~~

~~(1) A position **P**x is considered on the plan of the NDEs, **RE** method, of a hull with at **P**x **RE** required of length **L**s = 480 (≈ 3 **L**sr = 150 mm each).~~
~~Let **L**1 (= **L**s1) be the length of the first examination in the position **P**x of the plan of the NDEs, and **L**2, **L**3 the lengths **L**s of the extensions of the NDE caused by the presence of defects on **L**1.~~

~~(2) Where **L**1 shows defects beyond the limits of the applicable Normal Level (**NQL**), the following procedure may be adopted depending on the magnitude of the defects.~~

~~(3) The acceptance limits (**NAL**) in **L**1 are not exceeded:~~
- ~~consider the defects found as a warning sign, without the need, in normal circumstances, to demand the repair of the length of joint concerned.~~

~~(4) The acceptance limits (**NAL**) in **L**1 are exceeded:~~
- ~~repair the defective areas, and~~
- ~~demand two checks, **L**2 and **L**3 of extent equal to **L**1 found to be defective, located in continuation of **L**1 at both ends of it, or in any event on the same joint (checks to be performed using the same method as the first one).~~

~~(5) Both the additional **L**2 and **L**3 required have defects within the limits of the Normal Level (**NQL**):~~
- ~~other NDE extensions do not appear necessary.~~

~~(6) One or both of the additional **L**2 and **L**3 required have defects exceeding the Normal Level (**NQL**) and are:~~
  ~~(a) both within the acceptance limits (**NAL**):~~
  - ~~examine other joints similar to the defective one, proceeding as appropriate with equivalent criterion,~~
  - ~~the defects found constitute a warning sign for the production,~~
  - ~~repair, as deemed necessary, depending on the individual cases;~~

  ~~(b) one or both beyond the limits of acceptability (**NAL**):~~
  - ~~repair the joint concerned in the defective areas,~~
  - ~~examine other joints similar to that to be repaired, proceeding as appropriate with equivalent criterion as regards the evaluation and any steps to be taken,~~
  - ~~demand corrective actions on the production.~~

~~A.2 - LIST OF DEFECTS AND IDENTIFYING SYMBOLS~~

~~A.2.1~~

~~For the purpose of these Rules, the defects are identified by the symbols shown below:~~

~~- incomplete penetration~~	~~[**MP**]~~
~~- centre (within 0,5 T)~~	~~[**MPc**]~~
~~- surface (beyond 0,5 T)~~	~~[**MPs**]~~
~~- at the root (joints welded on one side only)~~	~~[**MPv**]~~
~~- slag inclusions~~	~~[**SC**]~~
~~- elongated~~	~~[**SCall**]~~
~~- central, non-elongated~~	~~[**SCc**]~~
~~- surface~~	~~[**Scs**]~~
~~- single pores~~	~~[**SOF**]~~
~~- clustered porosity~~	~~[**GR**]~~
~~- wormholes~~	~~[**T**]~~
~~- wormhole clusters~~	~~[**NT**]~~
~~- undercut~~	~~[**IM**]~~
~~- root undercut (joints welded on one side only)~~	~~[**IV**]~~
~~- surface irregularities (of the weld reinforcement or at the root)~~	~~[**IS**]~~
~~- irregularities of penetration at the root in joints welded on one side only (grooves or excessive penetration)~~	~~[**IP**]~~
~~- overlap~~	~~[**OV**]~~
~~- misalignment~~	~~[**SL**]~~
~~- bidimensional defects in general (cracks, lack of fusion)~~	~~[**DP**]~~
~~- centre (within 0,5 T)~~	~~[**DPc**]~~
~~- surface (beyond 0,5 T)~~	~~[**DPs**]~~

~~For a detailed description of some defects, see Appendix C.~~

A.3 - SYMBOLS AND DEFINITIONS OF DIMENSIONAL PARAMETERS CHARACTERIZING THE DEFECTS

A.3.1

L_S: length of the welding under examination
L_{Sr}: **L_S** reference standard; in these Rules **L_{Sr}** = 150, unless otherwise stated
T = thickness of members at the joint
L = defect length
H = defect dimension, other than **L** (height or width or diameter)
D = distance, in length, between two contiguous defects
S = sum of the individual defects (relative to defects of the same type, unless otherwise stated), in a length **L_{Sr}** = 150 mm. The parameter of the defect to which the sum refers may be added in brackets, e.g. **S**(**H**), **S**(**L**)
A_S = projected area of the weld; **A_S** may be assumed approximately equal to **L_S** · **T**, where **L_S** is the length of the weld examined and **T** is the thickness of the member (in the Rules **L_S** corresponds to **L_{Sr}** and is therefore equal to 150 mm)
A_t = approximate total area of the defects, in relation to the length **L_S**
W = height of the excess weld reinforcement or convexity
F_a = weld reinforcement angle
F_l = leg length of a fillet.

Note: For symbols and definitions not given above, see the individual defects.
Unless otherwise stated, the dimensions are understood to be in mm.

A.4 - NORMAL LEVEL

A.4.1

The limits for defects relative to the normal quality level (**NQL**) are listed below for the different types of defects considered in the Rules and identified by the symbols as per A.2. They are relative to **L_{Sr}** = 150 mm; where other **L_{Sr}** are stipulated, the limits vary in proportion.

[MPc] - back-welded joints:

L ≤ **T**, **L_{max}** = 25 mm; **H** ≤ 0,1 **T**, **H_{max}** = 2 mm; **S**(**L**) ≤ 2 **T**, **S**(**L**)$_{max}$ = 40 mm;
D ≥ **L** (where **L** is the defect with the greater length of two contiguous defects).

[MPs] - back-welded joints:

L ≤ **T**, **L_{max}** = 25 mm; **H** ≤ 0,07 **T**, **H_{max}** = 1,5 mm; **S**(**L**) ≤ 2 **T**, **S**(**L**)$_{max}$ = 40 mm;
D ≥ 2 **L** (where **L** is the defect with the greater length of two contiguous defects).

[MPv] - joints welded on one side only:

(a) if accepted as equivalent to the back-welded joints:
L ≤ 10 mm; **H** ≤ 1 mm; **S**(**L**) ≤ 2 **T**, **S**(**L**)$_{max}$ = 40 mm;
D ≥ 2 **L** (where **L** is the defect with the greater length of two contiguous defects).

(b) if accepted but not considered equivalent to the back-welded joints (i.e. special cases, secondary structures, small thicknesses):
L ≤ 25 mm; **H** ≤ 2 mm; **S**(**L**) ≤ 60 mm; **D** ≥ **L**.

[SCall] (longitudinal elongated slag, possibly aligned, having **H** (width) ≤ 1,5 mm and ratio (**L**/**H**) > 3):

L ≤ **T**, **L_{max}** = 25 mm; **H** ≤ 1,5 mm; (**L**/**H**) > 3; **S**(**L**) ≤ 2 **T**, **S**(**L**)$_{max}$ = 40 mm;
D ≥ **L** (where **L** is the defect with the greater length of two contiguous defects).

NOTES:
[1] If the **SC** are on two lines, they are to be considered separately in relation to **L**, **H**, **D** and together in relation to **S**(**L**); in such case, provided that they are not side by side, the limit of **S**(**L**) is **S**(**L**) ≤ 3 **T**, **S**(**L**)$_{max}$ = 60 mm; the distance **d** between the two lines is to be **d** ≥ 3 **H**, **H** being the width of the inclusion of greater width.
[2] If **H** > 1,5 mm and/or (**L**/**H**) ≤ 3, treat as [**SC**].

[3] For the calculation of " **S**(**L**)", the **MP**, **SCall** and **SC** are considered together as a defect of the same type.

[SC] (non-elongated or transversal elongated slag inclusions):

H ≤ 0,2 **T**, **H**max = 5 mm;
A (= **LH**) ≤ **T**/2, **A**max = 10 mm^2; **S**(**A**) ≤ 1,2 **T**, **S**(**L**)max = 30 mm^2
D ≥ **H** (where **H** is the greater of two contiguous defects).

[SOF] (diffused or single pores; if clustered **[GR]** applies, if mixed **[SOF+GR]** applies)

(a) 0,5 < **H** ≤ 3 mm; pores having diameter **H** ≤ 0,5 mm may be disregarded; however, if not occasional, the causes are to be found and eliminated;
At ≤ 0,1 **As** [1] where **At** is the total approximate area of the **SOF** and A_S is the projected area of the weld.
As may be assumed approximately equal to L_S · **T**, where L_S is the length of the weld examined and **T** is the thickness of the member (in general, in these Rules L_S = L_{sr} = 150 mm).

(b) in addition to the condition in (a), any pores having diameter **H** ≥ 2 are also to satisfy the following:
D ≥ 3 **H**, where **D** is the distance in any direction between two contiguous pores and **H** is the diameter of the larger of the two; **D** applies on single lengths "**a**" which include not more than 4 pores.
Da ≥ **a**, where **Da** is the distance between two contiguous lengths and "**a**" the greater of the two.

