



GUIDE FOR

NONDESTRUCTIVE INSPECTION OF HULL WELDS

FEBRUARY 2018

**American Bureau of Shipping
Incorporated by Act of Legislature of
the State of New York 1862**

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ABS Plaza
16855 Northchase Drive
Houston, TX 77060 USA**

Foreword (1 February 2018)

This *Guide for Nondestructive Inspection of Hull Welds* was originally published in 1975 and subsequently updated in 1986, 2002, 2011, and 2017. This Guide introduces details of inspection criteria and inspection techniques, which are considered as being widely recognized by the industry as a reliable means of inspection of structure members and their welds during the construction of surface vessels and other related marine and offshore structures.

The 2017 edition incorporated a new Section 4 with criteria for Phased Array Ultrasonic Testing (PAUT). PAUT has become a common nondestructive testing method in use in shipyards for marine and offshore structures across the world, as it provides quicker examination than conventional UT technique for complex geometries.

The February 2018 edition incorporates a new Section 5 for Time of Flight Diffraction (TOFD) ultrasonic inspection. The TOFD ultrasonic examination technique can provide improved detection and sizing capabilities of discontinuities compared to standard ultrasonic pulse-echo techniques. Both PAUT and TOFD produce a permanent record of the inspection in electronic format.

It is intended that this Guide is continually published as a Guide, rather than Rules, in order to collect more feedback from industry during its use and be able to reflect this feedback back into the Guide in a timely manner. Upon completion of this further calibration period, the Guide is to be published as the *Rules for Nondestructive Inspection of Hull Welds*.

This Guide becomes effective on the first day of the month of publication.

Users are advised to check periodically on the ABS website www.eagle.org to verify that this version of this Guide is the most current.

We welcome your feedback. Comments or suggestions can be sent electronically by email to rsd@eagle.org.



GUIDE FOR

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SECTION 1 General

1 Preparation for Inspection (1 September 2011)

1.1 Weld Surface Appearance

Welding in hull construction is to comply with the requirements of Section 2-4-1 “Hull Construction” of the *ABS Rules for Materials and Welding (Part 2)* and IACS Recommendation No. 47 “Shipbuilding and Repair Quality Standard”.

Methods used for preparing and cleaning welds and nondestructive test procedures are to be to the satisfaction of the Surveyor.

Slag is to be removed from all completed welds. All welds and adjacent base metal are to be cleaned by wire brushing or by any other suitable means prior to inspection. Surface conditions that prevent proper interpretation may be cause for rejection of the weld area of interest.

1.3 Visual Inspection of Welds

Welds are to be visually inspected to the satisfaction of the Surveyor. Visual inspection acceptance criteria are contained in Section 10 of this Guide.

Visual inspections of welds may begin immediately after the completed welds have cooled to ambient temperature. However, delayed cracking is a concern for extra high-strength steels, 415 N/mm² (42 kgf/mm², 60,000 psi) yield strength or greater. When welding these high-strength steels, the final visual inspection is to be performed not less than 48 hours after completion of the weld and removal of preheat. Refer to 1/1.5 below for requirements for delayed cracking inspection.

1.5 Inspection for Delayed (Hydrogen Induced) Cracking (1 July 2017)

1.5.1 Time of Inspection

Nondestructive testing of weldments in steels of 415 N/mm² (42 kgf/mm², 60,000 psi) minimum specified yield strength or greater is to be conducted at a suitable interval after welds have been completed and cooled to ambient temperature. The following guidance of interval is to be used, unless specially approved otherwise:

- Minimum 48 hours of interval time for steels of 415 MPa (42 kgf/mm², 60,000 psi) minimum specified yield strength or greater but less than 620 MPa (63 kgf/mm², 90,000 psi) minimum specified yield strength.
- Minimum 72 hours of interval time for steel greater than or equal to 620 MPa (63 kgf/mm², 90,000 psi) minimum specified yield strength.

At the discretion of the Surveyor, a longer interval and/or additional random inspection at a later period may be required. The 72 hour interval may be reduced to 48 hours for radiography testing (RT) or ultrasonic testing (UT) inspection, provided 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.

Minimum specified yield strengths are to be referenced from globally recognized material specifications such as ASTM, EN, DIN, ISO, API, etc. If the minimum specified yield strengths are significantly exceeded and delayed cracking is present, consideration to increasing the delayed inspection period may be required.

1.5.2 Delayed Cracking Occurrences

When delayed cracking is encountered in production, previously completed welds are to be re-inspected for delayed cracking to the satisfaction of the Surveyor. At the discretion of the Surveyor, re-qualification of procedures or additional production control procedures may be required for being free of delayed cracking in that production welds.

Note that base metal thickness and combined thickness of a joint influence weld and HAZ cooling rate and subsequently hardness level. Preheat may need to be increased to account for high thickness and combined thickness. Combined thickness is the sum of the material meeting at the joint line.

3 Methods of Inspection (*1 February 2012*)

Inspection of welded joints is to be carried out by approved nondestructive test methods, such as visual inspection (VT), radiography (RT), ultrasonic (UT), magnetic particle (MT), liquid penetrant (PT), etc. A plan for nondestructive testing is to be submitted. Radiographic or ultrasonic inspection, or both, is to be used when the overall soundness of the weld cross section is to be evaluated. Magnetic-particle or liquid penetrant inspection or other approved method is to be used when investigating the outer surface of welds or may be used as a check of intermediate weld passes such as root passes and also to check back-gouged joints prior to depositing subsequent passes. Surface inspection of important tee or corner joints in critical locations, using an approved magnetic particle or liquid penetrant method, is to be conducted to the satisfaction of the Surveyor. Where a method (such as radiographic or ultrasonic) is selected as the primary nondestructive method of inspection, the acceptance standards of that method govern. However, if additional inspection by any method indicates the presence of defects that could jeopardize the integrity of structure, removal and repair of such defects are to be to the satisfaction of the Surveyor. Welds that are inaccessible or difficult to inspect in service may be subjected to increase the levels of nondestructive inspection.

The extent and locations of inspection and selection of inspection method(s) are to be in accordance with:

- i) The applicable ABS Rules;
- ii) The material and welding procedures used;
- iii) The quality control procedures involved;
- iv) The results of the visual inspection, and
- v) The discretion of the Surveyor;

Where the length and number of inspection points is over and above the minimum requirements indicated on the inspection plan and as specified herein, then the length of any supplementary NDE may be reduced subject to the agreement with the attending Surveyor.

The extent of inspection of repaired locations is to be to the satisfaction of the attending Surveyor.

5 Personnel (*1 September 2011*)

(*1 July 2017*) The Surveyor is to be satisfied that personnel responsible for conducting nondestructive tests are thoroughly familiar with the equipment being used and that the technique and equipment used are suitable for the intended application. For each inspection method, personnel are to be qualified by training, with appropriate experience and certified to perform the necessary calibrations and tests and to interpret and evaluate indications in accordance with the terms of the specification. Personnel certified in accordance with the International Standard ISO 9712 – *Non-destructive testing – Qualification and certification of personnel*, ANSI/ASNT SNT-TC-1A, ANSI/ASNT CP-189, ANSI/ASNT CP-106, NAS 410, ANDE-1 or any other recognized and applicable national certification specification are to be classified in any one of the following three levels as described in 1/5.3, 1/5.5, and 1/5.7. Personnel who have not attained certification may be classified as trainees. Note that ABS considers ANSI/ASNT SNT-TC-1A recommendations to be minimum requirements. Alternatively, any special cases will be considered upon review.

There are two methods of certification:

- i) In-house (second party)
- ii) Independent agency (third party)

Examples of in-house qualification specifications include SNT-TC-1A and CP-189, where the certification scheme used is the written practice of the company, and the agency (certification body) issuing the certification is the company itself. Examples of independent agency qualification specifications include ISO 9712 and CP-106, where the certification scheme used includes but is not limited to CSWIP, PCN, CAN-ISO 9712, and PNS-ISO-9712, and the agencies issuing the certification are third parties such as TWI, BINDT, NRCAN, PHIL-NCB.

