FOUNDED 1862 ABS

GUIDE FOR

# NONDESTRUCTIVE INSPECTION OF HULL WELDS 2002

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American Bureau of Shipping
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the State of New York 1862

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# Foreword

This Guide is the third edition of the *Rules for Nondestructive Inspection of Hull Welds*, which was originally published in 1975 and updated as the second edition in 1986. This Guide aims to introduce further details of inspection criteria and additional inspection techniques, which are considered as being widely recognized by the industry as a reliable means of inspection of welds in the construction of surface vessels, offshore structures and other related marine structure.

It is intended that these new criteria be 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, it is intended that the criteria will be published as the *Rules for Nondestructive Inspection of Hull Welds*.

ABS welcomes any questions, comments and feedback as regards the application of this Guide.

The effective date of the Guide is 1 September 2002.

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GUIDE FOR

# NONDESTRUCTIVE INSPECTION OF HULL WELDS

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SECTION 1 General

## 1 Preparation for Inspection

A visual inspection is to be conducted to the satisfaction of the Surveyor. Methods used for preparing and cleaning welds and nondestructive test procedures are to be to the satisfaction of the Surveyor.

## 3 Methods of Inspection

Inspection of welded joints is to be carried out by an approved nondestructive test method, such as radiography (RT), ultrasonic (UT), magnetic particle (MT) or liquid penetrant (PT). Radiographic or ultrasonic inspection, or both, is to be used for internal (subsurface) inspection. Magnetic particle or liquid penetrant inspection or other equivalent approved detection method is generally to be used for surface inspection of welds. The extent and location of inspection and choice of inspection method(s) are to be in accordance with the applicable Rules, the material and welding procedures involved, the quality control procedures employed, the results of the visual inspection, and are to be to the satisfaction of the Surveyor.

## 5 Personnel

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. NDT personnel are to be qualified by training and 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, Training, Qualification and Certification of Non-destructive Testing Personnel, shall be classified in any one of the following three levels. Personnel who have not attained certification may be classified as trainees.

### 5.1 Other Recognized National Certifying Programs

The requirements of other recognized national certifying programs will be specially considered.

### 5.3 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 1 or for direct access to Level 2.

### 5.5 NDT Level 1

An individual certified to NDT Level 1 may be authorized to:

*i)* set up the equipment;

*ii)* carry out NDT operations in accordance with written instructions under the supervision of Level 2 or Level 3 personnel;

*iii)* perform the tests;

*iv)* record the conditions and date of the tests;

*v)* classify, with prior written approval of a Level 3, the results in accordance with documented criteria, and report the results.

An individual certified to Level 1 is not to be responsible for the choice of the test method or technique to be used.

### 5.7 NDT Level 2

An individual certified to NDT Level 2 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 2 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)* carrying out or supervising all Level 1 duties;

*viii)* training or guiding personnel below Level 2, and

*ix)* organizing and reporting results of nondestructive tests.

### 5.9 NDT Level 3

#### 5.9.1

An individual certified to NDT Level 3 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)* carrying out or supervising all Level 1 and Level 2 duties.

5.9.2

An individual certified to Level 3 shall 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 3.

# 7 NDT Procedures and Techniques

Procedures and techniques shall be established and approved by personnel certified to NDT level 3 in the applicable inspection method.

Techniques shall be prepared in accordance with the requirements stated in the applicable NDT section of this Guide.

NDT inspection shall be performed by certified level 1, 2 or 3 personnel.

Interpretation and evaluation of inspection results shall be performed by personnel certified to NDT level 2 or 3 in the applicable NDT inspection method.

# 9 Inspection for Delayed (Hydrogen Induced) Cracking

## 9.1 Time of Inspection

Nondestructive testing of weldments in steels of 400 $N/mm^2$ (41 $kgf/mm^2$, 58,000 psi) yield strength or greater is to be conducted at a suitable interval after welds have been completed and cooled to ambient temperature. The interval is to be a minimum of 24 hours for steels 400 $N/mm^2$ (41 $kgf/mm^2$, 58,000 psi) yield strength and a minimum of 72 hours for steels greater than 400 $N/mm^2$ (41 $kgf/mm^2$, 58,000 psi) yield strength, unless specially approved otherwise. The Surveyor, at his discretion, may require a longer interval and/or additional random inspection at a later period. At the discretion of the Surveyor, the 72 hour interval may be reduced to 24 hours for RT or UT inspections, 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.

## 9.3 Delayed Cracking Occurrences

When delayed cracking is encountered in production, previously completed welds are to be reinspected for delayed cracking to the Surveyor’s satisfaction. The Surveyor, at his discretion, may require requalification of procedures or additional production control procedures to assure that production welds are free of delayed cracking.

# 11 Acceptance Standards

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

## 13 Documentation

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

## 15 References

International Standard ISO 9712, *Training, Qualification and Certification of Non-destructive Testing Personnel*.

# SECTION 2 Radiographic Inspection

## 1 General

The requirements contained herein are primarily intended for radiographic inspection of welds in hull structures of surface vessels. These requirements are intended to apply to full penetration welds of steel and aluminum alloys.

## 3 Surface Condition

### 3.1 General

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.

### 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

It is incumbent upon the Surveyor to ensure that NDT personnel are qualified and certified by a combination of training and experience appropriate to the level of responsibility assigned.

### 5.3 Technique

Steel welds and structures can be radiographed utilizing either gamma rays or x-rays.

5.3.1

For materials up to and including 75 mm (3 in.) in thickness, gamma rays from Iridium 192 ($^{192}$Ir) radioisotopes or x-rays are to be used.

5.3.2

Material in excess of 75 mm (3 in.) thickness is to be inspected with gamma rays from Cobalt 60 ($^{60}$Co) radioisotopes.

5.3.3

Aluminum welds and structures up to 75 mm (3 in.) in thickness are to be inspected with x-rays. If x-ray generating machines are not available, ultrasonic angle beam inspection may be used as a substitute.

5.3.4

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.

# 7 Film Identification

## 7.1 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.

## 7.3 Multiple Films

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.

# 9 Radiography Quality Level

## 9.1 General

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

## 9.3 Radiographic Contrast

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 will provide the required quality level and definition may be used.

9.3.1

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 (0.5 ($^{1}/_{2}$) in.) high and 1.6 mm (0.0625 ($^{1}/_{16}$) in.) thick.

9.3.2

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.

9.3.3

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

## 9.5 Radiographic Definition

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

### 9.7 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 (refer to Section 2, Table 1).

### 9.9 Source-to-Film Distance

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

9.9.1

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

| | | |
|---|---|---|
| $U_g$ | = | 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.

9.9.2

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

### 9.11 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.

## 11 Image Quality Indicator (IQI)

### 11.1 General

Either standard hole-type (plaque) or wire-type IQIs are to be used.

### 11.3 Hole-type IQI

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.

## 11.5 Plaque Design (Penetrameter)

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. The size of the shim is to be a minimum of 3 mm (0.125 ($^1/_8$) 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.

## 11.7 Wire Design 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. It is incumbent upon the Surveyor to verify that the required image of the correct diameter wire is shown within the area of interest.

### 11.7.1

The ASTM IQI consists of six (6) wires, with the thickness of each wire increasing from left to right.

### 11.7.2

The ISO IQI consists of seven (7) wires, with the thickness of each decreasing from left to right.

### 11.7.3

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.

### 11.7.4

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

## 11.9 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 2 and 3).

## 11.11 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.

### 11.11.1 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.

#### 11.11.2 Level of Sensitivity

To ensure that the required level of sensitivity is maintained, the plaque thickness or the wire diameter is to be one size less than stated for source side placement (refer to Section 2, Tables 2 and 3).

# 13 Radiographic Density

## 13.1 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.

## 13.3 Calibration of Densitometer

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

### 13.3.1

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

### 13.3.2

Calibration of the instrument is to be verified and documented every 30 days.

## 13.5 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.

### 13.5.1

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.

### 13.5.2

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

## 13.7 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.

### 13.7.1

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

### 13.7.2

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

13.7.3

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

13.7.4

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.

# 15 Radiographic Film Quality

## 15.1 General

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

## 15.3 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 may be unacceptable. The weld area of interest is to be re-radiographed.

# 17 Radiographic Film Interpretation

## 17.1 General

Film interpretation and evaluation are only to be undertaken by qualified and certified Level 2 industrial radiographers.

## 17.3 Film Viewing Facilities

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

17.3.1

The viewing screen is to be clean and free of blemishes and marks.

17.3.2

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

# 19 Storage of Radiographs

## 19.1 General

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

### 19.3 Temperature and Humidity Control

This requires temperature and humidity control to ensure that no deterioration of the radiographic image occurs.

### 19.5 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.

## 21 Extent of Radiographic Inspection

### 21.1 General

Provision is to be made for the attending Surveyor to verify the radiographic inspection and examine radiographs of a representative number of checkpoints.

### 21.3 High Proportion of Non-conforming Indications

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

### 21.5 Surface Vessels

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

$n = L(B + D)/46.5$ SI and MKS units or $n = L(B + D)/500$ 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 $L/2$.

### 21.7 Reduction of Inspection Frequency

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

### 21.9 Other Marine Structures

The extent of radiographic inspection for other marine structures is to be governed by the applicable Rule requirements.

## 23 Location of Radiographic Inspection

### 23.1 General

In selecting checkpoints, the following should 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

### 23.3 Surface Vessels

Radiographic inspection within the midship 0.6*L* 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 0.6*L* is to be carried out at random in important locations, such as those specified in 2/23.3.

### 23.5 Other Marine Structures

Radiographic inspection is to be carried out at locations specified in the approved plans and by the Rules applicable to the structure.

## 25 Applicable Criteria

### 25.1 Surface Vessels – Class A Criteria

Radiographic inspection of full penetration welds for all surface vessels 150 m (500 ft) and over, in the midship 0.6*L* is to meet the requirements of Class A.

25.1.1

Class A may also be specified and applied to surface vessels less than 150 m (500 ft) when special hull material or hull design justifies this severity level.

25.1.2

Full penetration welds in way of integral or independent tanks, except membrane tanks, of all vessels intended to carry liquefied natural gas (LNG) or liquefied petroleum gas (LPG) cargo are to meet the requirements of Class A.

### 25.3 Surface Vessels – Class B Criteria

Radiographic inspection of full penetration welds for surface vessels under 150 m (500 ft), and for welds located outside midship 0.6*L*, regardless of the size of the vessels, is to meet the requirements of Class B, provided that Class A has not been specified in accordance with the special conditions noted in 2/25.1.1 and 2/25.1.2.

### 25.5 Other Marine Structures

Radiographic inspection of full penetration welds is to be in accordance with Class A, unless otherwise specified in the applicable Rules.

### 25.7 Applicability

The acceptance criteria of Subsection 2/27 is applicable for full penetration butt welds in locations where radiographic inspection is carried out in accordance with this Guide and where required by the attending Surveyor.

The acceptance criteria of Subsection 2/27 is not intended to apply to supplementary inspections conducted beyond Rule requirements.

# 27 Acceptance Criteria

## 27.1 Cracks

Welds in which radiographs exhibit any type of crack are to be considered unacceptable.

## 27.3 Incomplete Fusion or Incomplete Penetration

Lack of fusion in any portion of the weld deposit or between the weld deposit and the adjacent base metal is to be treated as incomplete fusion or incomplete penetration.

### 27.3.1 Class A and Class B

Radiographs of welds exhibiting indications of incomplete fusion or incomplete penetration greater than those shown in the respective curves of Section 2, Figure 1 for single and total accumulated length are non-conforming.

## 27.5 Slag

Non-metallic solid material entrapped in the weld deposit or between the weld deposit and the adjacent base metal is to be treated as slag.

### 27.5.1

When determining the total accumulated length of slag for each class, acceptable incomplete fusion or incomplete penetration indications are to be treated as slag.

### 27.5.2

Incomplete fusion, incomplete penetration and slag indications less than 3 mm (0.125 ($^1/_8$) in.) in length may be evaluated as slag or porosity, whichever is less restrictive.

### 27.5.3

Class A Radiographs of welds exhibiting indications of slag greater than those shown in the respective curves of Section 2, Figure 2 for single or total accumulated length are non-conforming.

### 27.5.4

Class B Radiographs of welds exhibiting indications of slag greater than those shown in the respective curves of Section 2, Figure 3 for single or total accumulated length are non-conforming.

## 27.7 Porosity

Gas pockets, circular voids, and well-dispersed tungsten inclusions are to be treated as porosity.

### 27.7.1 Class A and Class B

Radiographs of welds exhibiting porosity concentrations greater than those shown in the charts of Section 2, Figures 4 through 8, for any 150 mm (6 in.) weld length, for material ranging from 12.5 mm (0.5 ($^1/_2$) in.) to 50 mm (2 in.) in thickness, are non-conforming.

#### 27.7.2 Material Thickness Greater than 50 mm (2 in.)

For material thicknesses greater than 50 mm (2 in.), radiographs of welds exhibiting porosity distributions and concentrations that differ significantly from those shown in Section 2, Figures 4 through 8 are to have the actual number and size of the pores recorded and the total area of porosity calculated.

The calculated area is not to exceed $2.3t$ mm$^2$ ($0.09t$ in$^2$) in any 150 mm (6 in.) length of weld where $t$ is the thickness of the material in mm (in.).

#### 27.7.3 Isolated Pores

The maximum size of a single isolated pore may be $0.25t$ or 4.8 mm (0.1875 ($^3/_{16}$) in.), whichever is less, where $t$ is the thickness of the material, provided that there is only one such pore in any 150 mm (6 in.) weld length and the total area of porosity is in accordance with 2/27.7.1.

#### 27.7.4 Fine Porosity

Porosity smaller than 0.4 mm (0.015 ($^1/_{64}$) in.) in diameter may be disregarded.

### 27.9 Multiple Indications

Radiographs of welds exhibiting indications of porosity and slag (including acceptable incomplete fusion or incomplete penetration) are to be judged as follows:

#### 27.9.1

If the radiograph approximates all the permissible slag, only 50% of the permissible porosity is to be allowed.

#### 27.9.2

If the radiograph approximates all the permissible porosity, only 50% of the total accumulated permissible slag is to be allowed.

#### 27.9.3

The percent of permissible slag plus the percent of permissible porosity is not to exceed 150%.

### 27.11 Undercut

Undercut refers to a groove melted in the base metal adjacent to a weld toe at the face or root of the weld.

#### 27.11.1

For material with a thickness less than 25 mm (1 in.), radiographs of welds exhibiting undercut greater than the following are non-conforming:

*i)* any individual length greater than 50 mm (2 in.) with a depth greater than 0.8 mm (0.03125 ($^1/_{32}$) in.)

*ii)* any accumulative length in any 300 mm (12 in.) of weld is not to exceed 50 mm (2 in.) with a depth greater than 0.8 mm (0.03125 or ($^1/_{32}$) in.)