NOTE:
[1] The limit A_t, as per (a), expressed approximately in terms of **N**, max number of **SOF** on a given length L_{sr} = 150 mm, is given in the following table, where **T** is the thickness of the welded member and **Hm** the average diameter of the **SOF** present on the L_{sr} considered:

Nmax				
Hmedio / T	15	20	25	30
1,0	30	40	50	60
1,5	12	17	22	26
2,0	7	10	12	14
2,5	5	6	8	9
3,0	3	4	5	6

[GR] (clustered pores, also termed clusters; the **GR** defect means a group of various non-aligned pores included in a length **L** of joint. **L** denotes the length of the defect, **N** is the number of single pores in relation to **L**. In the case of **GR** associated with **SOF**, see **[SOF+GR]**).

H ≤ 1
L ≤ 2 **T**, **L**max = 30
N ≤ **T**, **N**max = 30
D ≥ 4 **L**

[SOF+GR] (single pores associated with others in clusters).

Consider jointly the two types of defect to determine the defective area, whose limit in this case is equal to 1,5 A_t, where A_t is the limit fixed for the single SOF.
The other limits used for both types of defect also apply.

Appendix A - LIMITS FOR DEFECTS - LEVELS

[TA] (a wormhole is intended as an elongated pore having **H** ≤ 1,5 mm and ratio (**L**/**H**) ≥ 3).

L ≤ **T**; **L**max = 12 mm
D ≥ **L**
S(**L**) ≤ 2 **T**; **S**(**L**)max = 30 mm.

[NT] (wormhole clusters; **L** and **H** are, respectively, the length in the direction of the joint and the width of the rectangle bounding the cluster).

A (= **LH**) ≤ 100 mm^2
D ≥ 14 **L**
S(**A**) ≤ 120 mm^2.

[IM] (undercuts).

H ≤ 0,5 mm
Greater values of **H** (as a rule not more than 1÷1,5 mm) may be tolerated occasionally, when well-faired and kept within the following limits and except when unacceptable for other reasons, e.g. reduction in thickness:
L ≤ 3 **T**; **L**max 60; **D** ≥ 2 **L**.

[SL] (misalignment; well-faired). Values given as quality levels, except when unacceptable for other reasons, as in particular for design considerations.

H ≤ 0,15 **T**, max:
- 2÷3 mm for transverse joints
- 4 mm for longitudinal joints.

Note: for joints welded on one side only, where one edge appears not fused, the limits of [MPV], i.e. incomplete penetration at the root, apply.

[IV] (root undercut in joints welded on one side only).

(a) if joints are to be considered equivalent to those with back welding:
the limits given for **[IM]**, undercut, apply
(b) if joints are **not** to be considered equivalent to those with back welding:
H ≤ 1,5 mm well-faired subject to the exception mentioned under **[IM]**.

[IS] surface irregularities in butt-welds (of the weld reinforcement or at the root).

H ≤ 1,5 mm (depth of underfill)
L ≤ 40 mm
D ≤ 4 **L**
S(**L**) ≤ 40 mm
other conditions:
- to be well-faired and without excessive irregularities
- any reductions in thickness to be within limits acceptable in individual cases.

[IR] (root irregularities, grooves or excessive penetration, in joints welded on one side only)

(a) if joints are to be considered **equivalent** to those with back-welding:
H ≤ 2 mm (**H** = reinforcement height at the root, if applicable)
L ≤ 7 mm
D ≥ 4 **T**
S ≤ **T**

(b) if joints are to be considered **not equivalent** to those with back-welding:

L ≤ **T**
D ≥ 2 **T**
S ≤ 4 **T**

[OV] (overlap)

L ≤ **T**

[SMV] (limits of the weld reinforcement in butt-joints).

H_a = height of the reinforcement; **b** = width of the weld in way of H_a
$H_a \leq$ (1 mm + 0,15 **b**)
H_a max = 4 mm
in addition the reinforcement is to be well-faired.

[SMF] (weld reinforcement limits in fillet welds, i.e. convex fillet).

H_a = excess on the theoretical thickness; **b** = width of the weld in way of H_a
$H_a \leq$ (1 mm + 0,15 **b**)
H_a max = 3 mm.

[DP] (internal bidimensional defects in general, central or on the surface).

The limits given for the **UE** method apply (see A.6).

[Concurrent defects]

When concurrent, defects which are classifiable as "elongated" (**MP**, **SCall**,..) or as "rounded" (**SOF**, **GR**,..) and non-elongated slag (**SC**) are considered separately and the following applies:

(a) For concurrent defects of equal classification, the most stringent limit stipulated for the types of defect present applies for **D** and **S**.
(b) For concurrent defects of different classification:
- for **D** the most favourable limit value applies;
- for **S**, if regulated by parameters of the same type (e.g. **L**) the most stringent limit applies;
- for **S**, if regulated by different parameters the applicable limit is stipulated case-by-case; however, in general, in the case of concurrence of elongated and rounded defects, **S** may be counted separately for the two classes, each with its own limit (see also (a) above).

(c) For concurrence in the section, the limit sum **S**(**H**) ≤ 0,15 **T** ≤ 3 mm applies, unless otherwise allowed or required in the individual cases.
(d) The limits for concurrence are not applicable to defects of shape.
(e) The possibility of "masking" between concurrent defects is to be considered, carrying out suitable checks as necessary.

[Defective areas]

The case of NDEs carried out with an extent of less than 100% is considered.
Where in a L_{sr} defects both of the same type or concurrent are found to an extent amounting to between 75% and 100% of the max sum S allowed by the quality level applied, in relation to the type of defect and/or when the continuity of defects along the joint is possible, the Surveyors may require NDE on L_{sr} contiguous to that found initially defective and proceed accordingly depending on the results.
This applies in particular **for aligned defects,** for **SOF** having **H** ≤ 2 and for **GR**; in fact, an accentuated presence of defects, while occasionally tolerable, may be symptomatic of anomalies in the manufacturing conditions or process.
Where defects are grouped near one end of an L_{sr} it may also be advisable to extend the check to the contiguous L_{sr}.

A.5 - SPECIAL LEVEL

A.5.1

The Special Level applies to welded joints involved in the applications specified in A.1.3.

As far as concerns the crossings mentioned in A.1.3, the term "crossing" is intended to mean an area constituted by two reference lengths L_{rs}, equal to 150 mm, one on each of the joints constituting the crossing and situated across it.

A.5.2

The limits for the different types of defect, relative to the special quality level (**SQL**), are stipulated in relation to the corresponding limits of the normal quality level (**NQL**), according to the following general criterion:

- elongated internal defects (**MP** all, **SCall**) and non-elongated **SC**:
  - **L**,**A**,**S** = 0,5 **NQL**
  - **H** (**SC** non-elongated) = 0,5 **NQL**
  - **D**,**Dz** = 2 **LQN**
- volumetric internal defects (**SOF**, **GR**, **TA** and similar):
  - **At** = 0,5 **NQL**
  - **L**, = 0,5 **NQL**; **N** = 0,75 **NQL**
  - **D**,**Da**,**Dz** = 2 **NQL**
- external defects **IM**, **IV**, **IR**, **OV**:
  - **IM**, **IV**:
  - **L** = 0,5 **NQL**
  - **D** = 1,5 **NQL**
  - **IR**:
  - **L** = 5 mm
  - **D** as **NQL**
- others as **NQL**.

A.5.3

By way of example, some of the most important defects modified in accordance with the criterion in A.5.2 are listed below.

[MPc] - back-welded joints:

L ≤ 0,5 **T**, L_{max} = 15 mm;
H ≤ 0,1 **T**, H_{max} = 2 mm;
S ≤ **T**, S_{max} = 20 mm;
D ≥ 2 **L**.

[MPv] - joints welded on one side only:

defect not allowed

[SCall]

L ≤ 0,5 **T**, L_{max} = 15 mm;
S ≤ **T**, S_{max} = 20 mm;
D ≥ 2 **L**.

[SOF]

(a) 0,5 < **H** ≤ 3 mm; pores having diameter **H** ≤ 0,5 mm may be disregarded; however, if not occasional, the causes are to be found and eliminated;
At ≤ 0,005 A_s (0,5% A_s) [1] (with reference to Note [1] of the category **[SOF]** of the Normal Level as per item A.4, the limit of A_t in terms of N is given by the values N of the normal level divided by two)

(b) in addition to the condition in (a), any pores having diameter **H** ≥ 2 are also to satisfy the following:
D ≥ 6 **H**; D_a ≥ 4 **a** (for **D** and D_a the other provisions relative to the normal level apply)

[GR]

H ≤ 1;
L ≤ **T**, **L**max ≤ 15;
N ≤ 0,75 **T**, **N**max = 15;
DL ≥ 6÷8 **L**.

[SOF+GR]

Consider jointly the two types of defect to determine the defective area, whose limit is equal to A_t given for **SOF**.
The other limits used for both types of defect also apply.

[IM]

H ≤ 0,5 mm;
L ≤ 2 **T**;
S ≥ 4 **T**;
D ≥ 6 **L**.

[IV]

The limits of [**IM**] apply.

A.6 - LIMITS FOR UE EXAMINATION

A.6.1

The limits are stipulated as stated in A.6.2 and A.6.3 below in relation to the Echo which identifies the Reference Level (**ERL**), as defined in 5.3 of Chapter 2.

A.6.2

Defects which give an echo no greater than 50% of the **ERL** - and provided there is no evidence suggesting bidimensional defects not allowed by the Rules, such as cracks and lack of fusion - may be disregarded except in the case of specific welding processes and applications at the discretion of Tasneef.