When the in-house certification method is employed, ABS may request any or all of the following:

- Supporting documentation for the certification scheme employed
- Random demonstration of existing company nondestructive procedures to the satisfaction of the attending Surveyor
- In-situ testing of inspectors (e.g., using a calibration block with known reflectors)

5.1 NDT Trainee

A trainee is an individual who works under the supervision of certified personnel but who does not conduct any tests independently, does not interpret test results and does not write reports on test results. This individual may be registered as being in the process of gaining appropriate experience to establish eligibility for qualification to Level I or for direct access to Level II.

5.3 NDT Level I (1 February 2018)

An individual certified to NDT Level I may be authorized to:

- i) Set up the equipment;
- ii) Carry out NDT operations in accordance with written instructions under the direct supervision of Level II and/or Level III personnel;
- iii) Perform the tests;
- iv) Record the conditions and date of the tests;
- v) Classify, with prior written approval of a Level III, the results in accordance with documented criteria, and report the results.

An individual certified to Level I is not to be responsible for the choice of the test method or technique to be used.

For phased array ultrasonic testing (PAUT) and time of flight diffraction (TOFD) techniques, as a minimum, UT Level II with additional PAUT and TOFD specific training and experience in is required.

5.5 NDT Level II

5.5.1

An individual certified to NDT Level II may be authorized to perform and direct nondestructive testing in accordance with established or recognized procedures. This may include:

- i) Defining the limitations of application of the test method for which the Level II individual is qualified;
- ii) Translating NDT codes, standards, specifications and procedures into practical testing instructions adapted to the actual working conditions;
- iii) Setting up and verifying equipment settings;
- iv) Performing and supervising tests;
- v) Interpreting and evaluating results according to applicable codes, standards and specifications;
- vi) Preparing NDT instructions;
- vii) Conducting or direct supervision of all Level I duties;

- viii) Training or guiding personnel below Level II, and
- ix) Organizing and reporting results of nondestructive tests.

5.5.2 (1 February 2018)

For PAUT and TOFD, a UT Level II with additional PAUT training and certification, to the satisfaction of the Surveyor, is required.

5.7 NDT Level III

5.7.1

An individual certified to NDT Level III may be authorized to direct any operation in the NDT method(s) for which he is certified. This may include:

- i) Assuming full responsibility for an NDT facility and staff;
- ii) Establishing and validating techniques and procedures;
- iii) Interpreting codes, standards, specifications and procedures;
- iv) Designating the particular test methods, techniques and procedures to be used for specific NDT work;
- v) Interpreting and evaluating results in terms of existing codes, standards and specifications;
- vi) Managing qualification examinations, if authorized for this task by the certification body, and
- vii) Conducting or supervising all Level I and Level II duties.

5.7.2

An individual certified to Level III is to have:

- i) Sufficient practical background in applicable materials, fabrication and product technology to select methods and establish techniques and to assist in establishing acceptance criteria where none are otherwise available;
- ii) A general familiarity with other NDT methods; and
- iii) The ability to train or guide personnel below Level III.

5.7.3 (1 February 2018)

For PAUT and TOFD, a UT Level III with additional PAUT training and certification, to the satisfaction of the Surveyor, is required.

7 NDT Procedures and Techniques (1 February 2018)

Procedures and techniques are to be established and approved by personnel certified to NDT Level III in the applicable inspection method.

Procedures are to be prepared in accordance with the requirements stated in the applicable NDT section of this Guide and submitted to the ABS Surveyor.

Advanced NDT inspection procedures beyond the common practices, geometries, weld configurations, and assemblies applied to Penetrant Testing (PT), Magnetic Particle Testing (MT), Ultrasonic Testing (UT), and Radiographic Testing (RT) are to be reviewed by ABS.

9 Acceptance Criteria (1 September 2011)

Acceptance criteria specified herein are only applicable to inspections required by the Rules and by the Surveyor.

11 Documentation

Adequate information as to the NDT methods, extent, location(s) and results of inspection is to be included in inspection records or reports so that conformity with the applicable NDT requirements is properly documented.

13 References of Qualification/Certification Standards and Recommended Practices/Guidelines (1 July 2017)

1. ISO 9712, *Nondestructive testing - Qualification and certification of NDT personnel*
2. ISO 11484, *Employer's qualification system for non-destructive testing (NDT) personnel (For steel products: tubes, pipes (seamless or welded), flat products, long products, rails, bars, sections, rod, and wire)*
3. ISO/IEC 17024, *Conformity assessment – General requirements for bodies operating certification of persons*
4. ISO/IEC 17011, *Conformity assessment – General requirements for accreditation bodies accrediting conformity*
5. ISO/TR 25107, *Non-destructive testing – Guidelines for NDT training syllabuses*
6. ISO 18490, *Non-destructive testing – Evaluation of vision acuity of NDT personnel*
7. ISO/TS 11774, *Non-destructive testing – Performance-based qualification*
8. CAN/CGSB-48.9712/ISO 9712, *Non-destructive testing – Qualification and certification of NDT personnel*
9. EN 4179, *Aerospace series. Qualification and approval of personnel for non-destructive testing*
10. NAS 410, *Standard for qualification and certification of nondestructive testing personnel*
11. ANSI/ASNT CP-189, *Standard for qualification and certification of non-destructive testing personnel*
12. ANSI/ASNT CP-105, *Nondestructive Testing – Qualification and Certification of Personnel*
13. ANSI/ASNT CP-106, *Standard for Qualification and Certification of Nondestructive Testing Personnel*
14. ASNT SNT-TC-1A, *Personnel Qualification and Certification in Nondestructive Testing*
15. ASME ANDE-1, *Nondestructive Examination and Quality Control Central Qualification and Certification Program*
16. ASME V, *Nondestructive Examination: Article 14 - Examination System Qualification*
17. IAEA TECDOC No. 628, *International Atomic Energy Agency – Training Guidelines in Non-destructive Testing Techniques*

15 Nondestructive Testing Terminology (1 September 2011)

The standard terminology for nondestructive testing as described in ASTM E1316 is to be used, except as noted otherwise.



SECTION 2 Radiographic Inspection

1 General (1 September 2011)

Radiographs are to be made using a single source of either x- or gamma radiation. These requirements are intended to apply to full penetration welds of steel and aluminum alloys.

3 Surface Condition

3.1 General (1 September 2011)

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. Welds and inspection surfaces are subject to the requirements of Subsection 1/1 of this Guide.

3.3 Cause for Rejection

Surface conditions that prevent proper interpretation of radiographs may be cause for rejection of the weld area of interest.

5 Radiographic Procedure

5.1 Personnel (1 September 2011)

The Surveyor is to be satisfied that NDT personnel are qualified and certified in accordance with Subsection 1/5.

5.3 Technique (1 September 2011)

5.3.1

Steel welds and structures can be radiographed by utilizing either gamma rays or x-rays. Aluminum alloys can be only radiographed by x-rays. Section 2, Table 1 below summarizes the methods to be used.

5.3.2

Wherever geometry permits, radiography is to be performed by the single-wall technique. In this technique, radiation passes through only one wall of the weld or structure. The radiation source is to be centered with respect to the length and width of the weld being radiographed.

TABLE 1
Material and Inspection Method (1 September 2011)

Materials	Thickness t , mm (in.)	Inspection Method
Steels	$t < 9$ mm ($11/32$ in.)	x-rays or Iridium 192 (^{192}Ir)
	9 mm ($11/32$ in.) $\leq t \leq 75$ mm (3 in.)	x-rays or Iridium 192 (^{192}Ir)
	$t > 75$ mm (3 in.)	Cobalt 60 (^{60}Co)
Aluminum Alloys	$t \leq 75$ mm (3 in.)	x-rays with Beryllium window
	$t > 75$ mm (3 in.)	RT is not recommended

Note: The principle for selecting x-rays or gamma rays is determined based on density and thickness of the test material. Thin/less dense material requires less radiation energy. Cobalt 60 emits two gamma rays at 1170 and 1330 keV and Iridium 192 emits several gamma rays with energies from 140 to 1200 (average about 340) keV. Typically, an industrial x-ray tube's target material is tungsten which has K shell emission at about 60 keV.