*iii)* assessment of depth is to be done by visual and mechanical means, and assessment of depth using radiography is not acceptable

27.11.2

For material with a thickness equal to or greater than 25 mm (1 in.), radiographs of welds exhibiting undercut greater than the following are non-conforming:

*i)* any individual length greater than 50 mm (2 in.) with a depth greater than 1.6 mm (0.0625 ($^1/_{16}$) in.)

*ii)* any accumulative length in any 300 mm (12 in.) of weld is not to exceed 50 mm (2 in.) with a depth greater than 1.6 mm (0.0625 ($^1/_{16}$) in.)

*iii)* assessment of depth is to be done by visual and mechanical means, and assessment of depth using radiography is not acceptable

27.11.3

In primary members, undercut is to be no more than 0.25 mm (0.01 in.) deep when the weld is transverse to tensile stress under any design loading condition. For all other cases, undercut is to be no more than 1 mm (0.04 in.).

# 29 Treatment of Welds with Non-conforming Indications

## 29.1 General

All radiographs of welds taken in accordance with 2/21.5 and 2/21.9 exhibiting non-conforming indications are to be brought to the attention of the attending Surveyor. Such welds are to be repaired and inspected as required by the Surveyor.

## 29.3 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.

## 29.5 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.

## 29.7 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.

# 31 References

American Welding Society, D1.1/D1.1M:2002, *Structural Welding Code, Steel.*

ASTM E94-93, *Standard Guide for Radiographic Testing*.

ASTM Standard E142-92, *Standard Method for Controlling Quality of Radiographic Testing*.

ASTM E747-97, *Practice for Design, Manufacturer and Material Grouping Classification of Wire Image Quality Indicators (IQI) Used for Radiology*.

ASTM E1025-95, *Practice for Design, Manufacturer and Material Grouping Classification of Hole-Type Image Quality Indicators (IQI) Used for Radiology*.

ASTM E1032-95, *Standard Test Method for Radiographic Examination of Weldments*.

International Standard ISO 1027-1983(E), *Radiographic Image Quality Indicators for Non-destructive Testing – Principles and Identification*.

## TABLE 1
## Geometric Unsharpness (See 2/9.7)

| *Material Thickness in Area of Interest* | | *Maximum Geometric Unsharpness ($U_g$)* | |
|---|---|---|---|
| *(mm)* | *(in.)* | *(mm)* | *(in.)* |
| 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 |

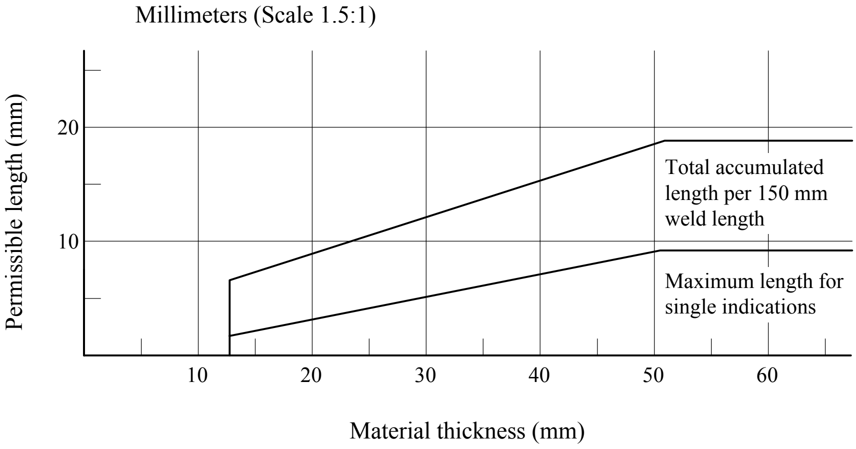
## TABLE 2
## Hole-type Image Quality Indicator (IQI) Requirements (See 2/11)

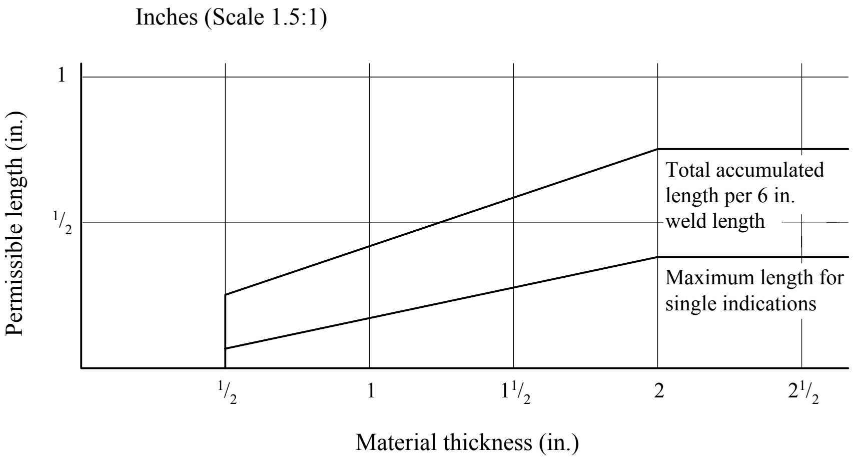
| *Nominal Material Thickness Range, (mm)* | *Nominal Material Thickness Range, (in.)* | *SOURCE SIDE* | | *FILM SIDE* | |
|---|---|---|---|---|---|
| | | *Designation* | *Essential Hole* | *Designation* | *Essential Hole* |
| Up to 6.5 incl. | Up to 0.25 incl. | 10 | 4T | 7 | 4T |
| Over 6.5 through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

## TABLE 3
## Wire Image Quality Indicator (IQI) Requirements (See 2/11)

| *Nominal Material Thickness Range, (mm)* | *Nominal Material Thickness Range, (in.)* | *SOURCE SIDE Maximum Wire Diameter* | | *FILM SIDE Maximum Wire Diameter* | |
|---|---|---|---|---|---|
| | | *(mm)* | *(in.)* | *(mm)* | *(in.)* |
| Up to 6.5 incl. | Up to 0.25 incl. | 0.25 | 0.010 | 0.20 | 0.008 |
| Over 6.5 through 10.0 | Over 0.25 to 0.375 | 0.33 | 0.013 | 0.25 | 0.010 |
| Over 10.0 through 16.0 | Over 0.375 to 0.625 | 0.40 | 0.016 | 0.33 | 0.013 |
| Over 16.0 through 19.0 | Over 0.625 to 0.75 | 0.50 | 0.020 | 0.40 | 0.016 |
| Over 19.0 through 38.0 | Over 0.75 to 1.50 | 0.63 | 0.025 | 0.50 | 0.020 |
| Over 38.0 through 50.0 | Over 1.50 to 2.00 | 0.80 | 0.032 | 0.63 | 0.025 |
| Over 50.0 through 62.5 | Over 2.00 to 2.50 | 1.00 | 0.040 | 0.80 | 0.032 |
| Over 62.5 through 100.0 | Over 2.50 to 4.00 | 1.25 | 0.050 | 1.00 | 0.040 |
| Over 100.0 through 150.0 | Over 4.00 to 6.00 | 1.60 | 0.063 | 1.25 | 0.050 |
| Over 150.0 through 200.0 | Over 6.00 to 8.00 | 2.50 | 0.100 | 1.60 | 0.063 |

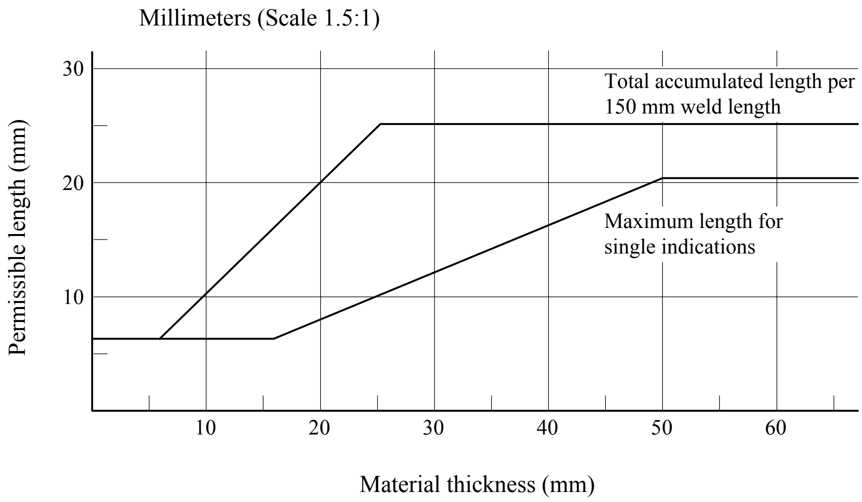
# FIGURE 1
# Class A and Class B Incomplete Fusion and Incomplete Penetration – Acceptable Length

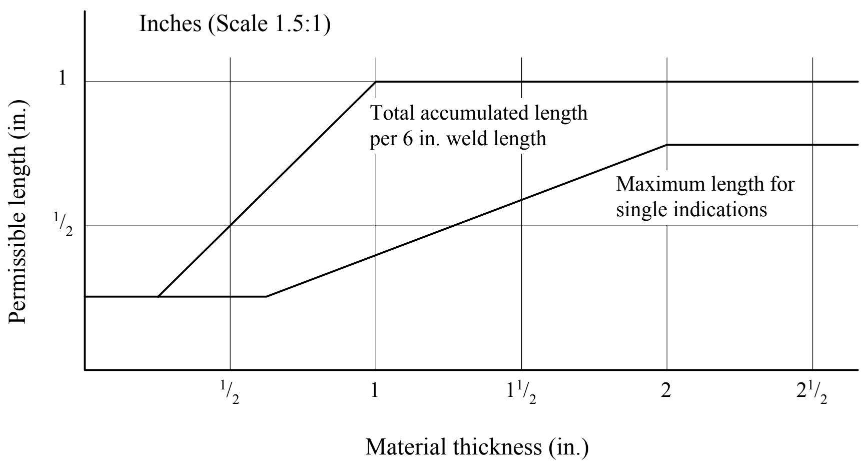


# FIGURE 2
# Class A Slag – Acceptable Length

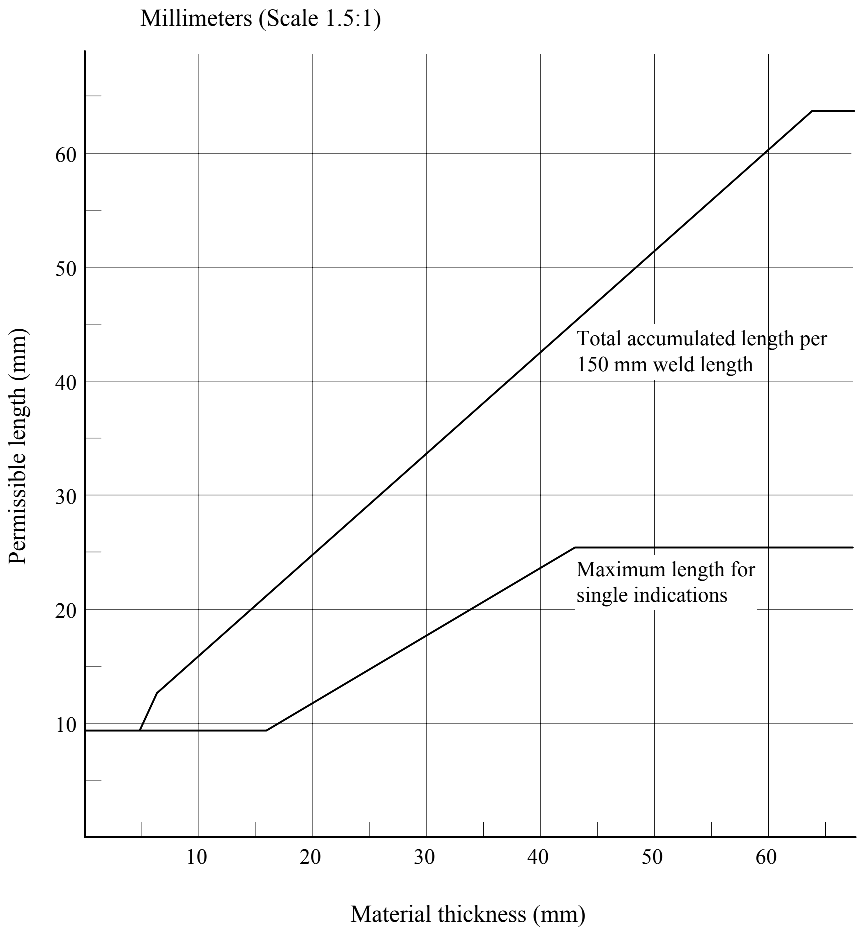
Total accumulated slag is to include incomplete fusion and incomplete penetration when allowed by Section 2, Figure 1.



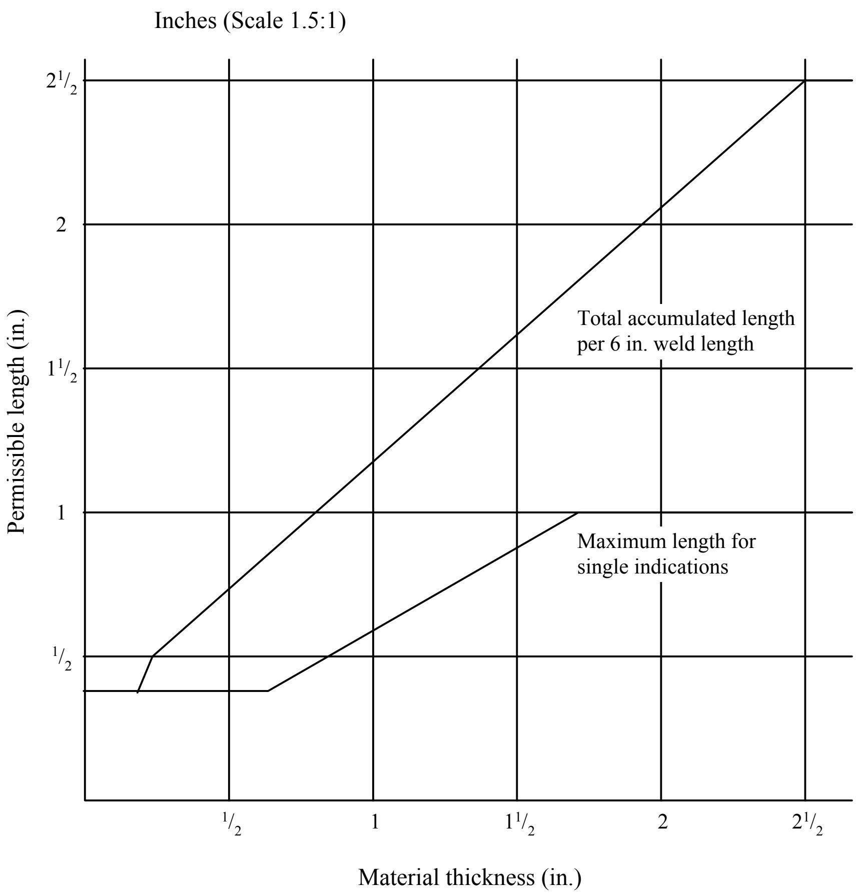



# FIGURE 3
# Class B Slag – Acceptable Length

Total accumulated slag is to include incomplete fusion and incomplete penetration when allowed by Section 2, Figure 1.