Nevertheless, where such defects recur with abnormal frequency, this may be justification for resorting to additional checks for evaluation in accordance with A.4 or A.5 and taking any appropriate steps.

A.6.3

For defects which give an echo greater than 50% of the **ERL** it is necessary:

- to evaluate the typology and deal with A.1, A.4 and A.5 as applicable
- to pay particular attention to any defects with an echo exceeding **ERL**, both for their typological and dimensional evaluation and the appropriate steps to be taken, bearing in mind that the bidimensional defects mentioned above are not allowable.

TABLE A.1

DISCONTINUITIES LIMITS - NORMAL [1]

Type of discontinuity	Symbol	Dimensions			
		L = Length **A** = Area	**H** = Width Height Diameter	**S** = Sum of discontinuities in **L**sr = 150 mm	**D** = Distance between discontinuities
Incomplete penetration at centre of thickness	**MPc**	**L** ≤ **T** **L**max = 25 mm	**H** ≤ 0,1x**T** **H**max = 2 mm	**S(L)** ≤ 2x**T** **S(L)** max = 40 mm	**D** ≥ **L**
Incomplete penetration at surface	**MPs**	**L** ≤ **T** **L**max = 25 mm	**H** ≤ 0,07x**T** **H**max = 1,5 mm	**S(L)** ≤ 2x**T** **S(L)** max = 40 mm	**D** ≥ 2x**L**
Incomplete penetration at root (a) (joints not back welded considered equivalent to back-welded joints)	**MPv**	**L** ≤ 10 mm	**H** ≤ 1mm	**S(L)** ≤ 2x**T** **S(L)** max = 40 mm	**D** ≥ 2x**L**
(b) (joints not back welded considered not equivalent to back-welded joints)	**MPv**	**L** ≤ 25 mm	**H** ≤ 2 mm	**S(L)** ≤ 60 mm	**D** ≥ **L**
Elongated slag inclusions **L/H** > 3	**SCall**	**L** ≤ **T** **L**max = 25 mm	**H** ≤ 1,5 mm	**S(L)** ≤ 2x**T** **S(L)** max = 40 mm²	**D** ≥ **L**
Not elongated or transverse slag inclusions (**L/H** ≤ 3)	**SC**	**A** (=**LxH**) ≤ **T/2** ≤10 mm²	**H** ≤ 0,2x**T** **H**max = 5 mm	**S(A)** ≤ 1,2x**T** **S(A)** max = 30 mm	**D** ≥ **H**
Porosity and single pores 0,5 mm < **H** ≤ 3 mm	**SOF**	See text			
Clustered porosity	**GR**	**L** ≤ 2x**T** **L**max = 30 mm	**H** ≤ 1 mm	**H** ≤ **T** **H**max = 30 mm	**D** ≥ 4x**L**
Wormholes (**L/H** ≥ 3 - **H** ≤ 1,5)	**TA**	**L** ≤ **T** **L**max = 12 mm		**S(L)** ≤ 2x**T** **S(L)** max = 30 mm	**D** ≥ **L**
Wormhole cluster	**NT**	**A** (=**LxH**) ≤ 100 mm²		**S(A)** ≤ 120 mm²	**D** ≥ 14x**L**
Misalignment	**SL**		**H** ≤ 0,15x**T** **H**max = 2-3 mm transverse joints **H**max = 4 mm longitudinal joints		
Surface irregularities in butt joints	**IS**	**L** ≤ 40 mm	**H** ≤ 1,5 mm	**S(L)** ≤ 40 mm	**D** ≥ 4x**L**
Irregularities at the root in joints welded on one side only (a) (joints considered equivalent to back-welded joints)	**IR**	**L** ≤ 7 mm	**H** ≤ 2 mm	**S(L)** ≤ **T**	**D** ≥ 4x**L**
(b) (joints considered not equivalent to back-welded joints)	**IR**	**L** ≤ **T**		**S(L)** ≤ 4x**T**	**D** ≥ 2x**T**
Embedded discontinuities	**DP**	See text in A.6 (**UE**)			

NOTE:
[1] See also the text of A.4.

TABLE A.2

LIMITS OF DISCONTINUITIES - SPECIAL LEVEL [1]

Type of discontinuities	Symbol	Dimensions			
		L = Length **A** = Area	**H** = Length Height Diameter	**S** = Sum of discontinuities in **L**sr	**D** = Distance between discontinuities
Incomplete penetration at centre of thickness	**MPc**	**L** ≤ 0,5x**T** **L**max = 15 mm	**H** ≤ 0,1x**T** **H**max = 2 mm	**S(L)** ≤ **T** **S(L)** max = 20 mm	**D** ≥ 2x**L**
Incomplete penetration at surface	**MPs**	**L** ≤ 0,5x**T** **L**max = 15 mm	**H** ≤ 0,07x**T** **H**max = 1,5 mm	**S(L)** ≤ **T** **S(L)** max = 20 mm	**D** ≥ 2x**L**
Elongated slag inclusions (**L/H** > 3)	**SCall**	**L** ≤ 0,5x**T** **L**max = 15 mm	**H** ≤ 1,5 mm	**S(L)** ≤ **T** **S(L)** max = 20 mm	**D** ≥ 2x**L**
Not elongated or transverse slag inclusions (**L/H** ≤ 3)	**SC**	**A** (=**LxH**) ≤ 6 mm^2	**H** ≤ 0,1x**T** **H**max = 3 mm	**S(A)** ≤ 0,5x**T** **S(A)** max = 15 mm	**D** ≥ 2x**H**
Porosity and single pores 0,5 mm < **H** ≤ 3 mm	**SOF**	See text			
Clustered porosity	**GR**	**L** ≤ **T** **L**max = 15 mm	**H** ≤ 1 mm	**N** ≤ 0,75x**T** **N**max = 15	**D(L)** ≥ 6-8x**L**
Wormholes (**L/H** ≥ 3 - **H** ≤ 1,5)	**TA**	**L** ≤ 0,5x**T** **L**max = 6 mm		**S(L)** ≤ **T** **S(L)** max = 15 mm	**D** ≥ 2x**L**
Wormhole cluster	**NT**	**A** (=**LxH**) ≤ 40 mm^2		**S(A)** ≤ 60 mm^2	**D** ≥ 20x**L**
Irregularities at the root in joints welded on one side only (a) (joints considered equivalent to back-welded joints)	**IR**	**L** ≤ 5 mm	**H** ≤ 2 mm	**S(L)** ≤ 0,5x**T**	**D** ≥ 4x**L**
Embedded discontinuities	**DP**	See text in A.6 (**UE**)			

NOTE:
[1] See also the text of A.5.