5.5 Film Identification

5.5.1 General

The radiographic film is to be properly marked to clearly indicate the hull number, or other equivalent traceable identification, and to identify the exact location of the area radiographed.

5.5.2 Multiple Films (1 September 2011)

When more than one film is used to inspect a length of weld or a complete circumferential weld, identification markers are to appear on each film, such that each weld section reference marker location is common to two successive films to establish that the entire weld has been inspected.

A radiograph of a repaired weld is to be identified with an "R". Refer to Subsection 2/19.

5.7 Radiography Quality Level

5.7.1 General

The radiographic quality level is a combination of radiographic contrast and definition.

5.7.2 Radiographic Contrast

(1 September 2011) Radiographic contrast is the difference in density between two adjacent areas on the film. It is primarily controlled by the energy level of the radiation source and type of film used. The fastest speed of film that provides the required quality level and definition may be used. The density contrast curve for the film, which is provided by film manufacturer, is to have a minimum of 5:1 ratio with the lightest density not less than 2.0.

5.7.2(a) Radiographic contrast can be greatly affected and reduced by back-scattered radiation. Back-scattered radiation is radiation that has passed through the weld and film, but is reflected back to the film by surfaces behind the film. Dependent on the film location, the surfaces may be bulkheads, pipes, tanks, etc. To verify that backscatter radiation is not a problem, a lead letter "B" is to be attached to the center of the rear of the film cassette. The size of the lead letter "B" is to be 12.5 mm ($1/2$ in.) high and 1.6 mm ($1/16$ in.) thick.

5.7.2(b) During interpretation of the radiograph, a light image of the lead letter "B" indicates a backscatter problem. The applicable radiograph(s) is to be considered unacceptable and the weld area of interest is to be re-radiographed.

5.7.2(c) To reduce the undesirable effects of back-scattered radiation, a thin sheet of lead can be placed behind the film cassette.

5.7.3 Radiographic Definition

Radiographic definition refers to the sharpness of the image outline and is controlled by geometric unsharpness.

5.7.4 Geometric Unsharpness

Due to sources of penetrating radiation having physical dimensions, radiographic images have an inherent shadow. This is referred to as geometric unsharpness (U_g). To improve the ability to detect images of fine discontinuities, it is required that the physical dimension of U_g be kept to a maximum, see Section 2, Table 2 below.

TABLE 2
Geometric Unsharpness U_g

<i>Material Thickness in Area of Interest, mm (in.)</i>	<i>Maximum U_g, mm (in.)</i>
0 - 50 (0 - 2)	0.50 (0.020)
50 - 75 (2 - 3)	0.75 (0.030)
75 - 100 (3 - 4)	1.00 (0.040)
> 100 (> 4)	1.75 (0.070)

5.7.5 Source-to-Film Distance (1 September 2011)

The correct source-to-film distance (*SFD*) is an important consideration in obtaining the required radiographic quality level and controls the geometric unsharpness.

Calculation of the correct U_g and *SFD* may be by a mathematical formula or prepared diagrams (nonograms).

$$U_g = \frac{f \times d}{D}$$

where (as shown in Section 2, Figure 1)

U_g	=	geometric unsharpness
f	=	physical size of the radiation source
d	=	distance from the front of the inspection component to the radiographic film
D	=	distance from the front of the inspection component to the radiation source

Therefore, $d + D = SFD$, and this calculation is to be included in the radiographic procedure/technique.

The *SFD* is not to be less than the total length of the radiographic film being exposed.

5.7.6 Minimum Quality Level

All radiographs are to have a minimum quality level of 2-4T or equivalent.

The quality level may be considered as acceptable when the image of the applicable Image Quality Indicator (IQI) is clearly shown within the area of interest.

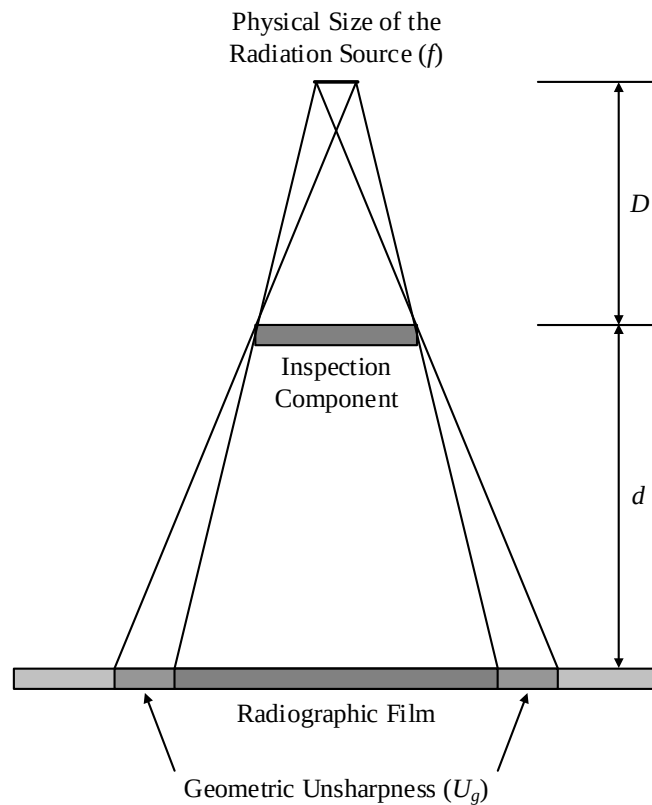
5.7.7 Film Length and Width (1 September 2011)

Film is to have sufficient length and is to be placed to provide at least 12 mm (1/2 in.) of film beyond the projected edge of the weld.

Welds longer than 350 mm (14 in.) may be radiographed by overlapping film cassettes and making a single exposure, or by using single film cassette and making separate exposures. In such case, the provision in 2/5.7.4 geometric unsharpness (U_g) requirement is to apply.

Film widths are to be sufficient to depict all portions of the weld joints, including heat-affected zones (HAZs), and are to provide sufficient additional space for the required hole-type IQIs or wire IQI and film identification without infringing upon the area of interest in the radiograph.

FIGURE 1
Geometric Unsharpness (1 September 2011)



5.9 Image Quality Indicator (IQI)

5.9.1 General (1 September 2011)

Radiographic sensitivity is to be judged based on either standard hole-type (plaque) or wire IQIs. The radiographic technique and equipment are to provide sufficient sensitivity to clearly delineate the required IQIs with essential holes or wires as described in the following paragraphs and in Section 2, Tables 3 to 6 below.

Hole-type IQI is to conform to ASTM Standard E 1025 and wire-type IQI is to conform to ASTM Standard E 747 or ISO Standard 1027.