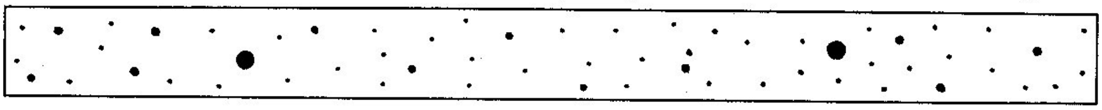
# FIGURE 3 (continued)
# Class B Slag – Acceptable Length



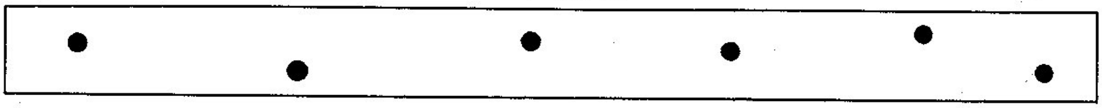
# FIGURE 4
# Class A and Class B Porosity Chart for 12.5 mm (0.5 in.) Thick Material

Total porosity area permitted 29 mm² per 150 mm (0.045 in.² per 6 in.) weld length.

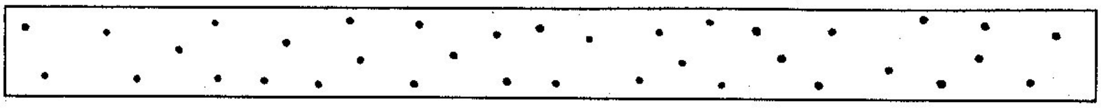
| *Pore type* | *Pore diameter* | *Allowable pores* |
|---|---|---|
| Assorted | 2.54 mm (0.10 in.) | 2 |
| | 1.02 mm (0.04 in.) | 12 |
| | 0.508 mm (0.02 in.) | 45 |



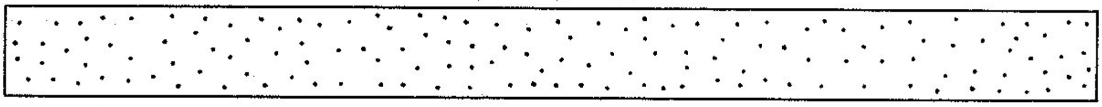
| | | |
|---|---|---|
| Large | 2.54 mm (0.10 in.) | 6 |



| | | |
|---|---|---|
| Medium | 1.02 mm (0.04 in.) | 36 |



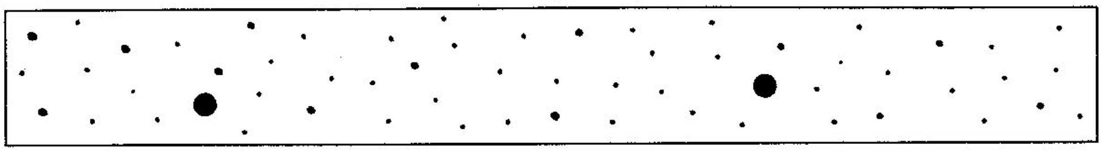
| | | |
|---|---|---|
| Fine | 0.508 mm (0.02 in.) | 143 |



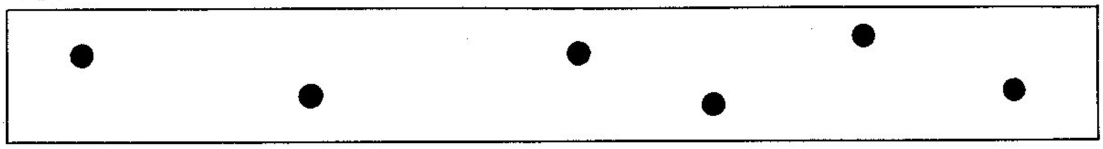
# FIGURE 5
# Class A and Class B Porosity Chart for 19.0 mm (0.75 in.) Thick Material

Total porosity area permitted 43.2 mm$^2$ per 150 mm (0.067 in.$^2$ per 6 in.) weld length.

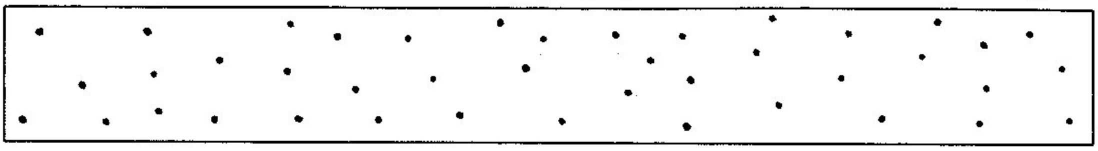
| *Pore type* | *Pore diameter* | *Allowable pores* |
|---|---|---|
| Assorted | 3.17 mm (0.125 in.) | 2 |
| | 1.14 mm (0.045 in.) | 13 |
| | 0.635 mm (0.025 in.) | 44 |



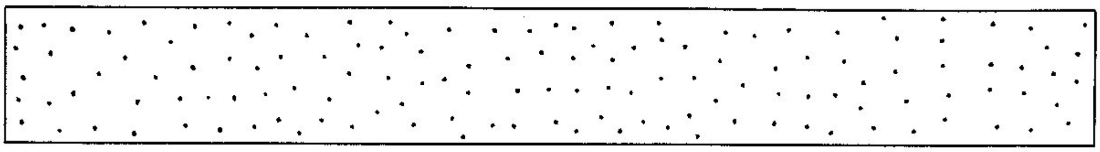
| | | |
|---|---|---|
| Large | 3.17 mm (0.125 in.) | 6 |



| | | |
|---|---|---|
| Medium | 1.14 mm (0.045 in.) | 42 |



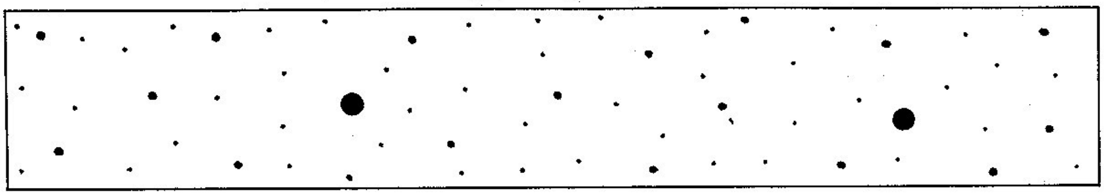
| | | |
|---|---|---|
| Fine | 0.635 mm (0.025 in.) | 137 |



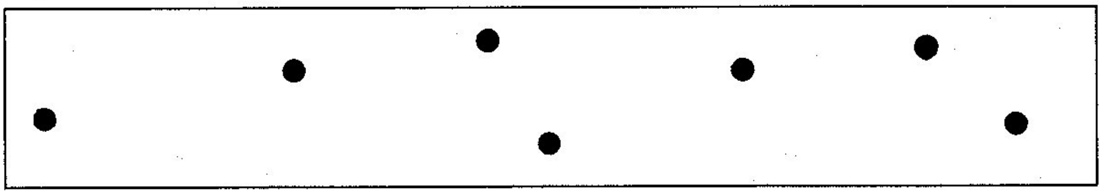
## FIGURE 6
## Class A and Class B Porosity Chart for 25 mm (1.0 in.) Thick Material

Total porosity area permitted 58.1 mm² per 150 mm (0.09 in.² per 6 in.) weld length.

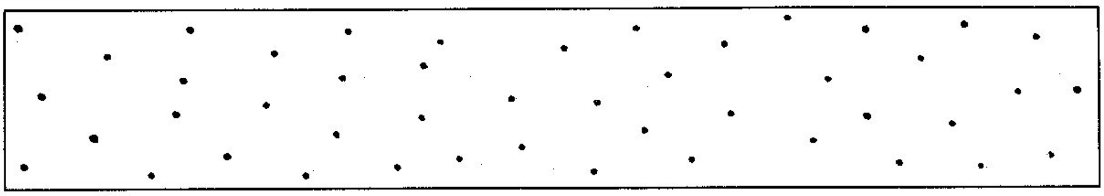
| *Pore type* | *Pore diameter* | *Allowable pores* |
| --- | --- | --- |
| Assorted | 3.17 mm (0.125 in.) | 2 |
| | 1.27 mm (0.05 in.) | 17 |
| | 0.762 mm (0.03 in.) | 45 |



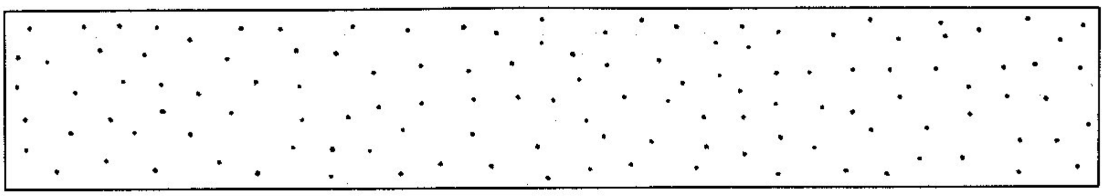
| | | |
| --- | --- | --- |
| Large | 3.17 mm (0.125 in.) | 7 |



| | | |
| --- | --- | --- |
| Medium | 1.27 mm (0.05 in.) | 46 |



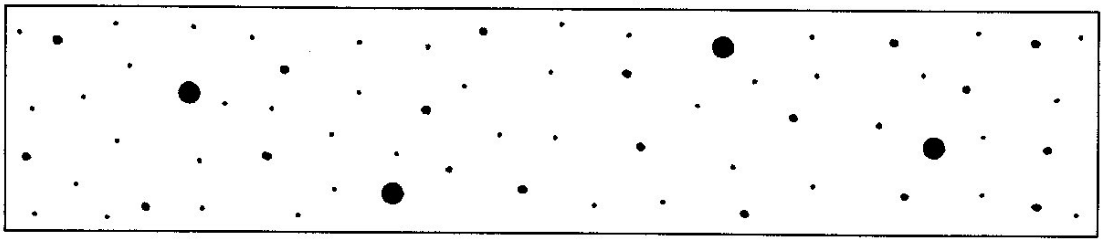
| | | |
| --- | --- | --- |
| Fine | 0.762 mm (0.03 in.) | 127 |



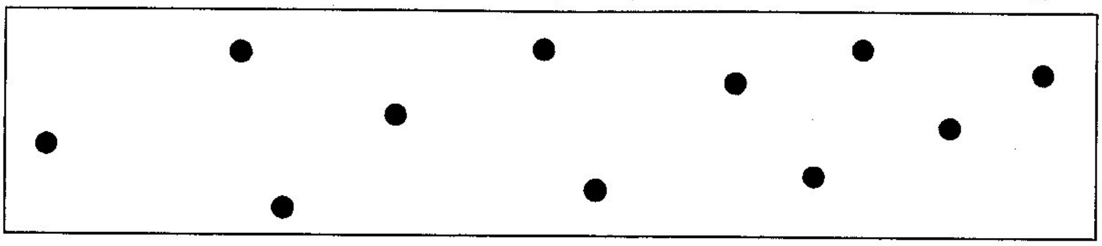
## FIGURE 7
## Class A and Class B Porosity Chart for 38.0 mm (1.5 in.) Thick Material

Total porosity area permitted 87.1 mm$^2$ per 150 mm (0.135 in.$^2$ per 6 in.) weld length.

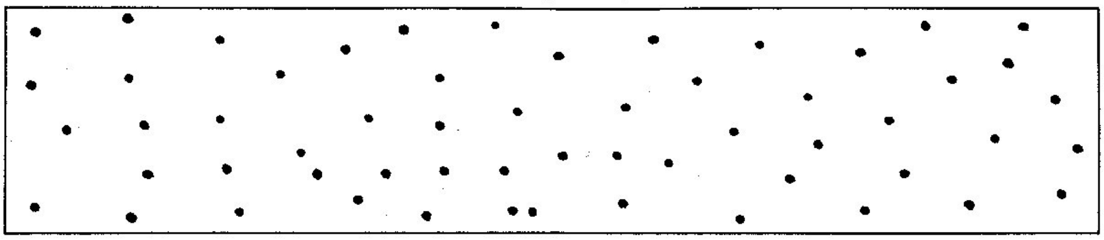
| *Pore type* | *Pore diameter* | *Allowable pores* |
|---|---|---|
| Assorted | 3.17 mm (0.125 in.) | 4 |
| | 1.4 mm (0.055 in.) | 18 |
| | 0.89 mm (0.035 in.) | 45 |



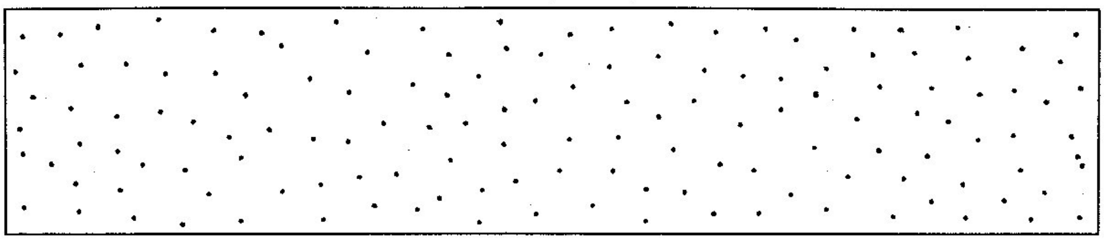
| Large | 3.17 mm (0.125 in.) | 11 |
|---|---|---|



| Medium | 1.4 mm (0.055 in.) | 57 |
|---|---|---|



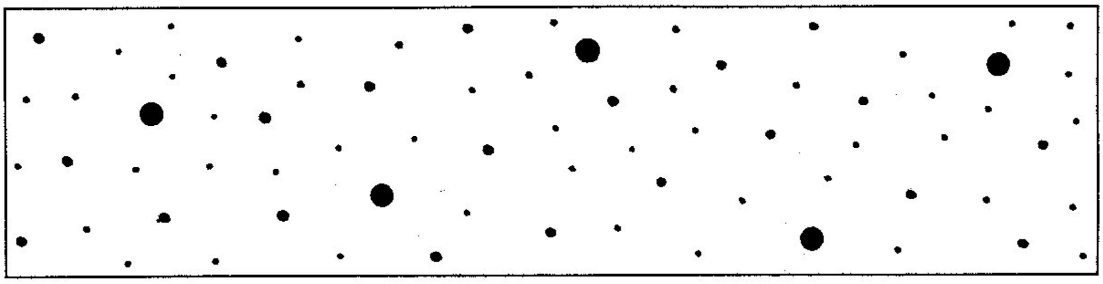
| Fine | 0.89 mm (0.035 in.) | 140 |
|---|---|---|



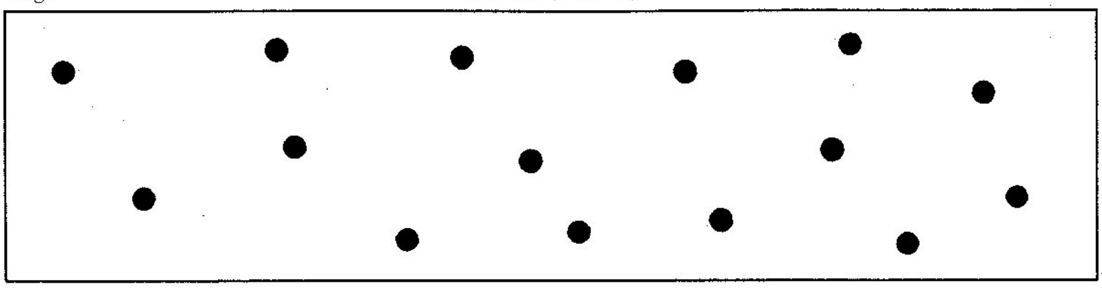
# FIGURE 8
# Class A and Class B Porosity Chart for 50 mm (2.0 in.) Thick Material

Total porosity area permitted 116 mm² per 150 mm (0.180 in.² per 6 in.) weld length.