FIGURE A.1

DEFECTS HEIGHT/WIDTH/DIAMETER - SPECIAL QUALITY LEVEL

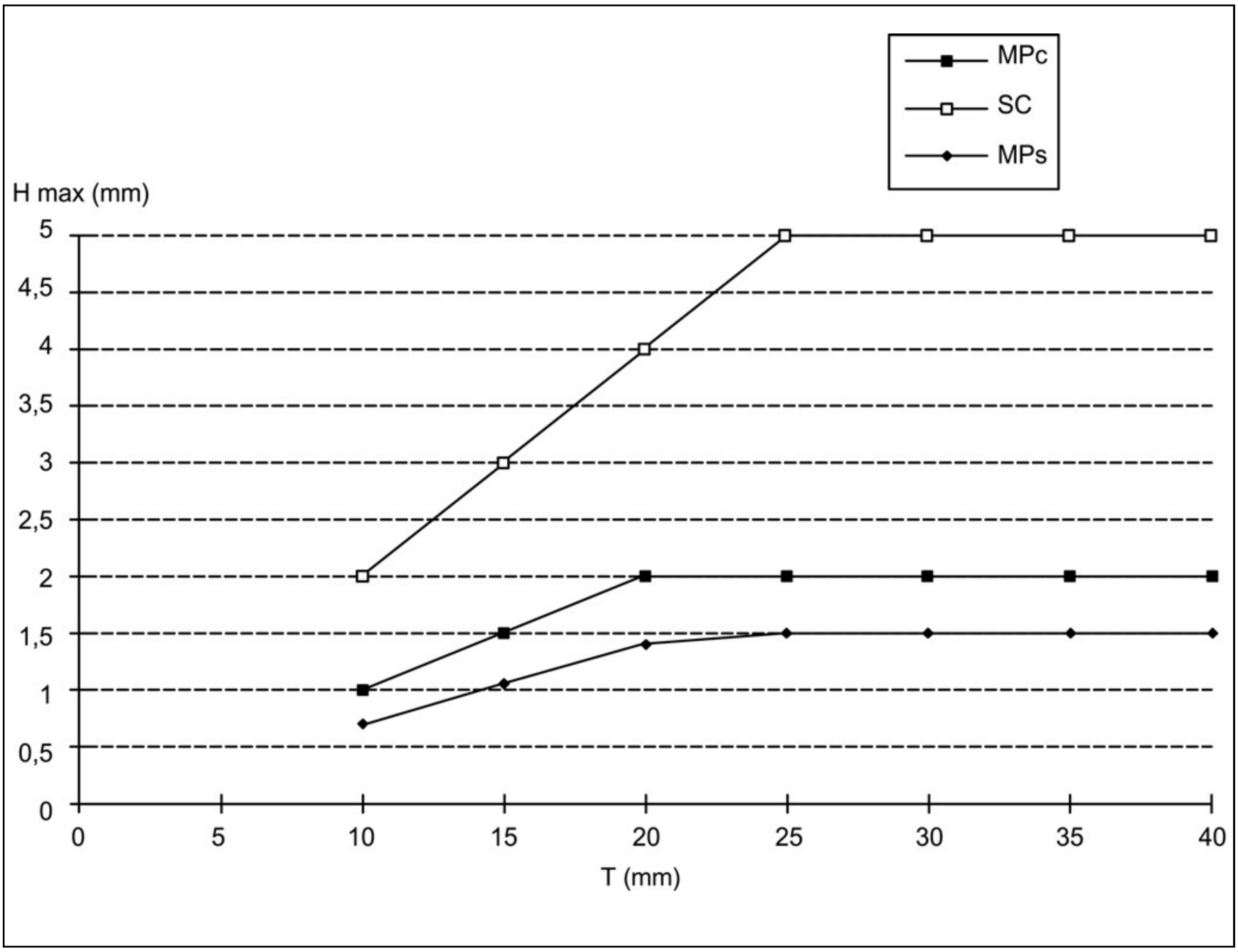


FIGURE A.2

DEFECTS HEIGHT/WIDTH/DIAMETER - NORMAL QUALITY LEVEL

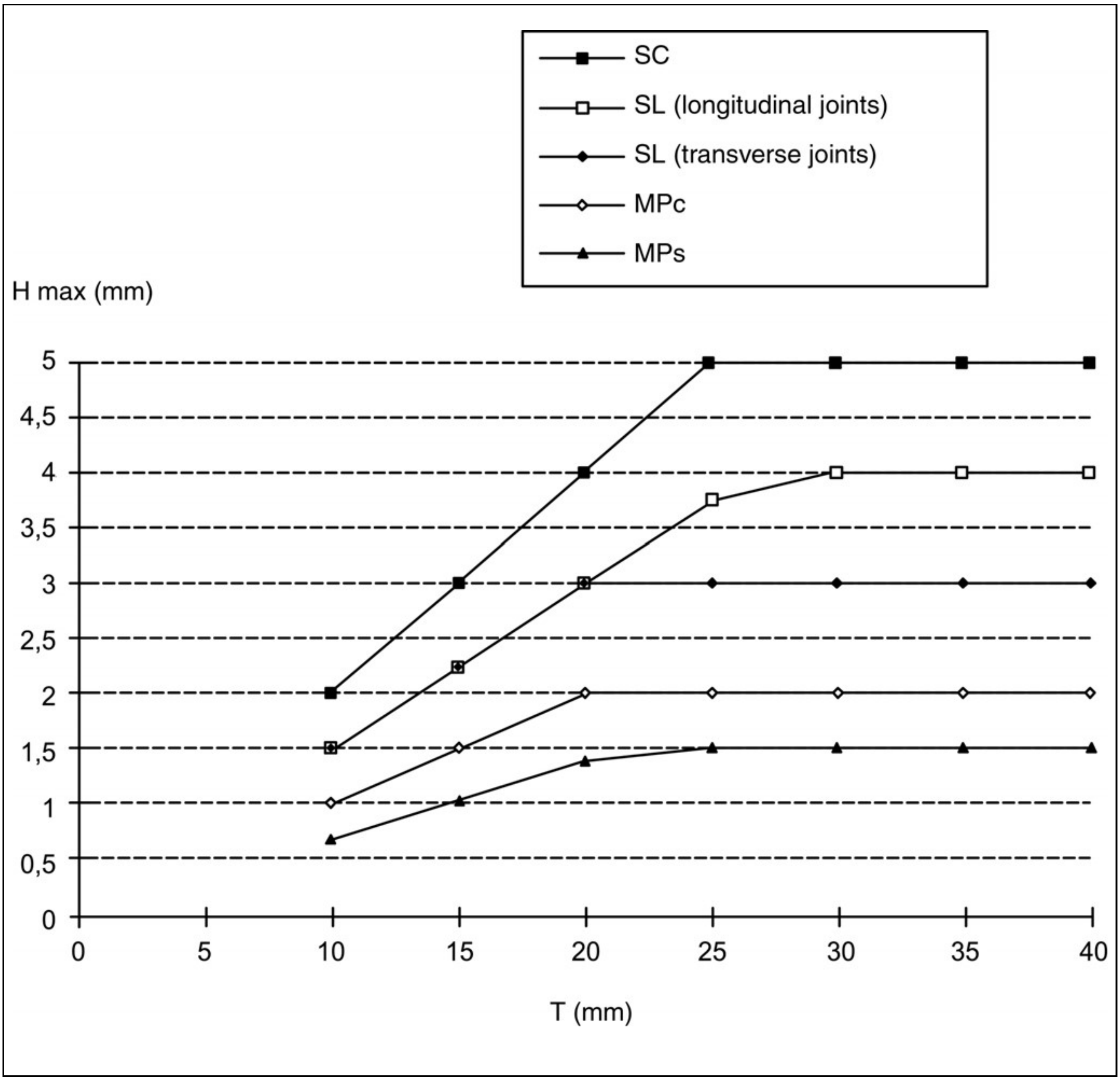
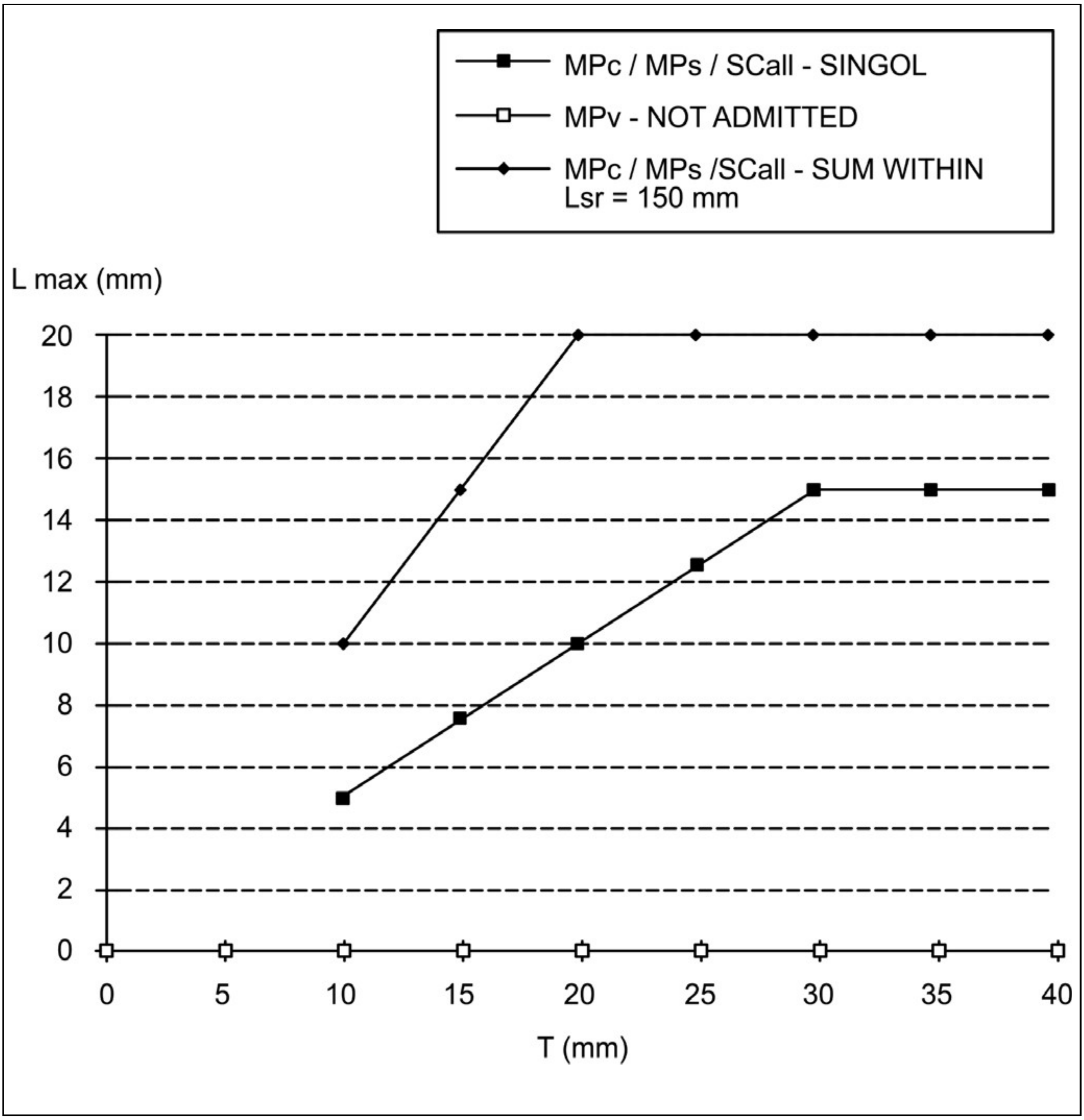