TABLE 3
Hole-type IQI Selection

Nominal Material Thickness Range, mm (in.)	SOURCE SIDE		FILM SIDE	
	Designation	Essential Hole	Designation	Essential Hole
Up to 6.5 (0.25) incl.	10	4T	7	4T
Over 6.5 (0.25) through 9.5 (0.375)	12	4T	10	4T
Over 9.5 (0.375) through 12.5 (0.50)	15	4T	12	4T
Over 12.5 (0.50) through 16.0 (0.625)	15	4T	12	4T
Over 16.0 (0.625) through 19.0 (0.75)	17	4T	15	4T
Over 19.0 (0.75) through 22.0 (0.875)	20	4T	17	4T
Over 22.0 (0.875) through 25.0 (1.00)	20	4T	17	4T
Over 25.0 (1.00) through 31.5 (1.25)	25	4T	20	4T
Over 31.5 (1.25) through 38.0 (1.50)	30	2T	25	2T
Over 38.0 (1.50) through 50.0 (2.00)	35	2T	30	2T
Over 50.0 (2.00) through 62.5 (2.50)	40	2T	35	2T
Over 62.5 (2.50) through 75.0 (3.00)	45	2T	40	2T
Over 75.0 (3.00) through 100.0 (4.00)	50	2T	45	2T
Over 100.0 (4.00) through 150.0 (6.00)	60	2T	50	2T
Over 150.0 (6.00) through 200.0 (8.00)	80	2T	60	2T

TABLE 4
Wire IQI Selection

Nominal Material Thickness Range, mm (in.)	SOURCE SIDE Maximum Wire Diameter	FILM SIDE Maximum Wire Diameter
	mm (in.)	mm (in.)
Up to 6.5 (0.25) incl.	0.25 (0.010)	0.20 (0.008)
Over 6.5 (0.25) through 10.0 (0.375)	0.33 (0.013)	0.25 (0.010)
Over 10.0 (0.375) through 16.0 (0.625)	0.41(0.016)	0.33 (0.013)
Over 16.0 (0.625) through 19.0 (0.75)	0.51 (0.020)	0.41(0.016)
Over 19.0 (0.75) through 38.0 (1.50)	0.63 (0.025)	0.51 (0.020)
Over 38.0 (1.50) through 50.0 (2.00)	0.81 (0.032)	0.63 (0.025)
Over 50.0 (2.00) through 62.5 (2.50)	1.02 (0.040)	0.81 (0.032)
Over 62.5 (2.50) through 100.0 (4.00)	1.27 (0.050)	1.02 (0.040)
Over 100.0 (4.00) through 150.0 (6.00)	1.60 (0.063)	1.27 (0.050)
Over 150.0 (6.00) through 200.0 (8.00)	2.54 (0.100)	1.60 (0.063)

TABLE 5
ASTM Wire IQI Designation, Wire Diameter and Wire Identity (1 September 2011)

Set A		Set B		Set C		Set D	
Wire Diameter, mm (in.)	Wire Identity	Wire Diameter, mm (in.)	Wire Identity	Wire Diameter, mm (in.)	Wire Identity	Wire Diameter, mm (in.)	Wire Identity
0.08 (0.0032)	1	0.25 (0.010)	6	0.81 (0.032)	11	2.54 (0.100)	16
0.10 (0.0040)	2	0.33 (0.013)	7	1.02 (0.040)	12	3.20 (0.126)	17
0.13 (0.0050)	3	0.41 (0.016)	8	1.27 (0.050)	13	4.06 (0.160)	18
0.16 (0.0063)	4	0.51 (0.020)	9	1.60 (0.063)	14	5.08 (0.200)	19
0.20 (0.0080)	5	0.63 (0.025)	10	2.03 (0.080)	15	6.35 (0.250)	20
0.25 (0.0100)	6	0.81 (0.032)	11	2.54 (0.100)	16	8.13 (0.320)	21

TABLE 6
ISO Wire IQI Designation, Wire Diameter and Wire Identity (1 September 2011)

W1 FE (W1-W7)		W6 FE (W6-W12)		W10 FE (W10-W16)		W13 FE (W13-W19)	
Wire Diameter, mm (in.)	Wire Identity	Wire Diameter, mm (in.)	Wire Identity	Wire Diameter, mm (in.)	Wire Identity	Wire Diameter, mm (in.)	Wire Identity
3.20 (0.125)	1	1.02 (0.040)	6	0.41 (0.016)	10	0.20 (0.0080)	13
2.54 (0.100)	2	0.81 (0.032)	7	0.33 (0.013)	11	0.16 (0.0063)	14
2.03 (0.080)	3	0.63 (0.025)	8	0.25 (0.010)	12	0.127 (0.0050)	15
1.60 (0.063)	4	0.51 (0.020)	9	0.20 (0.0080)	13	0.10 (0.0040)	16
1.27 (0.050)	5	0.41 (0.016)	10	0.16 (0.0063)	14	0.08 (0.0032)	17
1.02 (0.040)	6	0.33 (0.013)	11	0.127 (0.0050)	15	0.063 (0.0025)	18
0.81 (0.032)	7	0.25 (0.010)	12	0.10 (0.0040)	16	0.051 (0.0020)	19

5.9.2 Hole-type (Plaque – Penetrameter) IQI

With this type of IQI, the required quality level is achieved when, in addition to the image of the applicable hole, a minimum of three sides of the plaque image can be distinguished. A shim of material that is radiographically similar to the weld material may be used to provide the same amount of thickness below the IQI as the maximum thickness of the weld reinforcement. The size of the shim is to be a minimum of 3 mm ($\frac{1}{8}$ in.) larger than the plaque IQI.

The IQI is to be placed parallel to the longitudinal axis of the weld. The position of the IQI is to be such that the image of the IQI and shim is not to be projected within the area of interest. The area of interest is the weld, heat-affected zone (HAZ), and backing material, if used.

5.9.3 Wire IQI

There are presently two types of wire IQIs in use. Both consist of parallel strips of wires of varying diameters encased vertically in a clear, sealed plastic pouch. The Surveyor is to verify that the required image of the correct diameter wire is shown within the area of interest.

5.9.3(a) (1 September 2011) The ASTM IQI consists of six (6) wires, see Section 2, Table 5, with the thickness of each wire increasing from left to right.

5.9.3(b) (1 September 2011) The ISO IQI consists of seven (7) wires, see Section 2, Table 6, with the thickness of each decreasing from left to right.

5.9.3(c) The ASTM or ISO IQI is to be placed perpendicular to the longitudinal axis of the weld, such that the projected image is within the weld image. The required sensitivity is achieved when the required diameter wire image is visible within the weld image.

5.9.3(d) As the wire is placed in a transverse position across the face reinforcement, shims are not required.

5.9.4 IQI Selection

Selection of the applicable IQI quality level is to be based upon the plate thickness plus allowable weld reinforcement. Weld reinforcement is to be a combination of face plus root reinforcement. Backing material is not considered as part of the weld when selection of the IQI is made (refer to Section 2, Tables 3 and 4).

5.9.5 Location of IQI

Regardless of the IQI design, the IQI is to be placed on the side of the weld facing the source of radiation (source side) in the worst geometrical position which is required at either end of the applicable length of weld under inspection.

5.9.5(a) Film Side Placement of IQIs . If an IQI cannot be physically placed on the side of the weld facing the source of radiation, the IQI may be placed in contact with the back surface of the weld. This is to be indicated by the placement of a lead letter "F" adjacent to the IQI.

5.9.5(b) Level of Sensitivity. To maintain the required level of sensitivity, the plaque thickness or the wire diameter is to be one size less than stated for source side placement (refer to Section 2, Tables 3 and 4).

5.11 Radiographic Density**5.11.1 General**

Radiographic density is a measure of the film blackness. It is a logarithmic scale of light transmission through the film image and is accurately measured with a calibrated electronic transmission densitometer.

5.11.2 Calibration of Densitometer

Calibration of the densitometer instrument is to be verified by comparison to a calibrated step-wedge film.

5.11.2(a) The calibrated step-wedge film is to be traceable to the National Institute of Standards and Technology (NIST) or other equivalent national standard.

5.11.2(b) Calibration of the instrument is to be verified and documented every 30 days.

5.11.3 Step-Wedge Film Density

Verification of radiographic film density by direct comparison with a step-wedge film is more subjective than when using an electronic densitometer. Improper storage can lead to degradation of the accuracy of step-wedge films. Therefore, close attention is to be paid to the physical condition of the step-wedge film.

5.11.3(a) When radiographic density is verified solely with the use of a calibrated step-wedge film, the calibration date of the film is to be within the previous 12 months of use.

5.11.3(b) The calibrated step-wedge film is to be traceable to the National Institute of Standards and Technology (NIST) or other equivalent national standard.

5.11.4 Radiographic Film Density Requirements

The minimum density for single film viewing is to be 1.8 H&D for x-ray film and 2.0 H&D for gamma ray film.