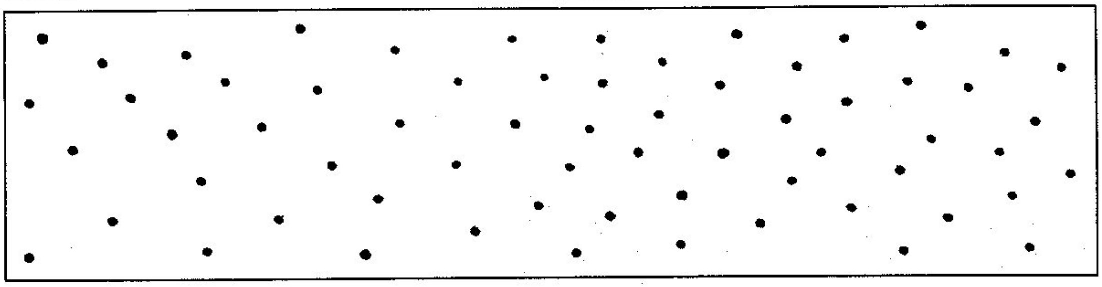
| *Pore type* | *Pore diameter* | *Allowable pores* |
|---|---|---|
| | 3.17 mm (0.125 in.) | 5 |
| Assorted | 1.52 mm (0.06 in.) | 21 |
| | 1.02 mm (0.04 in.) | 47 |



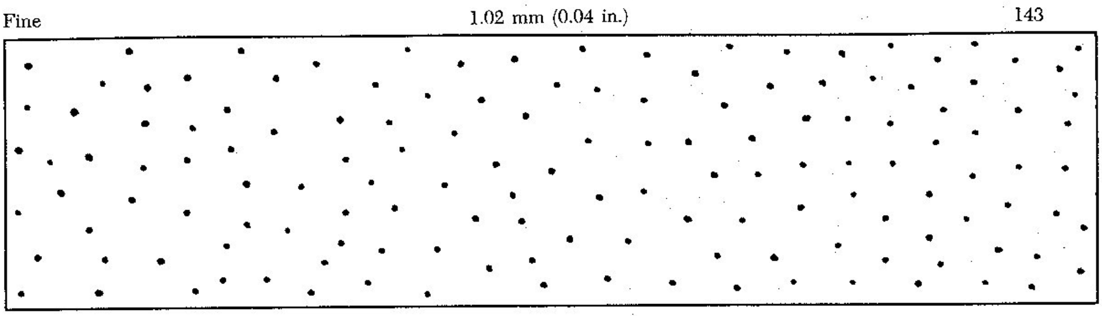
| | | |
|---|---|---|
| Large | 3.17 mm (0.125 in.) | 15 |



| | | |
|---|---|---|
| Medium | 1.52 mm (0.06 in.) | 64 |



| | | |
|---|---|---|
| Fine | 1.02 mm (0.04 in.) | 143 |



SECTION 3 Ultrasonic Inspection

# 1 General

When ultrasonic inspection is to be used as a quality control measure at a shipyard, it is incumbent upon the Surveyor to determine the yard's capability with this inspection method. Several important considerations, which should 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 is to be initially and periodically supplemented with a reasonable amount of radiographic inspection to determine that adequate quality control is achieved. Records are to be kept concerning the nature and severity of the indications and the amount of repair weld required based on each inspection method.

In addition to the ultrasonic inspection, the Surveyor may, at his discretion, require supplementary nondestructive testing, such as radiography, to verify the adequacy of the quality control system.

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 the Bureau, may also be applied to other marine structures. They are not intended to cover material under 8 mm (0.3125 ($^{5}/_{16}$) in.) in thickness for which modified techniques and standards would be required. 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 below 8 mm (0.3125 ($^{5}/_{16}$) in.) in thickness may be specially considered when proposed as a substitute for radiography.

# 3 Ultrasonic Procedure

## 3.1 Personnel

It is incumbent upon the Surveyor to ensure that NDT personnel are qualified and certified by a combination of training and experience appropriate to the level of responsibility assigned.

## 3.3 Technique

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

## 3.5 Ultrasonic Equipment

The ultrasonic test instrument is to be of the pulse echo type and is to be capable of generating frequencies in the range of 1 MHz to 5 MHz. The CRT screen presentation is to be an A-scan rectified video type and categorized by a clean, crisp trace.

## 3.7 Basic Instrument Qualification

Basic instrument qualification is to be made once each 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, horizontal linearity and amplitude control linearity. A 12.5 mm (0.5 ($^1/_2$) in.) diameter 2.25 MHz compressional 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, shown in Section 3, Figure 1 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.

### 3.7.1 Vertical Linearity

Vertical linearity is to be checked by positioning the master transducer over the depth resolution notch in the IIW Block so that the signal from the notch is at a height of three scale divisions (30% of the full screen height), and the signal from one of the back surfaces is at a height of 6 scale divisions (60% of the full screen height). Without moving the transducer, adjust the gain to successively set the signal from the back surface from 10% to 100% of full screen, in 10% increments. The corresponding amplitude of each signal from the notch is determined and must be 50% of the signal from the back surface, within ± 5% of full screen height. At each increment the ratio of the two signals is determined. The ratios are to be plotted on a graph at the position corresponding to the larger signal. The ratio must be within ± 5% of 2:1.

### 3.7.2 Horizontal Linearity

To determine horizontal linearity, use the master transducer referred to under 3/3.7 and obtain a minimum of 5 multiple reflection indications from the 25 mm (1 in.) thickness of the IIW block. Adjust the indications to coincide with equally spaced points across the horizontal scale. When properly adjusted no indication is to deviate from the appropriate point by more than ± 5%.

### 3.7.3 Amplitude Control Linearity

To determine the accuracy of the amplitude control of the instrument, position the master transducer over the 1.5 mm (0.0625 ($^1/_{16}$) 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* | *db control change* | *Indication limits % of full screen* |
|---|---|---|
| 80% | -6db | 32 to 48% |
| 80% | -12db | 16 to 24% |
| 40% | +6db | 64 to 96% |
| 20% | +12db | 64 to 96% |

## 3.9 Transducers

Straight beam transducer element size may vary from 12.5 mm (0.5 ($^1/_2$) in.) to 25 mm (1 in.) and may be round or square.

The angle beam transducer element size may vary from 12.5 mm (0.5 ($^1/_2$) in.) to 20 mm (0.75 ($^3/_4$) in.) in width and from 12.5 mm (0.5 ($^1/_2$) in.) to 16 mm (0.625 ($^5/_8$) in.) in height and may be round, rectangular or square.

Transducers are to have a nominal frequency of 2.25 MHz. Higher frequencies up to 5 MHz may be utilized for improved resolution or for material of thin cross section and 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. The transducers are to be affixed to suitable wedges designed to induce shear waves in the material under test within ± 2° of the following angles: 70°, 60° and 45°.

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 after each eight hours of use to verify the index point, that the wear face is flat and that the refracted angle is within the ± 2° of the proper angle.

The primary consideration for selecting the resulting angle of shear wave is the thickness of the plate. Other factors which may be considered in angle selection are weld joint geometry and groove angle and further evaluation of discontinuities detected.

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

| *Plate Thickness* | *Shear Wave Angle** |
|---|---|
| 8 mm (0.3125 (5/16) in.) to 38 mm (1.5 in.) | 70° |
| Over 38 mm (1.5 in.) to 64 mm (2.5 in.) | 60° and 70° |
| Over 64 mm (2.5 in.) | 45° and 60° |

*Other shear wave angles may be used provided it is demonstrated that they are suitable for the application involved.

## 3.11 Calibration Standards

### 3.11.1 IIW Block

Distance calibration (horizontal sweep) is to be performed using The International Institute of Welding (IIW) ultrasonic reference block as shown in Section 3, Figure 1. Other more portable blocks of approved design may be permitted for field use, provided they meet the intended requirements.

### 3.11.2 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.).

*3.11.2(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 will be conducted. If the examination will be 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.

*3.11.2(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.

*3.11.2(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.

## 3.13 Calibration for Examination

The same couplant is to be used for both calibration and field inspection. Application and temperature of the couplant and calibration block is to represent field conditions. 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, after every 30 minutes 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.

### 3.13.1 Straight Beam Calibration

Calibration for straight beam examination of the plate material is to be performed by placing the transducer on the plate surface and adjusting the sweep distance to display a minimum of two back reflections from the opposite side of the plate. The sensitivity is to be adjusted at an indication free area, so that the first back reflection is between 60% and 80% of full screen height.

### 3.13.2 Angle Beam Calibration (For Instruments without Automatic Distance Amplitude Correction)

Horizontal sweep distance is to be adjusted to represent the total sound path distance to be covered during the examination and in most cases, this is to be made on either a 125 mm (5 in.) or 250 mm (10 in.) scale on the display whichever is appropriate for the material thickness being examined. In some cases a 375 or 500 mm (15 or 20 in.) scale on the display may be necessary.

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

Position the search unit for maximum response from the hole which gives the highest amplitude, and adjust the sensitivity control to provide an 80% (± 5% of full screen height) of full screen indication 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 three 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.

This represents the DAC curve and serves as the Amplitude Reject Level (ARL).

A second DAC curve is to then be plotted from the same reflector holes and be marked on the screen at 50% of the ARL. (The response from the reflector holes is to be 6 db less sensitive when the points are marked).

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.

### 3.13.3 Capability of Equipment

The capability of equipment, calibrated in accordance with 3/3.13 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.

## 3.15 Surface Condition

The surfaces upon 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 the extent that allows the transducer intimate contact with the scanning surface.

## 3.17 Weld Inspection

### 3.17.1 Plate Lamellar Discontinuities

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 a straight beam (compressional wave) technique. 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.

### 3.17.2 Longitudinal Discontinuities

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. Simultaneously, while moving along the path of inspection, 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.

### 3.17.3 Transverse Discontinuities

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. The scan is then to be repeated on the same surface (if accessible) on the other side of the weld. Both scans are to be made with the transducer moved in the same direction. Alternatively, where inspection is not accessible from the same surface on both sides of a weld, a second scan is to be made on the opposite surface from either side of the weld. 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.

## 3.19 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. Using the centerline of the wedge of the transducer as an index, the extremity points of the discontinuities are determined as indicated in 3/3.19.1 and 3/3.19.2.

### 3.19.1 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)

### 3.19.2 Indications Greater than DRL

For indications with peak amplitudes 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 $^1/_2$ the major dimension of the transducer or drops to $^1/_2$ the peak amplitude, whichever occurs first (i.e. the points which define the shortest discontinuity length).

### 3.21 Ultrasonic Inspection Reports

Ultrasonic inspection reports are to be filed for record and are to include the hull number, exact location and length of the welds inspected, equipment used (instrument identity, transducer type, size, frequency, angle), base metal type and thickness, weld process, any unusual condition of weld bead (ground, undercut, etc.), weld joint design, the specific class to which examination is being carried out and all reflections which are interpreted as failing to meet the specified requirements (as defined in Subsection 3/11), dates of inspection and signature of ultrasonic operator. (A typical report form, shown in Section 3, Figure 4, is considered acceptable.) The method for review and evaluation of ultrasonic test reports is to assure adequate quality control and is to be to the satisfaction of the Surveyor.

## 5 Extent of Ultrasonic Inspection

### 5.1 Checkpoints

Provision is to be made for the attending 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.). Lengths of welds inspected at subassembly stage and final erection stage (as required under 3/7.1.1) 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 Surface Vessels

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

$n = L(B + D)/46.5$ SI and MKS units $\quad\quad$ $n = L(B + D)/500$ 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 Structures

The extent of ultrasonic inspection for other marine structures is to be governed by the applicable Rule requirements.

# 7 Location of Ultrasonic Inspection

## 7.1 General

In selecting checkpoints the following should be given emphasis in the selection of inspection locations:

*i)* Welds in highly 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

### 7.1.1 Surface Vessels

Ultrasonic inspection within the midship 0.6*L* 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

Ultrasonic inspection outside the midship 0.6*L* is to be carried out at random in important locations, such as those specified above, at the discretion of the Surveyor. Where inspection is to be carried out at weld intersections, in general a minimum of 250 mm (10 in.) of weld, measured from the intersection in each direction transverse to the axis of the vessel (butt weld), is to be inspected. In addition, a minimum of 125 mm (5 in.) of weld, measured from the intersection in each direction longitudinal to the axis of the vessel (seam weld), is to be inspected.

### 7.1.2 Other Marine Structures

Ultrasonic inspection is to be carried out at locations specified in the approved plans and by the Rules applicable to the structure.

# 9 Applicable Criteria

## 9.1 Surface Vessels

### 9.1.1 Class A Criteria

Results of the ultrasonic inspection of full penetration welds for all surface vessels 150 m (500 ft) and over, in the midship 0.6*L* are to meet the requirements of Class A. Class A may also be specified and applied to surface vessels less than 150 m (500 ft) when special hull material or hull design justifies this severity level. Full penetration welds in way of integral or independent tanks except membrane tanks of all vessels intended to carry liquefied natural gas (LNG) or liquefied petroleum gas (LPG) cargo are to meet the requirements of Class A.

### 9.1.2 Class B Criteria

Results of the ultrasonic inspection of full penetration welds for surface vessels under 150 m (500 ft) and for welds located outside midship 0.6*L* regardless of the size of the vessel, are to meet the requirements of Class B provided that Class A has not been specified in accordance with the special conditions noted in 3/9.1.1.