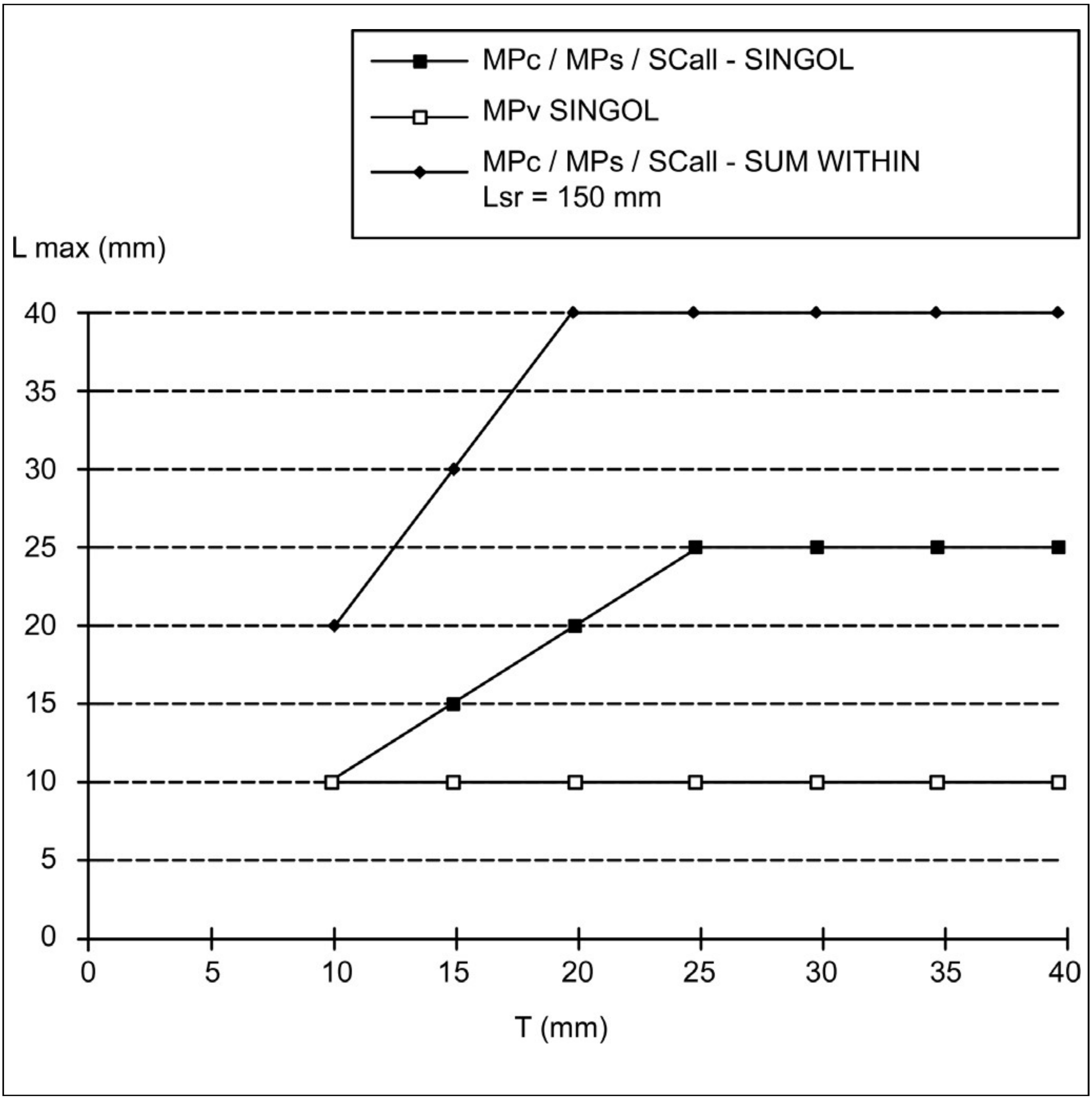
FIGURE A.3

LENGTH AND SUM OF THE DEFECTS - SPECIAL QUALITY LEVEL



~~FIGURE A.4~~

~~**LENGTH AND SUM OF THE DEFECTS - NORMAL QUALITY LEVEL**~~



B.1 - GENERAL

B.1.1

The provisions and procedures generally accepted by Tasneef are provided in this Appendix B for the different non-destructive examination methods; as stated in Chapter 2, compliance with these may, at the discretion of the Surveyors, exempt the interested parties from the requirement concerning the submission of detailed specifications.

B.2 - MAGNETIC PARTICLE EXAMINATION

B.2.1 - Techniques and examinations

The examination is to be carried out with suitable equipment and techniques for the detection of the defects concerned.

Techniques may be employed involving the passage of current in the piece or the use of external magnetization (by means of coil or yoke).

As a rule, the continuous method consisting of the magnetization of the piece during the application of the examination medium is used.

B.2.2 - Equipment

The equipment adopted for the tests is to provide the magnetization current or the magnetic flux suitable for the detection of the defects concerned.

The check of the application of the magnetic field generated may be performed directly by means of appropriate equipment such as Hall, Foerster, Berthold and also ASME probes.

B.2.3 - Detection media

Dry or wet magnetic particles are used, of the colour contrast type visible under white light, or fluorescent type visible in a darkened area with the aid of a Wood lamp.

In general, dry particles with magnetization by means of direct or half-wave or full-wave rectified current are used to detect internal defects and wet particle suspension with magnetization by means of alternating current is used to detect surface defects.

B.2.4 - Extent of the check

In general, unless otherwise required, the check is performed on 100% of the surface concerned.

It should be noted that each area is to be checked with the application of two magnetic fields, oriented perpendicular to each other and applied in succession, except for specific cases of defects oriented in one direction only for which the check may be performed with magnetization in one direction only.

In the case of checks on material with high tensile strength or high carbon equivalent content, special attention is to be given so as to avoid arcing between the prods and the piece under examination. Failing this, cracks may form in the contact areas. Where this occurs, grinding of the burnt zone is to be performed followed by a localized check. It may be convenient to use lead or copper tipped prods (or similar) in order to increase the contact area and reduce the density of the current.

B.3 - DYE PENETRANT EXAMINATION

B.3.1 - Surface preparation

As this method is aimed at detecting surface open discontinuities, the initial preparation of the piece is fundamental for the effectiveness of the check.

To this end the surface to be examined is to be free from oxides, weld spatter, slag, liquids or other substances liable to interfere with the check.

Initial treatments such as peening or sand-blasting may obscure the opening of the defect and impede its detection. Where the material is subjected to such treatment, it may be necessary to acid wash the surface with a solution of 5% nitric acid and subsequently use an inhibitor washing process.

B.3.2 - Techniques

The examination is to be carried out with the most suitable equipment for detecting the defects concerned.

Colour contrast or fluorescent, water washable, solvent removable or post-emulsified penetrants may be applied in conjunction with dry or wet developers.

As a rule, water washable penetrants are used for the check on rough surfaces.

Attention is to be paid to the temperatures allowed for the use of dye penetrants; as a rule they are between 15° and 50°C.

Temperatures outside this range are allowed provided that the effectiveness of the check is demonstrated; to this end it is sufficient to test samples for the purpose, such as ASME blocks or similar.

In the case of the use of fluorescent penetrants, the check area is to be completely darkened.

The penetrant may be applied to the piece by brushing, spraying or dipping; electrostatic applications are also allowed.

B.3.3 - Penetration times

The time necessary for the dye penetrant to act depends mainly on the size of the discontinuity on the surface (the smaller the size, the greater the penetration time required).

In general the time varies from a few minutes to approximately one hour. In the particular case of stress corrosion cracks, the penetration time is to be increased considerably up to as much as 240 minutes and post-emulsified penetrants are to be used.

B.3.4 - Washing

The procedure for removal of excess penetrant on the surface depends on the type of penetrant used, as follows.

- Water washable penetrants. Wash with water immediately after the penetration time has elapsed; the maximum pressure of the spray used is not to exceed 300 KPa.
- Solvent removable penetrants. After the penetration time has elapsed, wipe with a clean cloth and then remove remaining traces with a cloth moistened with solvent.
- Post-emulsified penetrants. After the penetration time has elapsed, apply the emulsifier for the stipulated time before washing with water at a maximum pressure of 300 KPa.

B.3.5 - Developers

Developers may generally be of the dry or wet type.

Dry developers (which are less sensitive) may be used where the defects present are such as to envisage the reception of appreciable quantities of penetrant.

In the case of the use of wet developers, an excess of deposit is to be avoided particularly in the presence of rough surfaces (threads, etc.).

The developer may be applied by spraying or dipping.

Brushing is not recommended.

B.3.6 - Interpretation of results

The presence of defects on the piece is detected by means of the coloured or fluorescent liquid which contrasts with the developer.

In order to identify the size and type of the defect it is advisable to watch for the building up of the indications.

In general it is advisable to have an initial check within 5 minutes of the drying of the developer and a second after 30 minutes.

B.4 - ULTRASONIC EXAMINATION

B.4.1 - Equipment

The equipment used is to satisfy the functional characteristics foreseen by EN 12223 or any other international requirement deemed equivalent.

B.4.2 - Surface conditions

The surfaces at the sides of the weld over which the transducer is to move are to be sufficiently free from weld spatter, rust or any other impediment which could interfere with the movement of the probe for a width not less than **D**:

$$\mathbf{D} = 2\,\mathbf{S}\tan\mathbf{x} + 30\ \text{mm}$$

where:

S = thickness of the piece to be checked

x = propagating angle of the ultrasonic waves.