5.11.4(a) The maximum density for single film viewing is to be 4.0 H&D for both x-ray and gamma ray films.

5.11.4(b) The base density of unexposed radiographic film is not to exceed 0.30 H&D.

5.11.4(c) When wire IQIs are used, a minimum of two density readings are required, one at each end of the area of interest.

5.11.4(d) When plaque IQIs are used, an additional density reading is to be taken through the body of the IQI on the shim. A density variation of +15% with the density of the area of interest is acceptable.

A density reading lower than the area of interest is acceptable as long as the minimum required density and quality level are obtained.

5.13 Radiographic Film Quality

5.13.1 General

Radiographs are to be processed in accordance with film manufacturer's recommendations, especially with regard to temperature and time control.

5.13.2 Artifacts and Blemishes

All radiographs are to be free of mechanical and/or processing artifacts and blemishes within the area of interest.

Radiographs with artifacts or blemishes that interfere with interpretation of the area of interest are unacceptable. The weld area of interest is to be re-radiographed.

5.15 Radiographic Film Interpretation

5.15.1 General (1 September 2011)

Film interpretation and evaluation are only to be undertaken by qualified and certified Level II and/or Level III industrial radiographers.

5.15.2 Film Viewing Facilities

Viewing and interpretation of finished radiographs are to be in an area that is clean, quiet, and provides subdued background lighting.

5.15.2(a) The viewing screen is to be clean and free of blemishes and marks.

5.15.2(b) The viewing light is to provide sufficient and variable intensity to view radiographs with a maximum density of 4:0 H&D.

7 Storage of Radiographs

7.1 General (1 September 2011)

The contract between the ship Owner and shipyard generally stipulates the period of time and storage location for completed radiographs.

Archive quality of the film is to be according to ISO 18917: *Photography – Determination of residual thiosulfate and other related chemicals in processed photographic materials – Methods using iodine-amylose, methylene blue and silver sulfide*, or in accordance with the film manufacturer recommended techniques. ASTM E 1254 is referred for Guide to Storage of Radiographs and Unexposed Industrial Radiographic Films.

7.3 Temperature and Humidity Control (1 September 2011)

Temperature and humidity control is required so that no deterioration of the radiographic image occurs.

7.5 Documentation and Filing System

An orderly documentation and filing system is to be implemented, such that the Surveyor can review radiographs within a reasonable period of time of request.

9 Report (1 September 2011)

Radiographic examination reports are to be filed for record and are to include the following items as a minimum:

- i) Hull number, exact location and length of the welds inspected
- ii) Base material type and thickness, weld thickness range and joint type
- iii) Radiation source used
- iv) X-ray voltage or isotope type used
- v) Distance from radiation source to weld
- vi) Distance from source side of weld to radiographic film
- vii) Angle of radiation beam through the weld (from normal)
- viii) Width of radiation beam
- ix) Film manufacturer's type/designation and number of film in each film holder/cassette
- x) Number of radiographs (exposures)
- xi) IQI type and location (source side or film side)
- xii) Specific acceptance class criteria for radiographic examination
- xiii) Dates of inspection and signature of radiographic examination operator
- xiv) Evaluation of weld(s) examined, evaluation date, name and signature of evaluator

11 Digital Imaging Systems (1 September 2011)

11.1 General

In the case of use of digital radiography (DR) to view and capture/store the image in electronic forms for viewing and evaluation for acceptance and rejection, the sensitivity of such examination as seen on the monitoring equipment and the recording medium is not to be less than that required for conventional film radiographic test. It is recommended to follow ASME Section V to meet the general requirements on DR method with regard to equipment, calibration, examination & inspection, evaluations, recording and documentation.

11.3 Procedure and Report

In addition to applicable items listed in Subsection 2/9 above, the procedure and report are also to contain the following essential items for a digital imaging system:

- i) Data of the monitoring equipment, including manufacturer, make, model, and serial number
- ii) Image acquisition equipment manufacturer, model, and serial number
- iii) Radiation and imaging control setting for each combination of variables established herein
- iv) Scanning speed,
- v) Image conversion screen to weld distance,
- vi) IQI type and location (source side or screen side),
- vii) Computer enhancement (if used),
- viii) Imaging software version and revision
- ix) Numerical values of the final image processing parameters (i.e., window (contrast), and level (brightness) for each view)
- x) Type of imaging recording medium,
- xi) Identification of the image file and its location

The technique details may be embedded in the detail file. When this is done, ASTM E 1475, Standard Guide for Data Fields for Computerized Transfer of Digital Radiographical Examination Data, may be used as guidance.

11.5 Record

Examinations used for acceptance or rejection of welds are to be recorded on an acceptable medium. The record is to be in-motion or static. A written record is to be included with the recorded images giving the following information as a minimum:

- i) Identification and description of welds examined
- ii) Procedure(s) and equipment used
- iii) Location of the welds within the recorder medium
- iv) Results, including a list of unacceptable welds, repairs and their locations within the recorded medium.

The control of documentations on unprocessed original images (raw images) and the digitally processed images in DR method are to be to the satisfaction of the Surveyor. Permanent records of all interpretable indications are to be stored electronically (such as on CD-ROM), maintained and retrievable throughout the life of the vessels or structures.

13 Extent of Radiographic Inspection

13.1 General (1 September 2011)

Provision is to be made for the Surveyor to verify the radiographic inspection and examine radiographs of a representative number of checkpoints. The weld length of inspection is to be indicated in the inspection plan required by the applicable Rule requirements and by the Surveyor.

If RT is the primary method of volumetric inspection and the minimum extent of RT coverage meets the extent requirements to the Surveyor's satisfaction, then any supplementary UT proposed is permitted to be to a minimum check length of 500 mm (20 in.) as indicated in 3/5.1.

13.3 Surface Vessels

The minimum extent of radiographic inspection within the midship $0.6L$ of surface vessels is to be governed by the following equation:

$$n = L(B + D)/46.5 \quad \text{SI and MKS units} \quad \text{or} \quad n = L(B + D)/500 \quad \text{US units}$$

where

- n = minimum number of checkpoints
- L = length of the vessel between perpendiculars, in m (ft)
- B = greatest molded breadth, in m (ft)
- D = molded depth at the side, in m (ft), measured at $L/2$.

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.

13.5 Other Marine and Offshore Structures (1 September 2011)

The extent of radiographic inspection for other marine and offshore structures is to be governed by the applicable Rule requirements (e.g., *ABS Rules for Building and Classing Mobile Offshore Drilling Units*).

15 Location of Radiographic Inspection

15.1 General

In selecting checkpoints, the following are to be given emphasis in the selection of inspection locations:

- i) Welds in high stressed areas
- ii) Other important structural elements
- iii) Welds which are inaccessible or very difficult to inspect in service
- iv) Field erected welds
- v) Suspected problem areas

15.3 Surface Vessels

Radiographic inspection within the midship $0.6L$ is to be carried out mainly in locations such as:

- i) Intersections of butts and seams in the sheer strakes, bilge strakes, deck stringer plates and keel plates
- ii) Intersections of butts in and about hatch corners in main decks
- iii) In the vicinity of breaks in the superstructure

At the discretion of the Surveyor, radiographic inspection outside the midship $0.6L$ is to be carried out at random in important locations, such as those specified above.

15.5 Other Marine and Offshore Structures (1 September 2011)

Radiographic inspection is to be carried out at locations specified in the approved plans and by the Rules applicable to the structure (e.g., *ABS Rules for Building and Classing Mobile Offshore Drilling Units*).

17 Acceptance Criteria for Radiographic Inspection (1 September 2011)

17.1 Applicability

The acceptance criteria of Section 10 are applicable for full penetration butt welds in locations where radiographic inspection is carried out in accordance with this Guide and where required by the Surveyor.

The acceptance criteria of Section 10 are not intended to apply to supplementary inspections conducted beyond Rule requirements.

19 Treatment of Welds with Non-conforming Indications

19.1 General (1 September 2011)

All radiographs of welds 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.