### 9.3 Other Marine Structures

Ultrasonic inspection of full penetration welds is to be in accordance with the Class A acceptance criteria unless otherwise specified in the applicable Rules.

### 9.5 Applicability

The acceptance standards of Subsection 3/9 are applicable for full penetration butt welds in locations where ultrasonic inspection is carried out in accordance with this Guide and where required by the attending Surveyor and are not intended to apply to supplementary inspections conducted beyond Rule requirements.

## 11 Acceptance Criteria

### 11.1 Class A

#### 11.1.1 Indications Greater than the ARL

Ultrasonic indications of welds producing a signal which exceeds the ARL (as established in 3/3.11) and has a length greater than 12.5 mm (0.5 ($^1/_2$) in.) are non-conforming. Indications less than 4.8 mm (0.1875 ($^3/_{16}$) in.) in length may be disregarded. Indications 4.8 mm (0.1875 ($^3/_{16}$) in.) to 12.5 mm (0.5 ($^1/_2$) in.) in length are to be evaluated in accordance with 3/11.1.2.

#### 11.1.2 Indications Greater than the DRL

Ultrasonic indications of welds producing a signal which exceed the DRL (as established in 3/3.11) are non-conforming if the signals are indicative of discontinuities greater in length than those shown in the respective curves of Section 3, Figure 5 for single or total accumulated length. Indications less than 4.8 mm (0.1875 ($^3/_{16}$) in.) in length may be disregarded.

#### 11.1.3 Indications Less than the DRL

Ultrasonic signals which are less than the DRL are to be disregarded.

### 11.3 Class B

#### 11.3.1 Indications Greater than the ARL

Ultrasonic indications of welds producing a signal which exceeds the ARL (as established in 3/3.11) and has a length greater than 12.5 mm (0.5 ($^1/_2$) in) are non-conforming. Indications less than 4.8 mm (0.1875 ($^3/_{16}$) in.) in length may be disregarded. Indications 4.8 mm (0.1875 ($^3/_{16}$) in.) to 12.5 mm (0.5 ($^1/_2$) in.) in length are to be evaluated in accordance with 3/11.3.2.

#### 11.3.2 Indications Greater than DRL

Ultrasonic indications of weld producing signals which exceed the DRL (as established in 3/3.11) are non-conforming if the signals are indicative of discontinuities greater in length than those shown in the respective curves of Section 3, Figure 6 for single or total accumulated length. Indications less than 4.8 mm (0.1875 ($^3/_{16}$) in.) in length may be disregarded.

#### 11.3.3 Indications Less than the DRL

Ultrasonic signals which are less than the DRL are to be disregarded.

# 13 Treatment of Welds with Non-conforming Indications

## 13.1 General

All non-conforming ultrasonic indications are to be brought to the attention of the Surveyor and welds are to be repaired and re-inspected as required by the Surveyor.

## 13.3 Discontinuity Extent

### 13.3.1 At One Location

Unless otherwise required by the Surveyor, when non-conforming indications are concentrated at one location, only this location need be repaired or otherwise treated to the satisfaction of the Surveyor, and no additional ultrasonic inspection need be carried out in the adjacent area.

### 13.3.2 At the End of a Checkpoint

When non-conforming indications are observed at the end of a checkpoint, additional ultrasonic inspection is required to determine the extent of the non-conforming area.

### 13.3.3 Additional Inspection

When a series of non-conforming indications are observed at a checkpoint 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.

# 15 Ultrasonic Inspection of Full Penetration Tee and Corner Joints

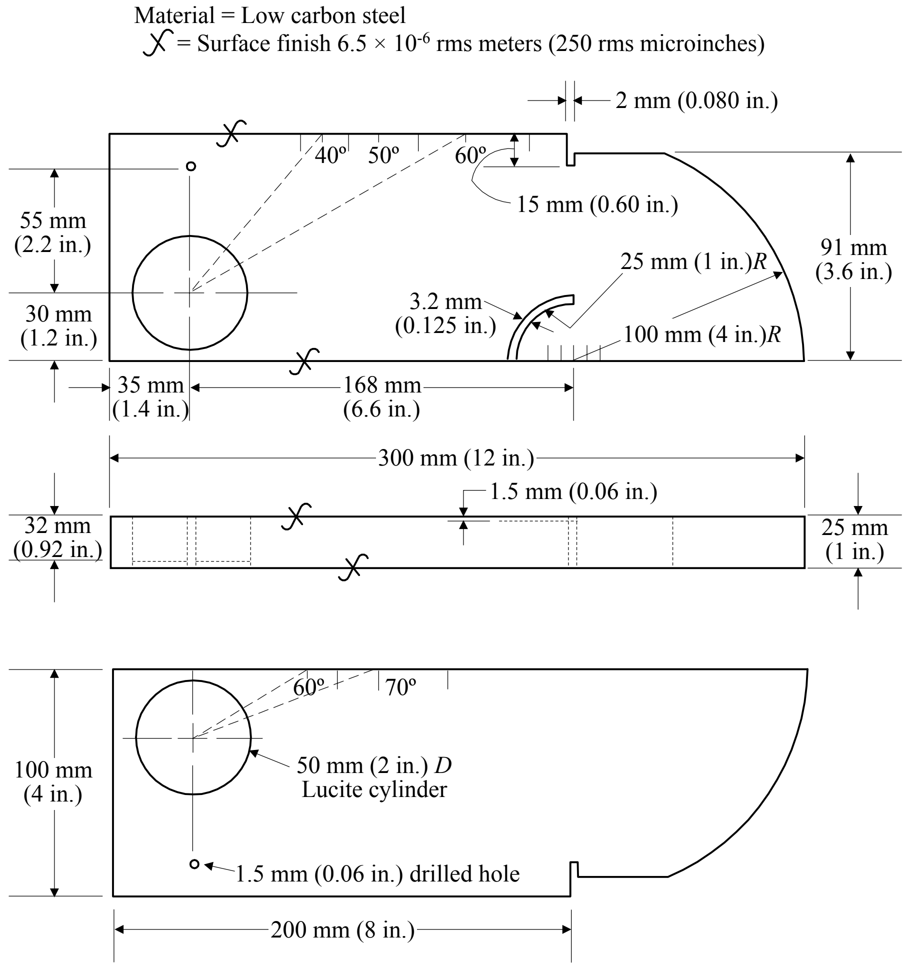
When required by the applicable Rules or in the course of a periodic or damage survey, the acceptance standards are to be consistent with the guidance of Appendix 2.

# 17 References

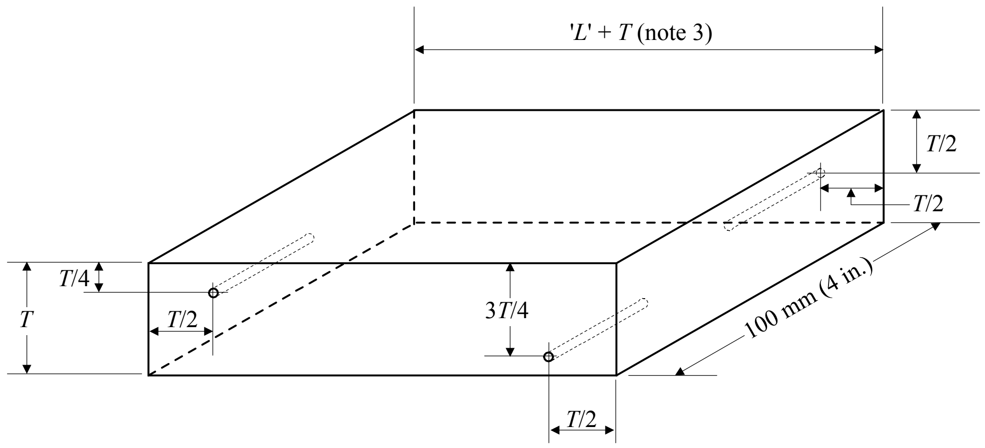
American Society for Non-destructive Testing Recommended Practice No. SNT-TC-1A – Table 1-C, Ultrasonic Testing Method

American Society for Testing and Materials ASTM E164 – *Recommended Practice for Ultrasonic Contact Examination of Weldments*.

# FIGURE 1
# International Institute of Welding (IIW) Ultrasonic Reference Block



# FIGURE 2
# Basic Calibration Block

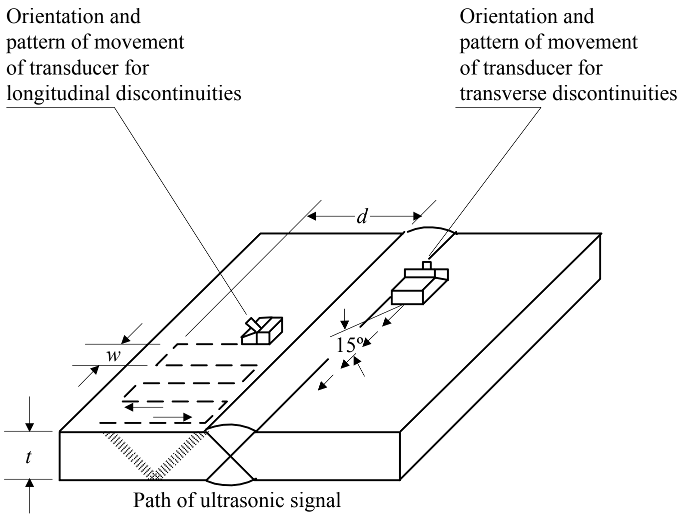



| **Weld Joint Thickness** | **Basic Calibration Block Thickness** |
|---|---|
| 25 mm (1 in.) or less | 19 mm (0.75 in.) or *T* |
| Greater than 25 mm (1 in) to 50 mm (2 in.) | 38 mm (1.5 in.) or *T* |
| Greater than 50 mm (2 in) to 100 mm (4 in.) | 75 mm (3 in.) or *T* |
| Greater than 100 mm (4 in) to 150 mm (6 in.) | 125 mm (5 in.) or *T* |

**Calibration Block Requirements**

1. Material to be on same product form and heat treatment as the material to be inspected.
2. Surface finish from which the scanning is to be conducted is to be representative of the component to be inspected.
3. '*L*' shall be sufficient to allow a minimum of two half skips (one vee path) of the sound beam using the transducer angle to be used.
4. Calibration Reflector Holes to be drilled parallel to the scanning surface.
5. Calibration Reflector Holes to be 1.2 mm (0.047 (3/64) in.) diameter × 38 mm (1.5 in.) deep.

# FIGURE 3
# Scanning Procedure for Welds not Ground Flush




*w* - is to be less than 90% of transducer crystal width (10% overlap)
*t* - material thickness
θ - transducer shear wave angle (see 3/3.9)
*d* - >2*t*(tan θ) + 3.2 mm (0.125 (1/8) in.)

# FIGURE 4
# Ultrasonic Inspection Report

REPORT NO. ____________________

1. Hull No. ______________________ 2. Location ____________________________________

3. a. Transducer ______________ ______________ ______________ ______________
   Identification Size Angle Freq. (MHz)

   b. Instrument make and model ____________________________________________

4. Acceptance Standard – ABS Class ______________, Other ______________
   A or B Specify

---

5. WELD DETAILS

   a. Base Metal __________________________________

   b. Thickness(es) ________________________________

   c. Weld Process ________________________________

   d. Surface Appearance ___________________________

6. WELD JOINT DESIGN (DESCRIBE OR SKETCH)

---

7. UNACCEPTABLE INDICATIONS*

   a. Specific Location

   b. Rejection Basis (ARL, Single DRL (S-DRL), Multiple (M-DRL))

   c. Amplitude Range

   d. Length

   e. Depth

   f. Orientation

   g. Distance from Surface

   h. Remarks (Interpretation of indications e.g. slag, fusion line, root, HAZ, crack, etc.)

---

8. Total Number Indications __________________. Total Length Indications ___________________.

9. Total Length Inspected ______________________________________________________________.

10. Inspected by ____________________________________________________ Date __________

    Comments ______________________________________________________________________.

11. Reviewed by ____________________________________________________ Date __________

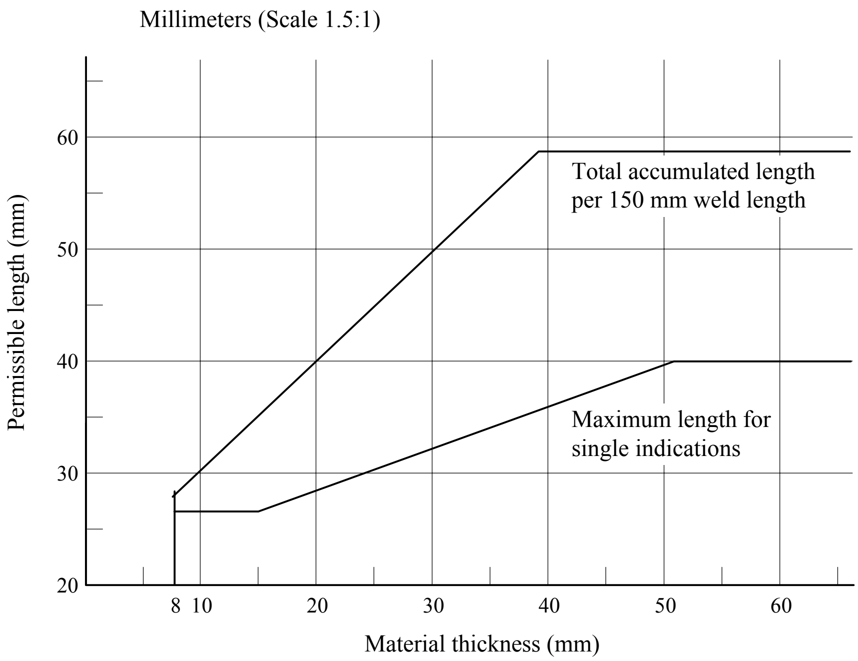
    Comments ______________________________________________________________________.