B.4.3 - Transducers

Transducers with a frequency of 2 MHZ are normally used. Transducers with a greater frequency are required in order to obtain better resolution or for uses on small thicknesses.

The choice of the refracted angle depends on the thickness of the material to be checked (the smaller the thickness, the greater the angle) and on the foreseeable orientation of the defect (the more the beam is perpendicular to the defect, the better the response).

In the case of detection of notch-type defects localized on the surface opposite to that of the transducer, where possible a refracted angle of 45° is recommended.

B.4.4 - Calibration

The equipment is regulated on the ISO V1 or V2 sample block for the calibration of the time axis such that the display on the screen normally shows an ultrasonic path **P** equal to at least:

$$P = 3\,S / \cos x$$

where:

S = thickness of the piece to be checked

x = refracted angle.

The regulation of the sensitivity (dB) is performed with special calibration blocks containing holes parallel to the surface of movement of the probe having diameter 1,5 mm and made from material ultrasonically equivalent to that to be checked.

The calibration block is shown in Fig. 1.

With the transducer in position 1 (see Fig. 1), the amplification is regulated so as to have the response echo at 80% of the calibrated screen height, indicating the corresponding point on the screen.

Without further adjusting the sensitivity, the transducer is moved to positions 2 and 3 thus providing two more points on the screen. By joining the three points a curve is obtained representing the primary reference level (Curve Distance-Amplitude, DAC).

The reference curve may also be obtained using the electronic systems with which some ultrasonic instruments are equipped.

The depth with respect to the surfaces of the block of the reference hole is to be such that the DAC reference curve obtained is suitable to cover the entire thickness of the material to be checked.

B.4.5 - Transfer

In the case of differences between the surfaces of the calibration block and that of the material to be checked, the corresponding difference in dB is to be verified.

The difference is to be added to the sensitivity.

B.4.6 - Scanning

Scanning is to be performed from both sides of the weld and with twice the sensitivity compared to that of calibration (+6 dB). The evaluation of the magnitude of the defect is to be carried out with the same calibration sensitivity taking into account any difference due to transfer.

Prior to performing the check of the weld with angle probes, in order to detect the presence of lamination in the plates it is necessary to carry out a check by means of normal non-angle probe, of the volume of the material, which will subsequently be scanned by the angle probe. The presence of lamination is to be recorded and the ultrasonic examination performed only from the opposite side using probes at various angles; where this is not possible it is necessary to use another method of inspection.

For the detection of discontinuities oriented along the weld axis, the transducer is to be moved as shown in Fig. 2.

For the purpose of ensuring complete examination of the entire volume of the weld, successive scans transverse to and along the joint are to overlap for at least 10% of the width of the transducer.

Following the scanning of both sides of the weld, in order to detect defects lying transverse to the weld a scan is to be performed from both sides of the weld with a probe positioned at an angle of 15° with respect to the weld axis.

In the case of automatic welding, the check for transverse defects is to be carried out by scanning with a probe 45° directly on the weld.

B.4.7 - Evaluation of the indications

The indications are to be evaluated with the same calibration sensitivity taking into account any dB added for losses of transfer.

B.5 - RADIOGRAPHIC EXAMINATION

B.5.1 - Radiographic technique

The radiographic technique described in EN 444, 462, 584-1 is acceptable.

Other radiographic techniques may also be accepted upon request provided they ensure comparable results to those obtained with aim standards.

B.5.2 - Surface preparation

Surfaces are to be free from irregularities, dirt or other substances which might impair the correct interpretation of the radiograph and mask the defects.

B.5.3 - Film

Fine grain high contrast film is to be used. Extra-fine grain very high contrast film may be required for specific applications (e.g. gamma-ray examination).

The film is to be free from any sign which might be interpreted as a defect and is to be permanently marked with all information enabling the identification and positioning of the area checked.

B.5.4 - I.Q.I. (Penetrameter)

The quality obtained with the radiographic technique is to be verified by means of the specific I.Q.I. (Penetrameter), normally of wire type in accordance with EN 462. The material of the wires is to be the same type as the material to be checked. The penetrameter is to be positioned on the area to be radiographed, on the source side and such that the wires cross the weld where the sensitivity is to be evaluated. Where the I.Q.I. cannot be positioned on the source side and must be placed on the film side, the suitability of the radiographic technique is to be demonstrated by tests for this purpose.

In the case of IQIs other than those indicated here, the sensitivity to be obtained is to be agreed with Tasneef.

B.5.5 - Sensitivity

The sensitivity is to be as foreseen in item 6.3 of Chapter 2.

In the case of radiographs with double-wall (elliptical) exposure, the sensitivity is calculated taking into account the thickness of the material through which the radiation passes.

B.5.6 - Radiographic density

The density required in the area concerned is:

- X-ray examination = 1,8 - 4
- Gamma-ray examination = 2 - 4.

In the case of multiple film exposures, the density of each film is to be not less than 1,3.

B.5.7 - Size of the film

The film is to have the following minimum dimensions:

- Crossing areas: 18x24 or 10x48 cm
- Areas outside crossings: 10x48 cm.

Other sizes may be accepted in the case of specific positions where the access of normal size film is locally impeded by the structural details.

B.5.8 - Treatment of the film

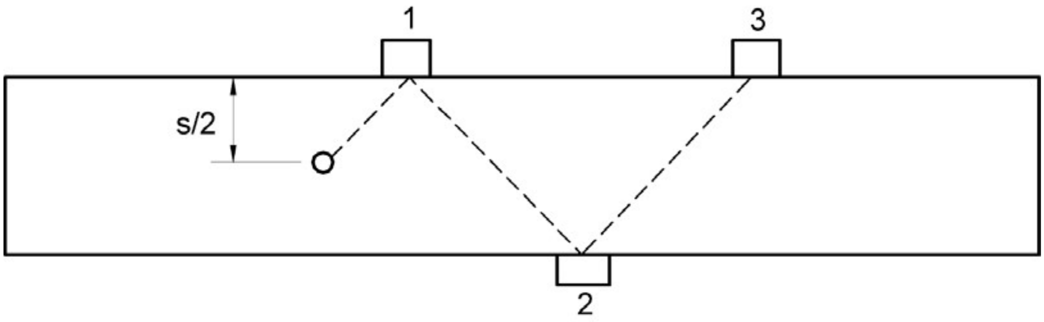
The film may be developed using manual or automatic processes provided that the Manufacturer's recommended times and temperatures are adhered to.

B.5.9 - Reading

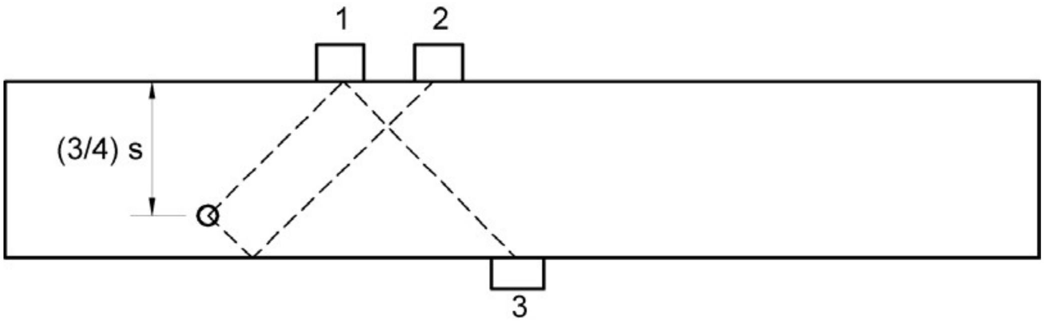
Illuminators enabling the interpretation of the film up to the maximum allowable density are to be available.

The evaluation of the density is carried out by means of the appropriate densitometers.

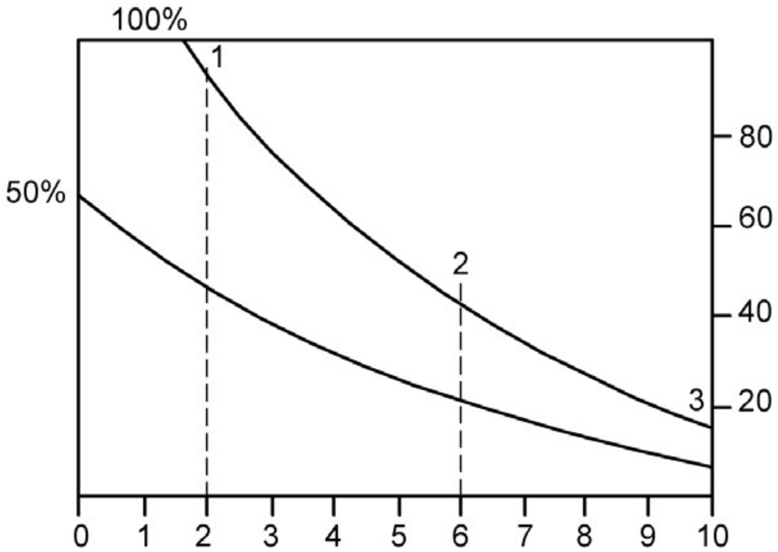
~~**PLATE B.1**~~



(a) Thickness ≤ 25 mm



(b) Thickness > 25 mm



Appendix C - DEFECTS IN WELDS

~~C.1 - WELDING DEFECTS~~

~~C.1.1~~

~~**(a) Defects in shape and dimensions**~~

- ~~Insufficient weld material (see Plate C.1 - Fig. 1)~~
  ~~The surface of the weld metal appears to be below the surface of the base material in some points.~~
  ~~The weld is to be completed until a moderate reinforcement is achieved.~~
- ~~Excess weld metal (see Plate C.1 - Fig. 2)~~
  ~~Although the weld reinforcement is properly faired with the adjacent plate material, it exceeds the normal limits.~~
  ~~Excess weld metal is to be avoided; however, provided it is properly faired into the adjacent base material, it does not necessarily require correction or removal.~~
- ~~Weld reinforcement improperly faired (see Plate C.1 - Fig. 3)~~
  ~~This defect can be described as a weld reinforcement whose upper surface reveals significant discontinuities with the surface of the adjacent base material, instead of being gradually tapered into it. This applies to both the main weld and the back weld. Improperly faired weld reinforcements are the result of inept or defective application of the welding process and are generally to be avoided.~~