19.3 Extent of Indication at One Location

Unless otherwise required by the Surveyor, when non-conforming indications are concentrated at one location away from the ends of the radiograph, only this location need be repaired or otherwise treated to the satisfaction of the Surveyor. No additional radiographic inspection is required in the adjacent area.

19.5 Extent of Indication at the End of a Radiograph

When non-conforming indications are observed at the end of a radiograph, additional radiographic inspection 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.

19.7 Additional Inspection

When a series of non-conforming indications is observed on a radiograph, and the pattern of the indications suggests that non-conforming discontinuities may exist for an extended distance, additional inspection is to be carried out to the satisfaction of the Surveyor.

21 References (1 July 2017)

- i) American Welding Society (AWS), D1.1, *Structural Welding Code, Steel*.
- ii) ASME Section V, Article 2 and Article 22.
- iii) ASTM E94, *Standard Guide for Radiographic Examination*.
- iv) ASTM E747, *Standard Practice for Design, Manufacturer and Material Grouping Classification of Wire Image Quality Indicators (IQI) Used for Radiology*.
- v) ASTM E1025, *Standard Practice for Design, Manufacturer and Material Grouping Classification of Hole-Type Image Quality Indicators (IQI) Used for Radiology*.
- vi) ASTM E1032, *Standard Test Method for Radiographic Examination of Weldments*.
- vii) ASTM E 1475, *Standard Guide for Data Fields for Computerized Transfer of Digital Radiographical Examination Data*
- viii) ASTM E 1254, *Standard Guide for Storage of Radiographs and Unexposed Industrial Radiographic Films*
- ix) ISO 1027, *Radiographic Image Quality Indicators for Non-destructive Testing – Principles and Identification*.
- x) ISO 18917, *Photography – Determination of residual thiosulfate and other related chemicals in processed photographic materials – Methods using iodine-amylose, methylene blue and silver sulfide*.
- xi) ASTM D1742, *Practice for Radiographic Examination*
- xii) ASTM E1000, *Guide for Radioscopy*
- xiii) ASTM E1255, *Practice for Radioscopy*
- xiv) ASTM E1030, *Test Method for Radiographic Examination of Metallic Castings*.
- xv) ASTM E999, *Guide for Controlling Quality of Radiographic Testing*.
- xvi) ASTM E142, *Method for Controlling the Quality of Radiographic Testing*



SECTION 3 Ultrasonic Inspection

1 General (*1 February 2018*)

When ultrasonic inspection is to be used as an inspection method at a shipyard, the Surveyor **is to be satisfied with** the yard's capability with this method. Several important considerations which **are to be** investigated are the yard's operator training and qualifying practices, reliability and reproducibility of results and the proper application of approved procedures, and acceptance standards.

Where a yard desires to use ultrasonic inspection as the primary inspection method, such testing, **at the Surveyor's discretion**, is to be initially and periodically supplemented or complemented with random radiographic inspections to **verify the adequacy of the quality control system**.

This **Section** covers conventional ultrasonic testing with straight beam and angle beam techniques. However, advanced techniques such as PAUT (see Section 4), or TOFD (**see Section 5**) technique may be used, provided appropriate training of the operator in advanced techniques is to satisfaction of the Surveyor.

Records are to be kept concerning the nature and severity of the indications and the amount of repair weld required based on **selected** inspection method.

The acceptance requirements contained herein are intended for the ultrasonic inspection of full penetration welds in hull structures of surface vessels, and when indicated by ABS, may also be applied to other marine and offshore structures. They are not intended to cover material with thickness less than 8 mm ($\frac{5}{16}$ in.) for which modified techniques and standards would be required (see Appendix 2 for guidance). These requirements are primarily intended for the inspection of carbon and low alloy steels. The requirements may be applied for the inspection of material with different acoustical properties, such as aluminum or stainless steel, provided the transducer design and calibration block material used are appropriate to the acoustical properties of the material under inspection.

Variations from the techniques recommended herein may be given consideration if they are shown to be more suitable to special situations. Ultrasonic inspection of materials with thickness less than 8 mm ($\frac{5}{16}$ in.) may be specially considered when proposed as a substitute for radiography.

ABS will also consider application of applicable ISO UT standards or equivalent for ultrasonic inspection in general. Examples include but are not limited to BS EN ISO 11666, "Non-destructive of welds – Ultrasonic testing – Acceptance levels", BS EN ISO 23279, "Non-destructive testing of welds – Ultrasonic testing – Characterization of indications in welds", and ISO 16810, "Non-destructive testing – Ultrasonic testing – General principles". Refer to the references in this Section for more standards.

3 Ultrasonic Procedure (*1 September 2011*)

3.1 Personnel (*1 February 2018*)

The Surveyor is to be satisfied that NDT personnel are qualified and certified **in ultrasonic testing** in accordance with Subsection 1/5.

When inspection is conducted **using** PAUT **and/or** TOFD techniques, the operator must provide proof of suitable training **and experience** to apply **the selected** techniques. **See details from Sections 4 and 5.**

3.3 Technique

An acceptable pulse echo ultrasonic technique is to be followed, such as that indicated in ASTM E164 or other recognized standards.

3.5 Calibration Blocks

3.5.1 IIW Block

Distance calibration (horizontal sweep) is to be performed using The International Institute of Welding (IIW) ultrasonic reference block Type US-1 as shown in Section 3, Figure 1A. Other more portable blocks of approved design may be permitted for field use such as Type MAB Miniature Angle-Beam reference block (Section 3, Figure 1B) and Type DSC Distance and Sensitivity reference (Section 3, Figure 1C), provided they meet the intended requirements.

For resolution calibration (RC) of angle beam transducer, the IIW reference block shown in Section 3, Figure 1D, may be used.

3.5.2 Basic Calibration Block(s)

Sensitivity calibration is to be performed using the Basic Calibration Block appropriate for the weld thickness to be inspected as shown in Section 3, Figure 2. Where the block thickness ± 25 mm (± 1 in.) spans two of the weld thickness ranges shown in Section 3, Figure 2, the block's use is acceptable in those portions of each thickness range covered by 25 mm (1 in.).

3.5.2(a) Block Selection. The material from which the block is fabricated is to be of the same product form, heat treatment, material specification and acoustically similar as the materials being examined. For calibration blocks for dissimilar metal welds, the material selection is to be based on the material on the side of the weld from which the examination is to be conducted. If the examination is conducted from both sides, calibration reflectors are to be provided in both materials. Where two or more base material thicknesses are involved, the calibration block thickness is to be determined by the average thickness of the weld.

3.5.2(b) Surface Finish. The finish on the surfaces of the block (from which the scanning is to be conducted) is to be representative of the surface finishes on the components to be examined.

3.5.2(c) Block Quality. The material from which the calibration block is to be made is to be completely examined with a straight beam search unit and is to be free of internal discontinuities.

3.5.2(d) Transfer Correction (1 July 2017). A transfer correction check is to be performed between the test object and the calibration block in accordance with techniques in BS EN ISO 16811. A number of locations characteristic of the test object are to be evaluated to determine an average. In accordance with BS EN ISO 17640, a transfer correction of less than 2 dB does not require compensation, between 2 and 12 dB requires a compensation, and greater than 12 dB requires further investigation. If no clear reasons can be determined for the high differences, additional actions of determining attenuation at a variety of locations on the test object are to be evaluated. Areas of high differences will require corrective actions.

Note: In the case of PAUT or TOFD technique, the reference calibration blocks are to be made to meet the ASME Section V requirements.

3.7 Ultrasonic Equipment

3.7.1 General

A pulse-echo ultrasonic instrument is to be used. The instrument is to be capable of displaying an A-scan rectified trace and operation at frequencies over a range of at least 1 to 5 MHz and is to be equipped with a stepped gain control in units of 2.0 dB or less. If the instrument has a damping control, it may be used if it does not reduce the sensitivity of the examination. The reject control is to be in the "off" position for all examinations unless it can be demonstrated that it does not affect the linearity of the examination.