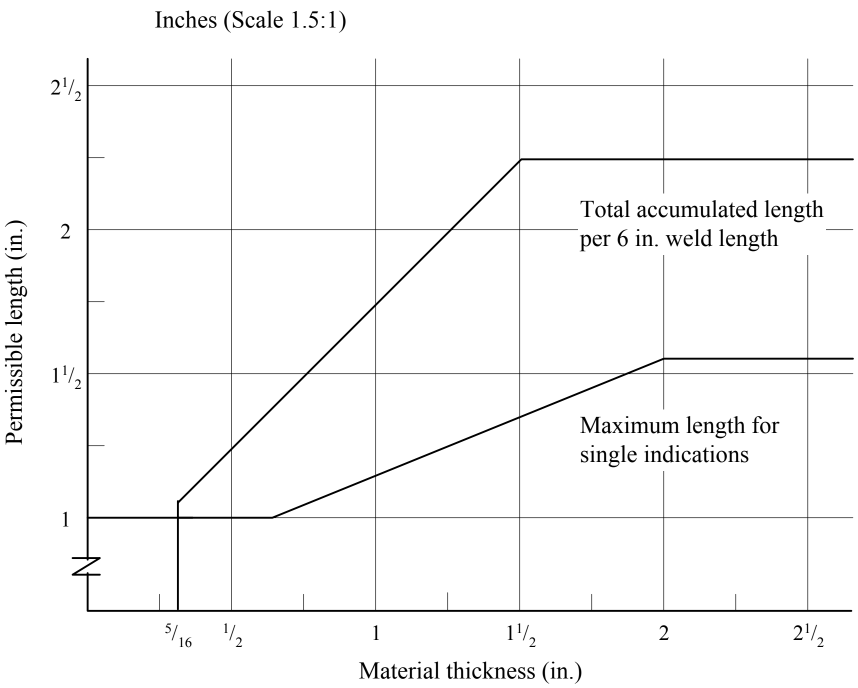
12. Repairs – Completed and Approved _____________, ____________________________________
    (as per 3/13) Date Name

    ____________________________________________________
    Title

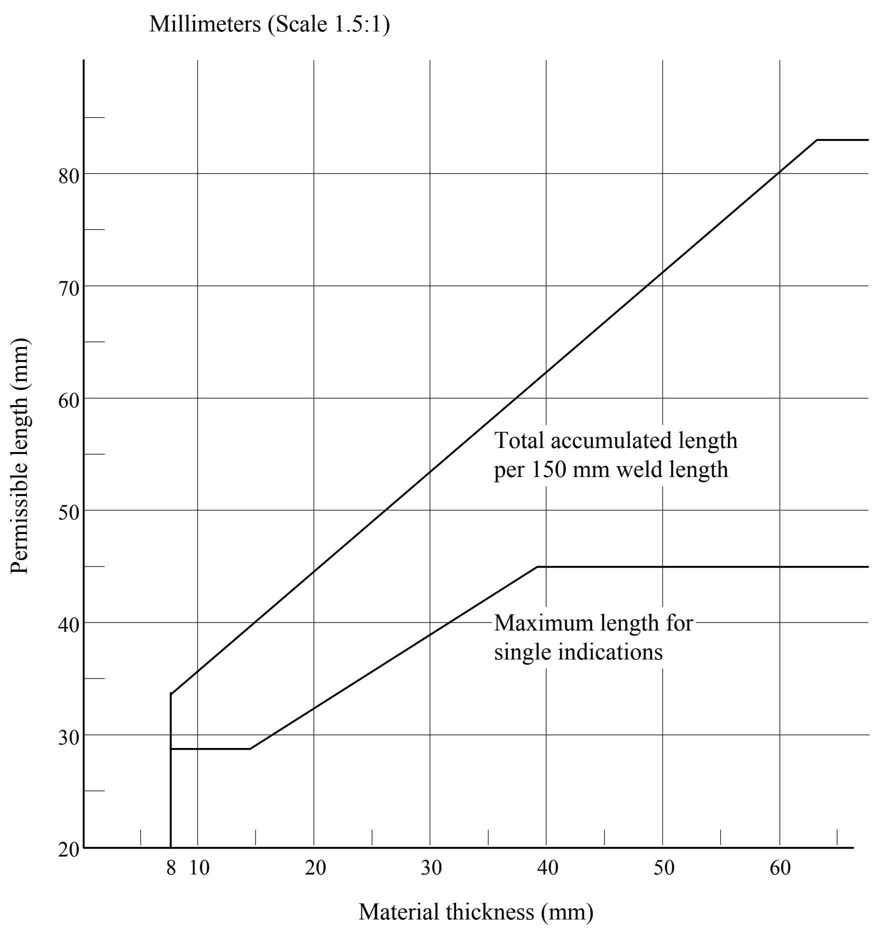
* Appropriate sketches may be used as alternates or supplements to 7a through 7g.

## FIGURE 5
## Class A – Maximum Acceptable Lengths for Ultrasonic Indications Greater than DRL

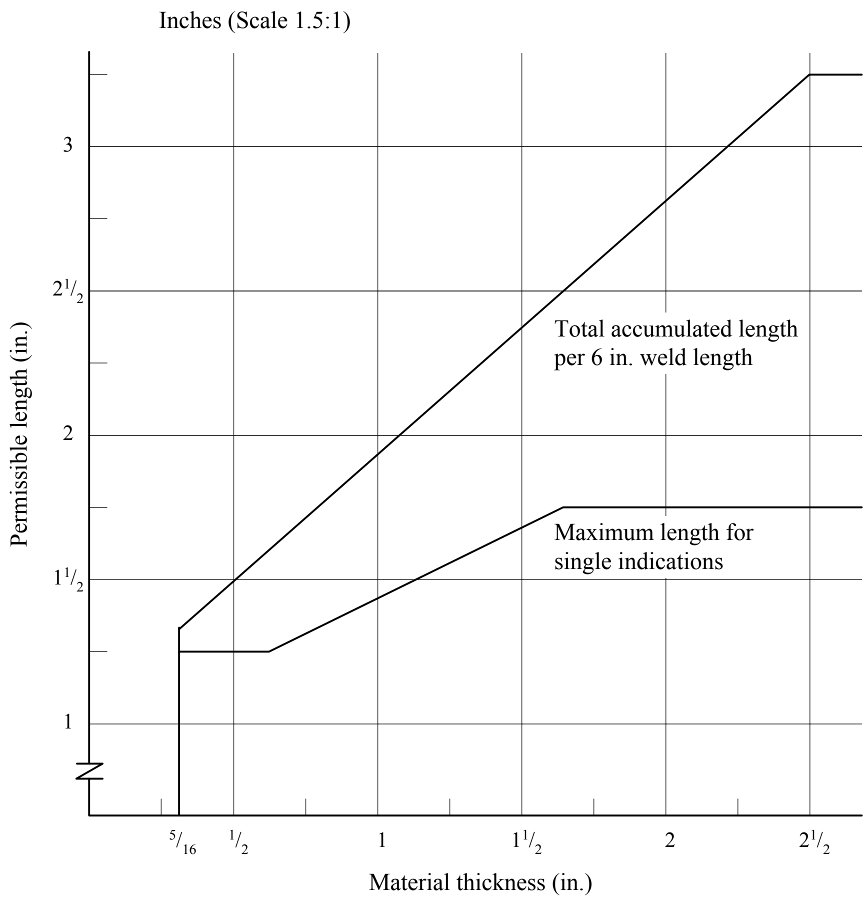


# FIGURE 6
## Class B – Maximum Acceptable Lengths for Ultrasonic Indications Greater than DRL



## FIGURE 6 (continued)
## Class B – Maximum Acceptable Lengths for Ultrasonic Indications Greater than DRL



# SECTION 4 Surface Inspection

## 1 Liquid Penetrant

### 1.1 General

The requirements contained herein are primarily intended for liquid penetrant surface inspection of welds in hull structures of surface vessels. These requirements are intended to apply to full and partial penetration welds of steel and aluminum alloys.

### 1.3 Surface Condition

#### 1.3.1 General

The inside and outside surfaces of the welds to be inspected by liquid penetrant are to be sufficiently free from irregularities that may mask or interfere with interpretation.

#### 1.3.2 Cause for Rejection

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

### 1.5 Liquid Penetrant Procedure

#### 1.5.1 General

A liquid penetrant, which may be a visible red liquid or a fluorescent yellow-green liquid, is applied evenly over the surface being examined and allowed to enter open discontinuities. After a suitable dwell time, the excess surface penetrant is removed. A developer is applied to draw the entrapped penetrant out of the discontinuity and stain the developer. The test surface is then examined to determine the presence or absence of indications.

#### 1.5.2 Personnel

It is incumbent upon the Surveyor to ensure that NDT personnel are qualified and certified by a combination of training and experience appropriate to the level of responsibility assigned.

#### 1.5.3 Technique

Steel and aluminium welds are to be inspected by either the visible or fluorescent solvent removable method.

Water-washable and post-emulsifiable penetrant methods are not recommended due to the strict requirements for water pressure and water temperature control.

#### 1.5.4 Procedure

Visible or fluorescent penetrant is to be applied to the inspection surface by spraying or brushing.

*1.5.4(a)* A minimum dwell time of 5 minutes is to be used. A longer dwell time is to be used for the detection of fine tight discontinuities.

*1.5.4(b)* At the completion of the applicable dwell time, removal of the excess surface penetrant is to be with lint-free material moistened with solvent remover.

*i)* Solvent remover is not to be sprayed directly onto the inspection surface.

*ii)* Sufficient time is to be allowed for the solvent to evaporate from the inspection surface.

*1.5.4(c)* A thin coating of non-aqueous developer is to be applied by spraying the inspection surface from a minimum distance of 300 mm (12 in.).

*i)* A minimum developing time of 10 minutes, or twice the dwell time, is to be used.

*ii)* Developing time is to commence as soon as the non-aqueous developer is dry.

*iii)* Developing time is not to exceed 60 minutes.

## 1.7 Examination

### 1.7.1 General

Preliminary examination of the inspection area may be carried out during the developing time. An indication that appears quickly would indicate a large discontinuity and, if not observed, may result in a diffused stain rather than a sharp indication after the full dwell time.

### 1.7.2 Final Examination

Final examination is to be made at the completion of the applicable developing time.

### 1.7.3 Personnel

Examination, interpretation and evaluation of indications are to be performed by certified Level 2 penetrant inspectors.

### 1.7.4 Visible Penetrant Examination

*1.7.4(a)* The visible penetrant is generally red in color and thus provides a high degree of contrast against the white developer.

*1.7.4(b)* A minimum light intensity of 1000 Lux (100 foot candles) at the inspection surface is to be obtained.

*i)* Either natural or artificial light is acceptable.

*ii)* Demonstration of the minimum light intensity is to be to the satisfaction of the attending surveyor.

*iii)* A calibrated photographic-type light meter is to be used to verify the required minimum intensity.

*iv)* Calibration of the light meter is to be performed and documented every 6 months.

*v)* The calibration standard is to be traceable to the National Institute of Standards & Testing (NIST).

*vi)* Other recognized standards may be acceptable subject to the satisfaction of the attending surveyor.

#### 1.7.5 Fluorescent Penetrant Examination

*1.7.5(a)* The penetrant will fluoresce when examined by ultraviolet (U/V) light. Fluorescent penetrant inspection will provide the highest sensitivity level. Inspection by U/V light requires a darkened area for examination.

*1.7.5(b)* Visible ambient light in the darkened inspection area is not to exceed 20 Lux (20 foot candles).

*i)* Before commencing inspection, a minimum period of 3 minutes is to be observed by the inspector to allow for the eyes to adapt to the lower light level.

*ii)* Photochromic lenses are not to be worn by the inspector during the inspection.

*1.7.5(c)* The U/V light is to be capable of providing a minimum intensity of 1000 $\mu W/cm^2$ at the inspection surface.

*1.7.5(d)* The U/V light is to have a minimum of 10 minutes to stabilize before inspection or measurement of the required minimum U/V light intensity.

*i)* The intensity of the U/V light is to be verified weekly.

*ii)* Demonstration of the minimum U/V light intensity is to be to the satisfaction of the attending surveyor.

*iii)* A calibrated U/V light meter is to be used to verify the required minimum intensity.

*iv)* Calibration of the U/V light meter is to be performed and documented every 6 months.

*v)* The calibration standard is to be traceable to the National Institute of Standards & Testing (NIST).

*vi)* Other recognized standards may be acceptable subject to the satisfaction of the attending surveyor.

### 1.9 Interpretation

#### 1.9.1 Shape

Indications are to be classified as either linear or rounded.

#### 1.9.2 Linear Indications

Linear indications are classified as having a length greater than 3 times (3x) the width.

#### 1.9.3 Rounded Indications

Rounded indications are classified as having a circular or elliptical shape and the length of the ellipse is equal to or less than 3 times (3x) the width.

### 1.11 Evaluation

Evaluation is to be made in accordance with the following acceptance criteria.

#### 1.11.1 Cracks

Welds are to be free of any type of crack.

#### 1.11.2 Incomplete Fusion

Welds are to be free of any lack of fusion between weld metal and base metal.

### 1.11.3 Porosity

Complete joint penetration (CJP) groove welds in butt joints transverse to the members subject to tensile stress are not to have visible piping porosity.

*1.11.3(a)* For all other groove welds and for fillet welds, the sum of the visible piping porosity 1 mm (0.04 in.) or greater in diameter is not to exceed 10 mm (0.375 ($^3/_8$) in.) in any linear 25 mm (1 in.) of weld and is not to exceed 19 mm (0.75 ($^3/_4$) in.) in any 300 mm (12 in.) length of weld.

*1.11.3(b)* The frequency of piping porosity in fillet welds is not to exceed one in each 100 mm (4 in.) of weld length and a maximum diameter shall not exceed 2.5 mm (0.1 in.). For fillet welds connecting stiffeners to web, the sum of the diameters of piping porosity is not to exceed 10 mm (0.375 ($^3/_8$) in.) in any linear 25 mm (1 in.) of weld and is not to exceed 19 mm (0.75 ($^3/_4$) in.) in any 300 mm (12 in.) length of weld.

*1.11.3(c)* Complete joint penetration groove welds in butt joints transverse to the members subject to tensile stress are not to have piping porosity. For all other groove welds, the frequency of piping porosity is not to exceed 100 mm (4 in.) of length and the maximum diameter is not to exceed 2.5 mm (0.1 in.)

### 1.11.4 Undercut

Undercut refers to a groove melted in the base metal adjacent to a weld toe at the face or root of the weld.

*1.11.4(a)* For material with a thickness less than 25 mm (1 in.), undercut is not to be greater than the following:

*i)* any individual length greater than 50 mm (2 in.) with a depth greater than 0.8 mm (0.03125 ($^1/_{32}$) in.)

*ii)* any accumulative length in any 300 mm (12 in.) of weld is not to exceed 50 mm (2 in.) with a depth greater than 0.8 mm (0.03125 ($^1/_{32}$) in.). Assessment of depth is to be done by visual and mechanical means. Assessment of depth using liquid penetrant is not acceptable.

*1.11.4(b)* For material with a thickness equal to or greater than 25 mm (1 in.), undercut is not to be greater than the following:

*i)* any individual length greater than 50 mm (2 in.) with a depth greater than 1.6 mm (0.0625 ($^1/_{16}$) in.)

*ii)* any accumulative length in any 300 mm (12 in.) of weld is not to exceed 50 mm (2 in.) with a depth greater than 1.6 mm (0.0625 ($^1/_{16}$) in.). Assessment of depth is to be done by visual and mechanical means. Assessment of depth using liquid penetrant is not acceptable.