~~**(b) Irregular appearance**~~

~~The following defects may be listed under this category:~~

- ~~severe lack of uniformity in the transverse direction (e.g. hollow spots due to lack or deficiency of overlap between the beads of the closing pass, or other reasons)~~
  ~~severe lack of uniformity in the longitudinal direction (e.g. irregularities in the bead(s) forming the closing pass, local accumulations or dislocations of the weld metal, etc.)~~
  ~~severe irregularities on the width of the weld or in the amount of the reinforcement.~~

~~Such defects are generally symptomatic of lack of skill on the part of the welder, in the case of manual welding, or improper application of the welding process used; as such, they offer grounds for suspecting the presence of internal defects.~~

~~(c) **Undercut** (see Plate C.1 - Fig. 3a))~~

~~Such defect appears in the form of cuts or grooves, of varying severity, along the edges of the weld fillet; while undesirable in all cases, it may be particularly important when found on structural members subjected to relatively high stresses in a direction perpendicular to the welded joint, or where there is an accumulation of stress lines in the weld.~~

~~(d) **Lack of fusion between weld reinforcement and base material on one or both edges of the weld** (see Plate C.1 - Fig. 4)~~

~~Such defect, which frequently occurs in submerged arc welding particularly when the weld reinforcement is excessive, is due to the excess molten metal expanding sideways over the relatively cold surface of the base material. At times this defect is associated with visible irregularity of the edges of the weld. It may be important in the case of major structural members or of joints subject to corrosion.~~

~~**(e) Pores and cracks**~~

~~Rather than external defects, pores and cracks may be considered internal defects showing at the surface of the weld, and as such are dealt with below (see C.3) together with the latter.~~

~~C.2 - EXTERNAL DEFECTS OF FILLET WELDS~~

~~C.2.1~~

~~**(a) Defects in shape and dimensions**~~

~~The defects considered here are those commonly occurring in ordinary fillets, i.e. in fillets foreseen with equal legs and a practically flat surface.~~

~~The following cases typically fall into this category:~~

- ~~Fillets of insufficient size (see Plate C.1 - Fig. 5)~~
  ~~This defect occurs when one or both legs of the fillet are below the required size or, where of the required size, the fillet has a concave section.~~

- **Asymmetrical fillets** (see Plate C.1 - Fig. 6)
  These are fillets having one leg of the required size while the other exceeds this size.
  The asymmetrical fillet may be made symmetrical without necessarily making it flat; a concave fillet may be accepted provided its throat dimension is not less than that corresponding to the required size of the fillet throat (see Plate C.1 - Fig. 7).
  It has no negative bearing (it is actually favourable) when the longer leg is oriented in the direction of the stress.
- **Convex fillets** (see Plate C.1 - Fig. 8)
  These are fillets which have a pronounced convex cross-section; by way of guidance, the convexity may be considered excessive when it exceeds 10% of the leg by more than 1 mm. The convex fillet may have a bearing in the case of joints stressed in a direction perpendicular to the weld.

(b) Irregular appearance
The provisions of C.1.1 (b) relative to butt welds apply.

(c) Undercut
The provisions of C.1.1 (c) relative to butt welds apply.

(d) **Fusion of the upper edge of lap-welded joints** (see Plate C.1 - Fig. 9)
Such defect appears in lap-welded joints when the fillet, which on one side extends over the surface of one of the plates forming the joint, on the other side reaches up to the edge of the other plate, thus melting away the edge of the latter in varying amounts. Excessive welding current or improper welding procedure may accentuate such defect and make the dimensional check of the fillet by means of measurement of its legs unreliable.
Where correction is necessary, this may be performed by depositing additional weld material on the fillet near the fused edge. In all cases, however, where the size of the fillet does not reach up to the edge of the plate, the defect may be avoided.

(e) Pores and cracks
The provisions of C.1.1 (e) relative to butt welds apply.

C.3 - INTERNAL DEFECTS

C.3.1 - Pores and wormholes

Such defects are generated by gas inclusions; pores have a spherical shape while wormholes have a circular cross-section and an elongated sometimes vermicular shape.

Pores are often spread over a certain zone, but they are generally restricted to a single bead, or part of a bead; they may arise due to an irregularity in the quality of the welding consumables or other materials affected by the weld and, in certain cases, also due to excessive welding current. Pores may also appear in clusters.

Pores often appear at the surface of the bead, although they may in fact not appear.

Wormholes tend to come in clusters and they sometimes have an extremely elongated shape. Such forms are typical defects of covered electrodes of the basic type which have not been properly dried or which have been improperly used; if the first pass of a butt-joint is deposited with a 4 mm electrode instead of a 3,25 mm rod, i.e. with an electrode slightly too large for this operation, wormholes and pores are very likely to occur not only in the first pass but also in the subsequent beads, which are often adversely affected by a defective first pass. Pores and wormholes in welds deposited with basic type electrodes do not generally appear at the surface.

Wormholes may also be frequent in submerged arc, gas-shielded or electroslag welding processes, where the plate is not properly cleaned or dried, or is affected by rust; in such cases, the defects often appear at the surface as a string of small holes, close together and aligned.

Pores and wormholes are clearly and easily detected by radiographic examination; on the other hand, their detection and evaluation by ultrasonic examination may present some difficulties.

C.3.2 - Cavities of other types

These do not have the regular shape which is typical of pores and wormholes and, in most cases, contain varying amounts of slag; they are often referred to as "inclusions".

These cavities vary considerably in shape, appearance and size; in this way they often reveal their own causes both in radiographic examination or through a fracture test. For example: long, thin cavities (sometimes a hairline) located at the boundary of the fused zone indicate a strong convexity and a lack of fusion in some of the inner passes of the joint (see Plate C.1 - Fig. 10); cavities of various shapes in the first pass may indicate a careless start of a new electrode; while cavities of a somewhat flattened shape between passes are typical of vertical downhand welding with electrodes of the basic type; etc.

Such defects are for the most part caused by carelessness or lack of skill in the welding operation, by improper application of the welding process (e.g. vertical downhand welding with electrodes of the basic type), by the use of off-centre electrodes or by insufficient cleaning between passes. In a number of cases these defects may be anticipated in the course of the welding by a visual examination of the various beads as the welding proceeds, since a bead deposited over an irregular or improperly faired surface is very likely to give rise to this type of defect.

These defects are generally detected by both radiographic and ultrasonic examination.

C.3.3 - Incomplete root penetration

Defects of this type are generally of appreciable length, while their depth varies according to the degree of penetration attained by the weld; their width and shape also vary to some extent depending, in addition to the welding parameters, on the type and degree of accuracy of the edge preparation and on the gap between the edges.

For example, in the case of butt welds without a gap carried out by submerged arc welding or deep penetration processes, the width of the defect will be practically null (see Plate C.1 - Fig. 11); in the case of manually welded butt joints with 60° double-Vee edge preparation, inadvertently welded without a gap and with insufficient chipping at the root (see Plate C.1 - Fig. 12), the defect will have the shape of the voids left at the root of the weld; in the case of a T-joint performed with insufficient current or faulty technique, the defects will have the shape of a groove of varying narrowness which may or may not be filled with slag (see Plate C.1 - Fig. 13).

Due to the inherent difficulty of chipping the root of double-Vee joints with 60° included angles, the defect is more frequent than in the case of single Vee joints; therefore it is advisable to bevel the edges to an included angle of 90° on the side where the chipping at the root is carried out.

As regards special welding processes, in particular submerged arc welding or deep penetration processes, the defect depends essentially on the (lack of) compliance with welding parameters and on poor alignment of the passes on the two sides of the joint (see Plate C.1 - Fig. 14).

In general, incomplete penetration is regarded as a serious defect; it may exceptionally be tolerated, if of limited extent, for joints which are only moderately stressed in a direction perpendicular to the weld.

C.3.4 - Lack of fusion

This is a bidimensional defect frequently associated with special welding processes under shielding gas, particularly if the joint is welded in positions other than flat; defects of this type are extremely difficult to detect with radiographic examination due to their typical orientation (seldom parallel to the X-ray beam) and to the good contact of the unfused surfaces. On the other hand, they are relatively easy to detect with ultrasonic waves. They occur when, due to its excessive volume or faulty operation, the molten weld metal spreads over an area beyond the zone where the arc has melted the material where the bead is being deposited.