3.7.2 Basic Instrument Qualification

Basic instrument qualification is to be made once each three (3) months or whenever maintenance is performed which affects the function of the equipment (whichever is less). Basic instrument qualification is to include checks of vertical linearity and horizontal linearity. A 12.5 mm ($1/2$ in.) diameter 2.25 MHz (or nearest size and frequency) compressional (straight beam) transducer is to be used as a master transducer for instrument qualifications. The master transducer is to be used primarily for qualification purposes and is not to be used for general inspections.

The standard International Institute of Welding (IIW) Reference Block Type US-1, shown in Section 3, Figure 1A is to be used for instrument qualification. Other types of reference blocks may also be used provided they provide the same sensitivity and functions, as does the IIW Reference Block.

3.7.2(a) Horizontal Linearity. The horizontal (range) linearity of the test instrument is to be qualified over the full sound-path distance being used during testing. For this qualification, the master transducer creating longitudinal (compression) waves is used. The procedures for horizontal linearity qualification are outlined as follows:

- Couple the straight-beam master transducer on the end surface (position 1 in Section 3, Figure 1A) of the IIW reference block to calibrate for a full range of 200 mm (8 in.)
- Place the master transducer over 100 mm (4 in.) width side (position 2 in Section 3, Figure 1A). Two (2) peaks at equal distance are expected.
- Place the master transducer over the thickness of the block (position 3 in Section 3, Figure 1A) and eight (8) peaks at equal distance are expected
- When properly adjusted, each intermediate trace deflection location is to be correct within $\pm 5\%$ of the screen width.

3.7.2(b) Vertical (Amplitude Control) Linearity. To determine the accuracy of the amplitude control of the instrument, position the master transducer over the 1.5 mm ($1/16$ in.) side drilled hole in the IIW block so that the indication is peaked on the screen. With the increases and decreases in attenuation or gain as shown in the table below, the indication must fall within the limits specified.

Indication Set At % of full screen height (FSH)	dB Control Change	Indication Limits % of full screen height (FSH)
80%	-6dB	38 to 42%
80%	-12dB	18 to 22%
40%	+6dB	78 to 82%
20%	+12dB	78 to 82%

An alternative method is to use the dB drop method by adjusting the reference echo to 100% of full screen height (FSH) from back wall (use of a small weight on top of the transducer to get a steady echo is advisable). When the gain is reduced by 6 dB the resulting echo should be 50% of FSH (± 1 dB). A further reduction of 6 dB in gain reduces the echo height to 25% of FSH (± 1 dB) and a further reduction of 6 dB reduces the echo height to 12.5 % of FSH.

3.7.3 Transducers

The nominal frequency is to be from 1 MHz to 5 MHz unless variables such as production material grain structure require the use of other frequencies for adequate penetration or better resolution.

3.7.3(a) Straight Beam Transducer. Straight beam transducer size may vary from 12.5 mm ($1/2$ in.) to 25 mm (1 in.) in round or square shape.

Resolution test for the straight beam transducer selected is required by coupling the transducer at position 4 as indicated in Section 3, Figure 1A. Instrumentation range is to be set for minimum 100 mm (4 in.) full scale. Adjust the gain so all three (3) echoes reach full screen height (FSH). Three (3) separate echoes must be displayed.

3.7.3(b) Angle Beam Transducer (1 July 2017). The angle beam transducer crystal size may vary from 10 mm ($13/32$ in.) to 20 mm ($3/4$ in.) in width and length. The transducer may be round, rectangular, or square.

Transducers are to have a nominal frequency of 2.25 or 2.5 MHz. Higher frequencies up to 5 MHz may be utilized for improved resolution or for material of thin cross section. Lower frequencies down to 1 MHz, when agreed to by the Surveyor, may be used for improved signal penetration or for material of heavy cross section [$> 19 \text{ mm}$ ($3/4 \text{ in.}$)]. The transducers are to be affixed to suitable wedges designed to induce refracted shear waves in steel within $\pm 2^\circ$ of the following angles: 70° , 60° and 45° .

Ultrasonic inspection of materials below 8 mm ($5/16 \text{ in.}$) in thickness may be specially considered for ultrasonic test. Modified techniques and standards may be required by using smaller angle beam transducer element size (i.e., dimension of elements less than the wall thickness) to maintain a small beam cross section and reduce strong signals associated with boundary effects. See Appendix 2 for guidance.

The transducer and wedge unit are to be clearly marked to indicate the frequency, nominal angle of refraction and the index point. The transducer and wedges are to be checked using the IIW block before use and after each eight (8) hours of use to verify the index point, that the wear face is flat and that the refracted angle is within the $\pm 2^\circ$ of the proper angle.

To increase the probability of detection, consideration needs to be given to the thickness of the plate, weld bevel, weld joint configuration, and type and location of anticipated discontinuities. This will determine the required number and angle/angles of probes to be applied during the inspection.

The shear wave angles to be used for various thicknesses are listed below:

Plate Thickness	Shear Wave Angle*
8 mm ($5/16 \text{ in.}$) to 19 mm ($3/4 \text{ in.}$)	60° or 70° **
Over 19 mm ($3/4 \text{ in.}$) to 38 mm ($1\frac{1}{2} \text{ in.}$)	45° or 60° or 70°
Over 38 mm ($1\frac{1}{2} \text{ in.}$)	45° (required) & 60° or 70°

* Other shear wave angles may be used provided it is demonstrated that they are suitable for the application involved. For thick plates, consideration for the refracted angle is to provide as near as possible for a perpendicular incident angle on the weld bevel face. For thin plates, the sound path of ultrasonic beam in test material is to be minimized for not greater than 100 mm (4 in.).

** Tubular joint nodes and set-on nozzle joints may require two or more probe angles.

Resolution test for the angle beam transducer selected is required by coupling the transducer at an appropriate position for the refracted angle marked on the IIW type RC reference block as shown in Section 3, Figure 1D. Three (3) distinguishable echo signals from the three (3) side-drilled holes must be displayed on A-scan screen.

3.7.4 Couplant

The couplant, including additives, is not to be detrimental to the material be examined.

3.9 Calibration for Examination

3.9.1 General

The same couplant is to be used for both calibration and field inspection. For contact examination, the temperature differential between the calibration block and examination surfaces is to be within 20°F (12°C). For immersion examination, the couplant temperature for the calibration is to be within 20°F (12°C) of the couplant temperature for examination. Attenuation in couplants, wedge materials and base material varies with temperature and a calibration performed at a given temperature may not be valid for examination at significantly hotter or colder temperatures. The ultrasonic equipment is to be calibrated for horizontal sweep distance and sensitivity with the reference calibration standards just prior to examination each time it is used. Recalibration is to be performed whenever there is a change in examiner (except for automated equipment), after every four (4) hours of continuous use, whenever the power supply to the transmitter has been changed or interrupted, or whenever the calibration of the equipment is suspected of being in error.

The basic calibration block configuration and reflectors are to be as shown in Section 3, Figure 2. The block size and reflector locations are to be adequate to perform calibrations for the beam angles used.

The calibration for examination to detect discontinuities pertinent to the item under inspection is to be demonstrated to the satisfaction of the Surveyor, preferably using samples or reference blocks containing known discontinuities.

3.9.2 DAC Calibration of Angle Beam and Straight Beam

The transducer calibration for straight beam is required to be dual-element (twin-crystal) for steel plate thickness less than or equal to 50 mm (2 in.) or single element if steel plate thickness is greater than 50 mm (2 in.) for both lamination checks and weld inspection, such as Tee and Corner welds to be tested for incomplete penetration from the flat face opposite when accessible.

After determination of weld configuration, plate thickness, and transducer's angle and frequency, ultrasonic sound path can be calculated for horizontal sweep distance. A formula is to be used to calculate the sound path by following:

$$\text{Sound Path} = 2 \times \text{Plate Thickness} / \cos(\text{refracted angle})$$

A DAC curve is to be established from the responses from the Side drilled holes (SDH) in the appropriate thickness of Basic Calibration Block shown in Section 3, Figure 2.