*1.11.4(c)* In primary members, the depth of undercut is not to be more than 0.25 mm (0.01 in.) deep when the weld is transverse to tensile stress under any design loading condition. For all other cases, depth of undercut is not to be more than 1 mm (0.04 in.).

## 1.11 Treatment of Welds with Non-conforming Indications

### 1.11.1 General

Weld exhibiting non-conforming indications are to be brought to the attention of the attending Surveyor. Such welds are to be repaired and inspected as required by the Surveyor.

### 1.13 Post-Cleaning

#### 1.13.1

Removal of penetrant and developer shall be by non-aqueous solvent.

*1.13.1(a)* It is permissible to spray the non-aqueous solvent directly onto the inspection area at this stage.

*1.13.1(b)* Mechanical/abrasive methods are not to be used.

### 1.15 References:

American Welding Society, D1.1/D1.1M:2002, *Structural Welding Code, Steel*.

ASTM E165-95, *Standard Test Method for Liquid Penetrant Examination*.

## 3 Magnetic Particle

### 3.1 General

The requirements contained herein are primarily intended for magnetic particle surface inspection of welds in hull structures of surface vessels. These requirements are intended to apply to full and partial penetration welds of ferromagnetic steel.

### 3.3 Surface Condition

#### 3.3.1 General

The inside and outside surfaces of the welds to be inspected by magnetic particle are to be sufficiently free from irregularities that may mask or interfere with interpretation.

#### 3.3.2 Cause for Rejection

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

### 3.5 Magnetic Particle Procedure

#### 3.5.1 General

When a ferromagnetic material is magnetized, surface-breaking discontinuities will cause the induced magnetic flux to attract fine magnetic particles to the discontinuity site. When viewed under adequate lighting, the accumulated particles will present a visual indication of the length and width of the discontinuity.

#### 3.5.2 Personnel

It is incumbent upon the Surveyor to ensure that NDT personnel are qualified and certified by a combination of training and experience appropriate to the level of responsibility assigned.

#### 3.5.3 Technique

Steel welds are to be inspected by either the visible or fluorescent particle method.

*3.5.3(a)* The visible method may be performed with either wet or dry particles.

*3.5.3(b)* If a surface-breaking discontinuity is oriented parallel to the magnetic flux, it will not provide an indication. The sharpest indication will be obtained when the magnetic flux is perpendicular to the discontinuity.

*i)* The area of interest is to be inspected in at least two (2) directions.

*ii)* Each direction is to be perpendicular to the other.

### 3.5.4 Equipment

*3.5.4(a) General.* The equipment used to generate magnetic flux for in-situ inspection in the marine environment may be either an electromagnetic yoke or permanent magnets. Both devices provide portability and simplicity of use.

*3.5.4(b) Yoke.* A yoke is a hand-held U-shaped electromagnet, which produces a longitudinal magnetic flux between the legs. The legs may be fixed or articulated.

*3.5.4(c) Permanent Magnet.* A permanent magnet may be U-shaped, with a fixed distance between the legs. A variation is that a permanent magnet may consist of two (2) magnets connected by flexible steel cable.

*3.5.4(d) Magnetic Field Strength*

*i)* When using an electromagnetic yoke or permanent magnet, adequate field strength is to be considered acceptable by lifting a calibrated test bar.

*ii)* The weight of the test bar is to be:

- 5 kgs (10 lbs.) for an A.C. yoke
- 18 kgs (40 lbs.) for a D.C. yoke
- 18 kgs (40 lbs.) for a permanent magnet

*iii)* The calibration weight of the test bar is to be traceable to the National Institute of Standard and Testing (NIST). Other recognized standards may be acceptable subject to the satisfaction of the attending Surveyor. The test bar is to be permanently marked with a unique serial number and actual weight.

*iv)* Additional verification of the magnetic field strength is to be demonstrated by the detection of known artificial discontinuities in a magnetic field indicator.

- The "pie" gauge and slotted shim are acceptable examples of a magnetic field indicator.
- Magnetic field strength is to be considered acceptable when the artificial discontinuities are clearly observed between the legs of the electromagnetic yoke or permanent magnet.
- Both the lift test and artificial discontinuities test are to be performed at the beginning and completion of each inspection day.

*3.5.4(e) Visible Magnetic Particles.* Visible magnetic particle inspection may be performed with dry powders or wet contrasting inks.

*i)* Dry powders are to be applied by gently dusting the inspection area while the magnetizing flux is generated.

*ii)* Examination of the inspection area is to be performed as the magnetic flux is still being generated.

*iii)* The contrasting ink technique consists of a white lacquer under suspension, and is to be applied by spraying. The magnetic particles are suspended in black ink and are also to be applied by spraying.

- The white lacquer and black ink are to be applied by spraying the inspection surface from a minimum distance of 300 mm (12 in.).

- The black ink is only to be applied when the white lacquer is fully dry.

*3.5.4(f) Fluorescent Magnetic Particles.* Magnetic particles are coated with a fluorescent material suspended in a light petroleum distillate and held under pressure in small spray cans. The fluorescent particles are to be applied by spraying the inspection surface from a minimum distance of 300 mm (12 in.).

*3.5.4(g) Examination.* Examination of the inspection area is to be performed as the magnetic flux is being generated. Examination, interpretation and evaluation of indications are to be performed by qualified and certified Level 2 magnetic particle inspectors.

### 3.5.5 Visible Particle Inspection

*3.5.5(a)* Colored dry powder particles provide contrast with the inspection surface. A higher level of contrast is obtained with the use of the white and black ink particles.

*3.5.5(b)* A minimum light intensity of 1000 Lux (100 foot candles) at the inspection surface is to be obtained.

*i)* Either natural or artificial light is acceptable.

*ii)* Demonstration of the minimum light intensity is to be to the satisfaction of the attending Surveyor.

*iii)* A calibrated photographic-type light meter is to be used to verify the required minimum intensity.

*iv)* Calibration of the light meter is to be performed and documented every 6 months.

*v)* The calibration standard is to be traceable to the National Institute of Standards and Testing (NIST).

*vi)* Other recognized standards may be acceptable subject to the satisfaction of the attending Surveyor.

### 3.5.6 Fluorescent Particle Inspection

*3.5.6(a)* The fluorescent particles will fluoresce when examined by ultraviolet (U/V) light and will provide the highest level of sensitivity. Inspection by U/V light requires a darkened area for examination.

*3.5.6(b)* Visible ambient light in the darkened inspection area is not to exceed 20 Lux (20 foot candles).

*i)* Before commencing inspection, a minimum period of 3 minutes is to be observed by the inspector to allow for the eyes to adapt to the lower light level.

*ii)* Photochromic lenses are not to be worn by the inspector during the inspection.

*3.5.6(c)* The U/V light is to be capable of providing a minimum intensity of 1000 $\mu W/cm^2$ at the inspection surface.

*3.5.6(d)* The U/V light is to have a minimum of 10 minutes to stabilize before inspection or measurement of the required minimum U/V light intensity.

*i)* The intensity of the U/V light is to be verified weekly.

*ii)* Demonstration of the minimum U/V light intensity is to be to the satisfaction of the attending Surveyor.

*iii)* A calibrated ultraviolet light meter is to be used to verify the required minimum intensity.

*iv)* Calibration of the U/V light meter is to be performed and documented every 6 months.

*v)* The calibration standard is to be traceable to the National Institute of Standards and Testing (NIST).

*vi)* Other recognized standards may be acceptable subject to the satisfaction of the attending Surveyor.

## 3.7 Interpretation

### 3.7.1 Shape

Indications are to be classified as either linear or rounded.

### 3.7.2 Linear Indications

Linear indications are classified as having a length greater than 3 times (3x) the width.

### 3.7.3 Rounded Indications

Rounded indications are classified as having a circular or elliptical shape and the length of the ellipse is equal to or less than 3 times (3x) the width.

### 3.7.4 Interpretation of Indications

*3.7.4(a) Valid Indications.* All valid indications formed by magnetic particle examination are the result of magnetic leakage fields. Indications may be relevant, non-relevant, or false.

*3.7.4(b) Relevant Indications.* Relevant indications are produced by leakage fields which are the result of discontinuities. Relevant indications require evaluation with regard to the acceptance standards stated in 4/3.9.

*3.7.4(c) Non-relevant Indications.* Non-relevant indications can occur singly or in patterns as a result of leakage fields created by conditions that require no evaluation, such as changes in section (like keyways and drilled holes), inherent material properties (like the edge of a bimetallic weld), magnetic writing, etc.

*3.7.4(d) False Indications.* False indications are not the result of magnetic forces. Examples are particles held mechanically or by gravity in shallow depressions, or particles held by rust or scale on the surface.

## 3.9 Evaluation

Evaluation of welds is to be made in accordance with the following criteria.

### 3.9.1 Cracks

Welds are to be free of any type of crack.

### 3.9.2 Incomplete Fusion

Welds are to be free of any lack of fusion between weld metal and base metal.

### 3.9.3 Porosity

Complete joint penetration groove welds in butt joints transverse to the members subject to tensile stress are not to have visible piping porosity.

*3.9.3(a)* For all other groove welds and for fillet welds, the sum of the visible piping porosity 1 mm (0.04 in.) or greater in diameter is not to exceed 10 mm (0.375 ($^3/_8$) in.) in any linear 25 mm (1 in.) of weld and is not to exceed 19 mm (0.75 ($^3/_4$) in.) in any 300 mm (12 in.) length of weld.

*3.9.3(b)* The frequency of piping porosity in fillet welds is not to exceed one in each 100 mm (4 in.) of weld length and a maximum diameter of piping porosity is not to exceed

2.5 mm (0.1 in.). For fillet welds connecting stiffeners to web, the sum of the diameters of piping porosity is not to exceed 10 mm (0.375 ($^3/_8$) in.) in any linear 25 mm (1 in.) of weld and is not to exceed 19 mm (0.75 ($^3/_4$) in.) in any 300 mm (12 in.) length of weld.

*3.9.3(c)* Complete joint penetration groove welds in butt joints transverse to the members subject to tensile stress are not to have piping porosity. For all other groove welds, the frequency of piping porosity is not to exceed 100 mm (4 in.) of length and the maximum diameter is not to exceed 2.5 mm (0.1 in.).

#### 3.9.4 Undercut

Undercut refers to a groove melted in the base metal adjacent to a weld toe at the face or root of the weld.

*3.9.4(a)* For material with a thickness less than 25 mm (1 in.), undercut is not to be greater than the following:

*i)* any individual length greater than 50 mm (2 in.) with a depth greater than 0.8 mm (0.03125 ($^1/_{32}$) in.)

*ii)* any accumulative length in any 300 mm (12 in.) of weld greater than 50 mm (2 in.) with a depth greater than 0.8 mm (0.03125 ($^1/_{32}$) in.). Assessment of depth is to be done by visual and mechanical means. Assessment of depth using magnetic particle is not acceptable.

*3.9.4(b)* For material with a thickness equal to or greater than 25 mm (1 in.), undercut is not to be greater than the following:

*i)* any individual length greater than 50 mm (2 in.) with a depth greater than 1.6 mm (0.0625 ($^1/_{16}$) in.)

*ii)* any accumulative length in any 300 mm (12 in.) of weld greater than 50 mm (2 in.) with a depth greater than 1.6 mm (0.0625 ($^1/_{16}$) in.). Assessment of depth is to be done by visual and mechanical means. Assessment of depth using magnetic particle is not acceptable.

*3.9.4(c)* In primary members, the depth of undercut is not to be greater than 0.25 mm (0.01 in.) when the weld is transverse to tensile stress under any design loading condition. For all other cases, depth of undercut is not to be greater than 1 mm (0.04 in.).

### 3.11 Treatment of Welds with Non-conforming Indications

#### 3.11.1 General

Welds exhibiting non-conforming indications are to be brought to the attention of the attending Surveyor. Such welds are to be repaired and inspected as required by the Surveyor.

### 3.13 Demagnetization

#### 3.13.1

Demagnetization is to be required if any of the following operations are to be performed in the inspection area:

welding

painting

plating

*3.13.1(a)* Demagnetization is to be required if the inspection area is in close proximity to sensitive electronic instrumentation or a compass.

*3.13.1(b)* Demagnetization is to be performed by a sufficient number of passes over the inspection area by an energized electromagnetic yoke.

3.13.2

After demagnetization, any remaining residual magnetism is not to exceed 3 Gauss (240 $Am^{-1}$). Verification of the level of residual magnetism is to be performed with a calibrated residual field meter.

### 3.15 Post-cleaning

3.15.1

Post-cleaning of the inspection area is to be required if any of the following operations are to be performed:

welding

painting

plating

Post-cleaning is to be completed with the use of compressed air, brushing, or solvent cleaning.

### 3.17 References

American Welding Society, D1.1/D1.1M:2002, *Structural Welding Code, Steel*.

ASTM E709-95, *Standard Guide for Magnetic Particle Examination*.

## 5 Alternating Current Field Measurement (ACFM)

### 5.1 General

The requirements contained herein are primarily intended for the surface inspection of hull structures of surface vessels and, when indicated by the Bureau, may also be applied to other marine structures. These requirements are intended to apply to the welds of steel and aluminum alloys.

### 5.3 Surface Condition

The system operator is to confirm that the surface condition is acceptable prior to carrying out the inspection.

5.3.1

The surface is to be free of loose flaking corrosion and in clean condition to allow smooth probe travel.

5.3.2

Coating removal is not required as long as it is not more than 6.5 mm (0.25 ($^1/_4$) in.) thick and non-conducting.

5.3.3

The surface being inspected is to be in an unmagnetized state. If the procedure is to be conducted after any previous magnetic inspection technique, demagnetization of the surface is to be carried out.

## 5.5 ACFM Testing Procedure

### 5.5.1 Personnel

It is incumbent upon the Surveyor to ensure that NDT personnel are qualified and certified by a combination of training and experience appropriate to the level of responsibility assigned.

## 5.7 Technique

### 5.7.1 General

The capability of equipment calibrated to detect discontinuities pertinent to the item under inspection is to be demonstrated to the satisfaction of the Surveyor, preferably using samples containing known discontinuities.

### 5.7.2 Calibration

*5.7.2(a)* The equipment and probes to be used are to be calibrated prior to the examination of the first weld using samples containing known discontinuities.

*3.7.2(b)* Each combination of ACFM unit and probe to be used during the examination is to be used with the operations check block.

*5.7.2(c)* Results obtained with the combinations used are to be the same as the slots in the block. If they differ by 10%, a check is to be performed to ensure that the correct probe files and gain have been used. Recalibration is to be performed until the correct results are obtained.

*5.7.2(d)* System performance is to be verified every four hours with the probe in use or at the end of the examination being performed.

*5.7.2(e)* If the flaw responses from the operations check block have changed substantially, the welds examined since the last operations check block verification are to be re-examined.

*5.7.2(f)* The ACFM equipment is to be re-calibrated every 12 months by the manufacturer.