In other words, the fused metal overflows over an area where the temperature is insufficient to melt the material and obtain a proper union; the resulting bond between the weld metal and the underlying solid material is very weak. Such defect is similar to that in C.1.1 (d), which is typical of submerged arc welding processes; in the case of manual welding this generally depends on the loss of control of the molten weld metal, particularly with covered electrodes, and/or on the use of welding current which is too low, particularly in the case of welding processes welding under shielding gas in positions other than flat.

In a fractured weld, the defects have a very typical appearance; it is generally possible to trace the surface over which they occurred. In a transverse macro section, they appear as neat lines of random shape and direction; when located on the original sides of the bevel - as often occurs in processes under shielding gas or in the first pass of a manual weld - they will obviously have the direction of the bevel. These defects may also occur in T-joints.

C.3.5 - Cracks

These are bidimensional defects which may occur either in the weld metal or in the adjacent base material, or sometimes both. Cracks may or may not extend to the surface of the affected material.

Where their presence is not of a merely sporadic nature, it is necessary to check the base material (at least the chemical analysis) in order to ascertain whether it is of adequate quality.

(a) Cracks in the base metal in the proximity of the weld

Cracks of this type seldom occur in butt-joints in normal and higher strength hull steels; however, in the case of T-joints involving materials of appreciable thickness (generally greater than 30 mm) and welded with fillets of considerable size, longitudinal cracks may develop along the edges of the weld (e.g. in the case of steels prone to the risk of lamellar tearing); in order to avoid this, it is advisable to resort to specific welding procedures (for example preliminary buttering of the surfaces to be welded).

Cracks may develop in both butt-joints and T-joints on material of medium thickness in high strength steels; this is one of the reasons for which preheating, in some cases, and the use of electrodes of the basic type (approved with the designation **H** or **H15**, **HH** or **H10**, **H5**), in all cases, are required for such steels. Owing to the restricted amount of hydrogen around the arc, these electrodes prevent or limit the danger of cracks due to the inclusion of this gas in the weld metal. When these cracks are oriented transversely, they generally extend through the weld to the adjacent base metal on both sides of the joint, while the depth is generally limited to a fraction of the thickness.

(b) Cracks in the weld metal

When using steels, electrodes and welding processes foreseen in Part D of Rules for the Classification of Ships, cracks in the weld metal seldom develop; they may arise more frequently with other types of steel, such as those which may be encountered in the course of repair work.

In ordinary manual welding, these cracks develop mostly in the first pass, both in butt welds and fillet welds.

In the latter case, cracks may develop at the root and extend partially along the throat section without reaching the surface of the weld (see Plate C.1 - Fig. 16), or they may develop at the surface without extending all the way down to the root (see Plate C.1 - Fig. 15). In both cases they generally develop at high temperature, thus appearing often, in a fractured section of the weld, as coloured patches.

On the other hand, they are not coloured when they are sunk in the body of the weld, as is the case with interdentritic cracks usually associated with submerged arc welding or processes under shielding gas.

Longitudinal cracks both in butt welds and fillet welds are commonly oriented approximately perpendicular to one of the surfaces of the original bevel; in such case they may be detected with various non-destructive examination methods. They may, as is sometimes the case with submerged arc welding processes (see Plate C.1 - Fig. 17), evade detection in radiographic examination; in this case it is necessary to resort to ultrasonic examination or to macro or mechanical tests. These cracks tend to form in relation to the carbon content, the presence of severe impurities in the materials involved or improper welding parameters; the prescribing of steels having a controlled chemical analysis when associated with these welding processes and an investigation at the time of approval aimed at obtaining the best combination of welding parameters tends to prevent the occurrence of such cracks during production welding.

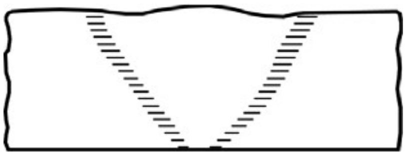
Cracks oriented along the plane bisecting the joint sometimes occur at the cross of two butt welds; this is likely to happen in submerged arc welding and is affected by the sequence of the two welds.

Cracks of generally diagonal orientation may develop in the weld metal near the base material when the latter is of poor quality; in general, they are of limited depth. The use of electrodes of the basic type is recommended in order to prevent such cracks.

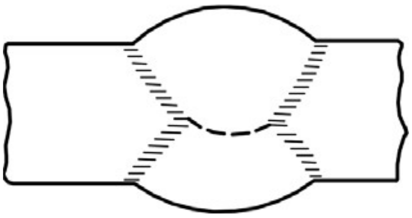
Finally, specific mention should be made here of the cracks which develop in the craters where the arc is interrupted, in particular in special welding processes including submerged arc welding and those under shielding gas; this is one of the reasons why, in association with the above processes, the weld is generally required to be carried beyond the ends of the joint proper.

~~PLATE C.1~~

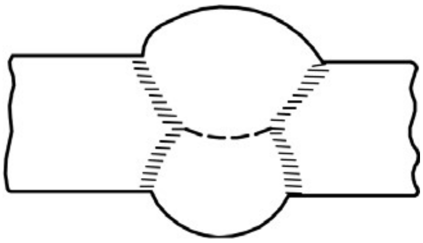
~~**Figure 1**~~



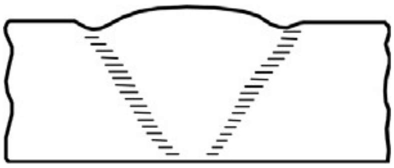
~~**Figure 2**~~



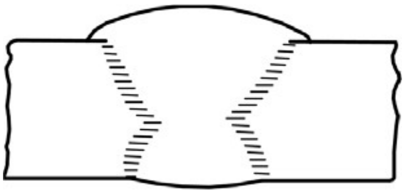
~~**Figure 3**~~



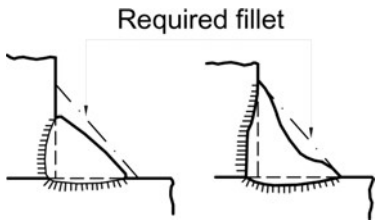
~~**Figure 3a**~~



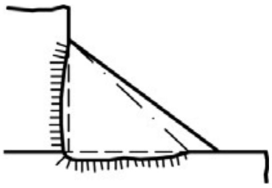
~~**Figure 4**~~



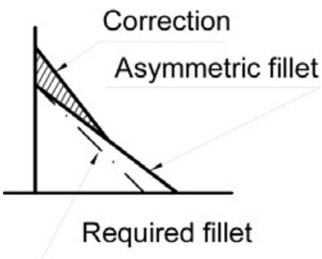
~~**Figure 5**~~



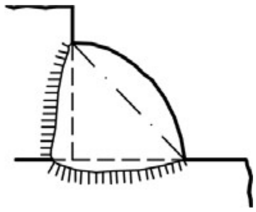
~~**Figure 6**~~



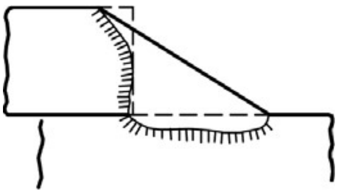
~~**Figure 7**~~



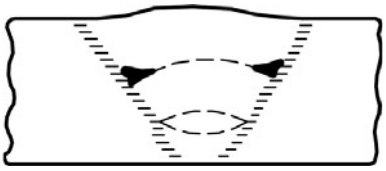
~~**Figure 8**~~



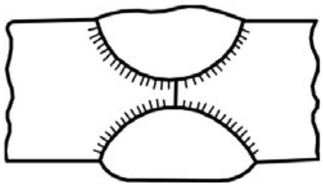
~~**Figure 9**~~



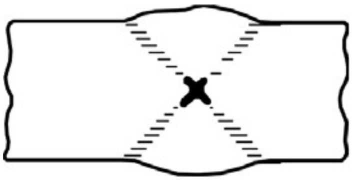
~~**Figure 10**~~



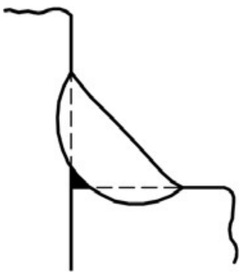
~~**Figure 11**~~



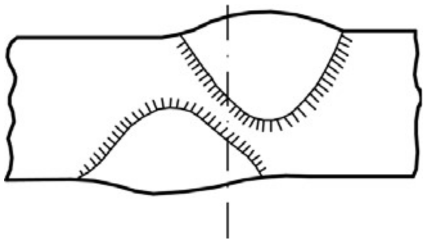
~~**Figure 12**~~



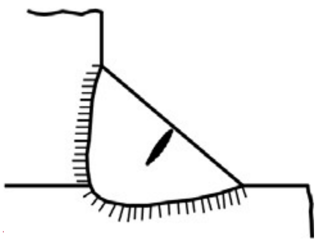
~~**Figure 13**~~



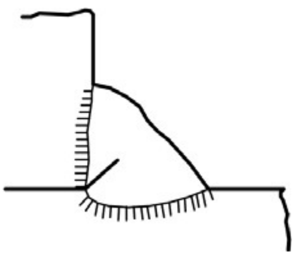
~~**Figure 14**~~



~~**Figure 15**~~



~~**Figure 16**~~



~~**Figure 17**~~