The following method is used only for instruments without Automatic Distance Amplitude Correction (DAC).

3.9.2(a) DAC of the Basic Calibration Block: Position the search unit for maximum response from the hole which gives the highest amplitude, and adjust the sensitivity control to provide an 80% ($\pm 5\%$) of FSH from the hole. Mark the peak of the indication on the screen.

Without changing the sensitivity control, position the search unit to obtain a maximized response from at least two (2) other reflector holes which cover the calculated maximum sound path distance. Mark the peak of each indication on the screen and connect the points with a smooth line manually or automatically.

3.9.2(b) Amplitude Reject Level (ARL). The DAC from 3/3.9.2(a) represents the DAC curve and serves as the Amplitude Reject Level (ARL).

3.9.2(c) Disregard Level (DRL). A second DAC curve is to then be plotted from the same reflector holes by dropping gain level by 6 dB. This lower DAC curve serves as the Disregard Level (DRL)

For instruments with automatic distance amplitude correction, the maximum response from the side drilled holes in the basic calibration block is to be equalized over the appropriate distance range and set at 80% and 40% of full screen height for the (ARL) and (DRL) respectively.

3.11 Weld Inspection

3.11.1 Surface Condition

Surfaces on which the transducer makes contact in the course of weld inspection are to be free from loose scale, loose paint, weld spatter, dirt, other foreign matter or excessive roughness to an extent that allows the transducer intimate contact with the scanning surface. Welds and inspection surface are subject to the requirements from Subsection 1/1.

3.11.2 Plate Lamellar Discontinuities Using Straight Beam Technique

In order to detect lamellar discontinuities in the base plate (i.e., parallel to the surface of the plate) that may be present in way of welds which are to be inspected, the surface adjacent to the weld, on the side or sides where the weld inspection is carried out, is to be inspected by using a straight beam (compressional wave) technique (dual-element if steel plate thickness is less than or equal to 50 mm (2 in.) or single element if steel plate thickness is greater than 50 mm (2 in.)). When these inspections reveal lamellar discontinuities which would interfere with the shear wave weld inspection, the weld inspection is to be made from the opposite side of the weld. If a shear wave ultrasonic inspection cannot be conducted because of laminations on both sides of the weld, the weld location is to be inspected by an alternate nondestructive test technique, such as radiography.

3.11.3 Longitudinal Discontinuities Using Angle Beam Technique

In order to detect longitudinal discontinuities (i.e., along the axis of the weld), the transducer is to be moved in a selected, overlapping pattern similar to that shown in Section 3, Figure 3 (left side of weld). Simultaneously, while moving along the path of inspection and detecting flaw indication, the transducer is to be oscillated through a small angle. The length of weld to be inspected is to be scanned with the transducer directed in two distinct paths: either on both sides of the weld from the same surface, or on opposite surfaces from the same side of the weld.

3.11.4 Transverse Discontinuities Using Angle Beam Technique

In order to detect transverse discontinuities, the transducer is to be angled about 15 degrees from the weld axis and moved parallel to the weld length, as shown in Section 3, Figure 3 (right side of weld). The scan is then to be repeated on the same surface on the other side of the weld if accessible or on opposite surfaces from the same side of the weld. Both scans are to be made with the transducer moved in the same direction. For welds in which the surfaces have been ground, the transducer is placed on the weld surface and moved along the weld axis with the sound beam directed parallel to the weld.

3.11.5 Discontinuity Length Determination

When discontinuities are indicated, the sound beam is to be directed so as to maximize the signal amplitude. The transducer is then moved parallel to the discontinuity and away from the position of maximum signal amplitude until the indication drops toward the base line (6 dB drop). Using the centerline of the wedge of the transducer as an index, the extremity points of the discontinuities are determined as indicated in the following 3/3.11.5(a) and 3/3.11.5(b):

3.11.5(a) Indications Greater than ARL: For indications with peak amplitudes greater than the ARL, the extremity points of the discontinuity are defined as the points at which the signal drops to 50% of the ARL. (6 db change)

3.11.5(b) Indications Greater than DRL (1 February 2018): For indications with peak amplitudes greater than DRL but equal to or less than the ARL, the extremity points of the discontinuity are defined as the points where the signal amplitude either remains below the DRL for a distance equal to $\frac{1}{2}$ the major dimension of the transducer or drops to $\frac{1}{2}$ the peak amplitude, whichever occurs first (i.e., the points which define the shortest discontinuity length).

3.11.6 Adjacent Discontinuity

Adjacent discontinuities separated by less than $2L$ of sound metal (L equals length of longest discontinuity) are to be considered as a single discontinuity.

3.13 Ultrasonic Inspection Reports (1 February 2018)

Ultrasonic inspection reports are to be filed for record and are to include the following items as a minimum:

- Hull number, exact location and length of the welds inspected
- Equipment used (instrument maker, model, and identity; transducer type, identity, size, frequency, and angle)
- Beam angle(s) used
- Couplant used (brand name or type)
- Calibration block identification
- Base metal type and thickness, weld process, surface condition such as any unusual condition of weld bead (ground, undercut, etc.), weld joint design
- Specific acceptance class criteria for examination
- All reflections which are interpreted as failing to meet the specified requirements (as defined in Subsection 3/11 above)
- Dates of inspection and signature of ultrasonic examination operator
- Evaluation of weld(s) examined, evaluation date, name and signature of evaluator

A typical report form, shown in Section 3, Figure 4, is considered acceptable. The method for review and evaluation of ultrasonic test reports is required for adequate quality control and is to be to the satisfaction of the Surveyor.

In case of using PAUT and/or TOFD, permanent records of all interpretable indications are to be stored electronically, maintained and retrievable throughout the life of the vessels or structures by the owner of the vessel. Contract agreements or any alternative agreements with ABS oversight can supersede this requirement.

5 Extent of Ultrasonic Inspection

5.1 Checkpoints (1 February 2012)

Provision is to be made for the Surveyor to witness the ultrasonic inspection of a representative number of checkpoints. Each checkpoint is to consist of approximately 1250 mm (50 in.) of weld length. However, in cases where extensive production experience has indicated that a high proportion of checkpoints (such as 90 to 95%) are free of non-conforming indications, consideration may be given to reducing the length of checkpoints to 750 mm (30 in.). If the percentage of non-conforming indications rises then a 1250 mm (50 in.) of the length is to be reapplied.

If the number of checkpoints is increased above the minimum required by this Guide, applicable ABS Rules or specified by the Surveyor, then consideration is to be given to reducing the length of each checkpoint to a minimum of 500 mm (20 in.) provided the total weld length checked by ultrasonic testing is at least equivalent to the multiple of 1250 mm (50 in.) $\times$ the minimum required number of checkpoints. Reduction in ultrasonic inspection length to 500 mm (20 in.), as indicated above, is subject to prior agreement of the Owner.

Lengths of welds inspected at subassembly stage and final erection stage (as required under 3/7.1.1 below) may be combined to form a single checkpoint (of 1250 mm (50 in.) as appropriate). If the proportion of non-conforming indications is abnormally high, the number of checkpoints is to be increased.

5.3 Ship-Type Vessels (1 February 2012)

The minimum checkpoints of inspection within the midship 0.6L of ship-type vessels are to be governed by the following equation:

$$n = L(B + D)/46.5 \quad \text{SI and MKS units} \qquad n = L(B + D)/500 \quad \text{US units}$$

where

n	=	minimum number of checkpoints
L	=	length of the vessel between perpendiculars, in m (ft)
B	=	greatest molded breadth, in m (ft)
D	=	molded depth at the side, in m (ft), measured at $L/2$

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

5.5 Other Marine and Offshore Structures (1 September 2011)

The extent of ultrasonic inspection for other marine and offshore structures is to be governed by the applicable Rule requirements (e.g., *ABS Rules for Building and Classing Mobile Offshore Drilling Units*).