## 5.9 Capability and Performance Check of the Equipment

### 5.9.1 Instrument Settings

The procedure in 4/5.9.2 is intended to help the user select an operating frequency. Demonstrably equivalent methods may be used. The standard operating frequency is 5 kHz, but depending on the type of equipment being used, higher or lower operating frequencies are available. A higher operating frequency will give better sensitivity on good surfaces, while a lower operating frequency may allow detection of sub-surface defects in non-magnetic metals. If the system available for inspection is not capable of operating at the frequency described by this practice, the inspector is to declare to the attending Surveyor that conditions of reduced sensitivity may exist.

### 5.9.2 Equipment Performance Check

The test system is to consist of an ACFM crack microgauge, a PC, the probe and the operation check block.

*5.9.2(a)* The equipment performance check is to be performed using the appropriate operation check block containing slots of 50 mm × 5 mm (2.0 in. × 0.2 in.) and 20 mm × 2 mm (0.8 in. × 0.08 in.).

*5.9.2(b)* The probe is to be placed at the toe of the weld with the nose of the probe parallel to the longitudinal direction of the weld.

*5.9.2(c)* The probe is then to be scanned across the operation check block and over the 50 mm × 5 mm (2.0 in. × 0.2 in) slot, producing a standardized data plot.

*5.9.2(d)* Flaw indications are created when:

- the background level $B_x$ value is reduced and then returns to the nominal background level (Figure 1), and this is associated with
- a peak or positive (+ve) indication, followed by a trough or negative (-ve) indication (or a trough followed by a peak, depending on direction of scan) in the $B_z$ values.

*5.9.2(e)* The resultant effect of the changes in $B_x$ and $B_z$ is a downward loop in the X-Y plot (Figure 1).

*5.9.2(f)* The presence of a flaw is confirmed when all three of these indications are present, i.e., the $B_x$, the $B_z$ and a downward loop in the X-Y plot. The loop is to fill approximately 50% of the height and 175% of the width of the X-Y plot.

*5.9.2(g)* The scanning speed or data sampling rate can then be adjusted if necessary, depending on the length and complexity of weld to be examined.

*5.9.2(h)* Once the presence of the flaw has been confirmed by the $B_x$ and $B_z$ indications, the flaw is to be sized.

5.9.3

Flaw sizing is based upon the use of mathematical models constructed to simulate the current flow around defects and the changes in surface magnetic field which would result. The model is run for a large number of discrete defects with various lengths and depths, and the results of the model are used to compile look-up tables of expected response versus defect sized. These tables are an integral part of the inspection software. The operator enters background and minimum values of $B_x$, along with the $B_x$ length and any coating thickness, to allow the software to predict length and depth.

The results from the model are to be rigorously checked against a library of real defects to confirm the validity of the sizing tables.

5.9.4

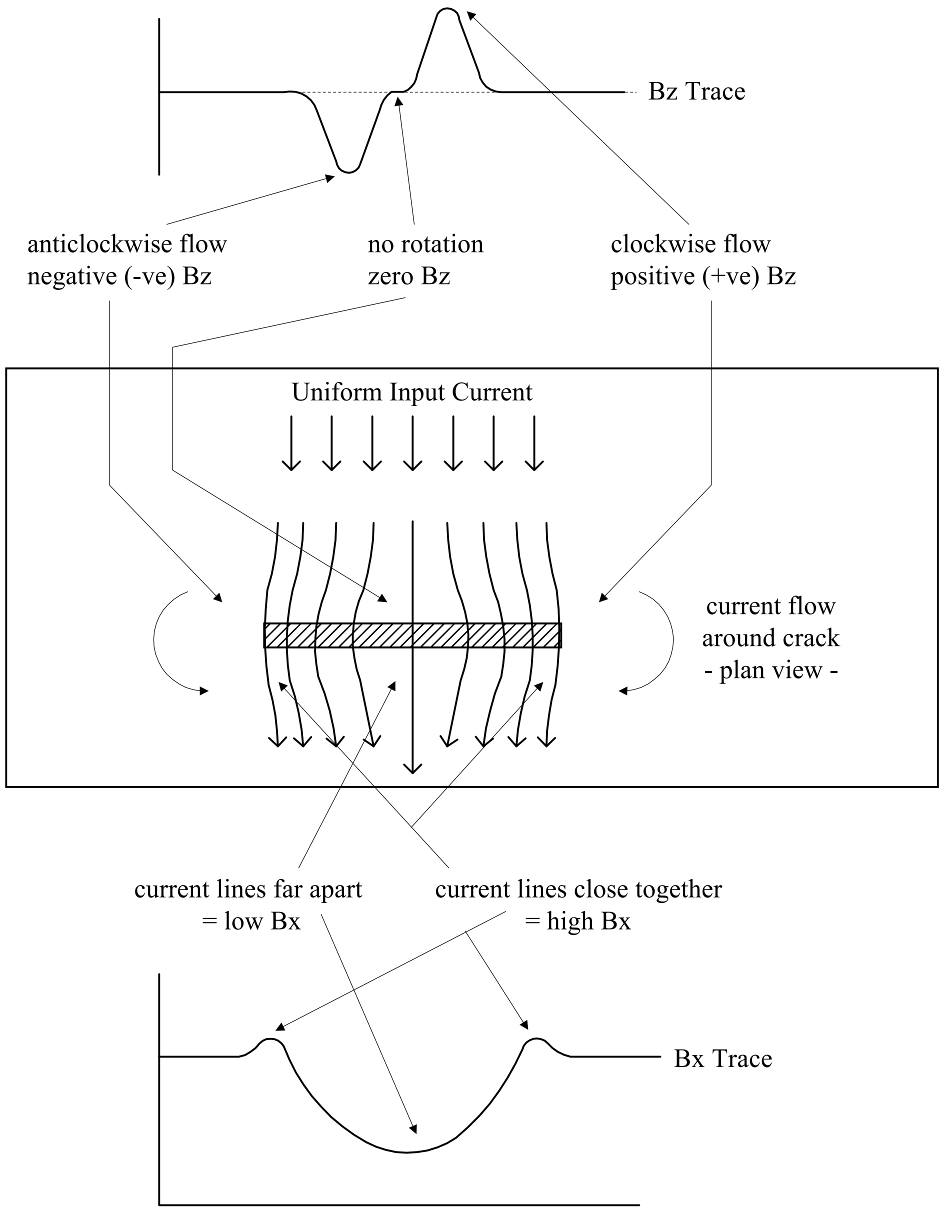
If these values differ from those expected from the operation check block, then the instrument and probe settings are to be checked.

Each probe has a unique probe file, the validity of which has been checked against the flaw sizing tables in the mathematical model. The instrument settings can be checked using the same software package.

## 5.11 Extent of ACFM Inspection

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

## FIGURE 1




# 7 Eddy Current (EC) Inspection

## 7.1 General

The requirements contained herein are primarily intended for the surface inspection of hull structures of surface vessels and, when indicated by the Bureau, may also be applied to other marine structures. These requirements are intended to apply to the welds of steel and aluminum alloys.

## 7.3 Surface Condition

The system operator is to confirm that the surface condition is acceptable prior to carrying out the inspection.

7.3.1

The inspection surface is to be free of dirt, flaking paint, excessive corrosion, or any contaminants which may interfere with the test results.

7.3.2

Coating removal is not required providing that it can be demonstrated that the discontinuities sought can be detected under these conditions. This may involve coating the reference specimen with a similar coating during calibration.

## 7.5 EC Testing Procedure

### 7.5.1 Personnel

It is incumbent upon the Surveyor to ensure that NDT personnel are qualified and certified by a combination of training and experience appropriate to the level of responsibility assigned.

## 7.7 Technique

### 7.7.1 General

The capability of equipment calibrated to detect discontinuities pertinent to the item under inspection is to be demonstrated to the satisfaction of the Surveyor, preferably using samples containing known discontinuities.

### 7.7.2 Calibration

EC Probes (Transducers) of sufficient diameter and frequency range are to be used.

*7.7.2(a)* A diameter of EC Probes less than 3.2 mm (0.125 ($^1/_8$) in.) and a frequency range between 100 kHz – 2 MHz are acceptable for surface crack detection.

*7.7.2(b)* The area of influence for each scan will be restricted to an area of less than 3.2 mm (0.125 ($^1/_8$) in.) width. Therefore, many scans in a raster scan pattern are to be required to ensure full coverage.

*7.7.2(c)* The equipment and probes to be used are to be calibrated prior to the examination of the first weld using samples containing known discontinuities.

*7.7.2(d)* System performance is to be verified every 30 minutes with the probe in use and at the end of the examination being performed.

*7.7.2(e)* If the system performance calibration has changed, the welds examined since calibration are to be re-examined.

*7.7.2(f)* The EC equipment is to be re-calibrated every 12 months by the manufacturer.

## 7.9 EC Application

7.9.1

A high frequency oscillator circuit produces alternating current in the range typically of 100Hz – 10 MHz and is applied to a small coil. The alternating current flowing through the coil generates an alternating magnetic field around the coil.

7.9.2

When the alternating magnetic field is in close proximity to an electrically conductive material (the test item) a secondary electrical current will be created in the test item due to electromagnetic induction. The distribution of the current will be determined by the test settings and material properties. The secondary electrical current will generate its own magnetic field which will interact with the magnetic field of the coil and modify it. The shape and magnitude of the secondary field will be determined by the secondary current induced into the specimen.

7.9.3

The secondary magnetic field will also modify the primary current flowing through the coil by changing the impedance of the coil. The change in impedance can be detected using sensitive bridge circuitry within the eddy current set. When the test settings are maintained constant during the test, the only changes in the impedance of the coil will be due to changing material properties.

7.9.4

If reference specimens are available with varying degrees of the anomaly present the EC instrument can be calibrated to detect and quantify the condition of the inspection material.

## 7.11 Extent of EC Inspection

The extent of EC inspection is to be in accordance with the approval plans, applicable Bureau Rules and to the satisfaction of the attending Surveyor.

## 7.13 References

ASTM E 376, *Standard Practice for Measuring Coating Thickness by Magnetic field or Eddy Current (Electromagnetic) test methods*.

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# APPENDIX 1 Guidance for Radiographic (RT) and Ultrasonic (UT) Inspection of Hull Welds

## 1 Purpose of ABS *Guide for Nondestructive Inspection of Hull Welds*

The purpose of the ABS *Guide for Nondestructive Inspection of Hull Welds* (*NDT Guide*) is to provide means to ascertain that the internal soundness of full penetration butt welds in ship hull and other marine structures are of generally satisfactory quality. For other weld joints, see Appendix 2, "Guidance for Ultrasonic Inspection of Full Penetration Tee and Corner Welds."

The use of RT or UT in accordance with this Guide provides a measure of general shipyard quality control. Acceptance levels for allowable sizes of discontinuities specified in the *NDT Guide* are not based on fracture mechanics analyses since the variety and the complexity of factors involved could make such analyses of questionable validity. The acceptance/rejection levels of this Guide are based on experience and indicate the level of quality that should be reasonably expected with normal shipyard procedures and practices. The reject level at an isolated location does not necessarily indicate that the discontinuity represents a threat to the safety of the vessel. An abnormally high reject rate indicates that the fabrication and welding are not being adequately controlled, and may in some instances necessitate rejecting and repairing entire weldments. When relatively high levels of reject rate are being experienced, it is important to take immediate corrective action(s) to avoid the introduction of extensive areas of questionable weld quality. Corrective actions to improve the quality of welding may consist of re-examinations and/or requalifications of weld procedures and welder or in extreme cases, curtailment of welding until the causes producing the unsatisfactory level of overall weld quality are found and eliminated. Isolated rejectable indications within a vessel whose general weld quality is satisfactory are to be treated individually in accordance with Subsections 2/15 and 3/13 of the *NDT Guide*.

## 3 Choice of Nondestructive Testing (NDT) Method

The *NDT Guide* covers the use of RT and UT. However, the interpretation of indications using either of these methods is to be conducted in conjunction with visual examination of the corresponding welds. For example, a surface condition such as undercut may give an indication with both RT and UT, and therefore, might be misinterpreted as a rejectable internal indication based on length on a radiograph or on percentage of screen height on a cathode ray tube (CRT). With a visual examination, the indication caused by the undercut can be taken into account in interpretation of the indications obtained from RT or UT. An actual depth measurement of the undercut might change the acceptance/rejection status of the condition, depending on the code or other criteria used. The undercut, however, should be dealt with to the satisfaction of the Surveyor. For this and other reasons, a visual examination is essential prior to using NDT methods for detection of internal discontinuities. In addition, the person doing the interpretation, as well as all interested parties, should be thoroughly knowledgeable with the welding process and the joint design of the weld being evaluated.

RT and UT are used for detection of internal discontinuities, and in essence, they supplement each other. Each method is suited for the detection of particular types and orientations of discontinuities.

RT is generally most effective in detecting non-planar (three-dimensional) discontinuities, such as porosity and slag, and is less effective for detecting planar (two-dimensional) discontinuities, such as laminations or cracks.

UT, on the other hand, is generally most effective for detecting planar discontinuities and is less effective for detecting non-planar discontinuities.

Either RT or UT can be chosen as the primary method of inspection. However, if a yard desires to use UT as the primary method, such testing is to be supplemented initially and by periodical checks with a reasonable amount of radiographic inspection to determine that adequate quality control is achieved as in Subsection 3/3 of the *NDT Guide*. Although one method may not be directly relatable to the other, either one would indicate conditions of inadequate control of the welding process. Since either method is acceptable as an inspection method, the choice might be influenced the following considerations:

Need for permanent record (not generally provided by UT)

The type and orientation of discontinuities of concern

Equipment availability and cost

Yard experience with a particular method

Accessibility for inspection (i.e. UT generally requires access to only one surface, whereas RT requires two)

Personnel safety

Portability

The Surveyor, at his discretion, may require a specific NDT method where he believes the method selected by the shipyard (UT or RT) is not appropriate for types and orientation of discontinuities of concern.

RT and UT methods are supplementary to each other in that each has different discontinuity detection characteristics and capabilities, and therefore, each has its corresponding criteria which must be used accordingly. Because of distinct differences in characteristics between the two methods, it is not reasonable to expect that a weld examined and found acceptable by one method will always be acceptable by the other method. Therefore, the results obtained with the particular method originally selected as the basis for approval governs unless gross defects considered detrimental to the integrity of the structure are discovered when using the other method. It should be emphasized that the primary purpose of the Rules requiring NDT of hull structural welds is to provide means to verify that butt welds are of generally satisfactory quality.

# 5 Extent and Location of RT or UT

For surface vessels, details of extent and location of inspection are included in the *NDT Guide*. For other structures, such as Mobile or Fixed Offshore Structures, see the welding section of the appropriate Rules.

Because the specified extent of inspection represents only a small percentage of total weld length, the results of the inspection only provide a general indication of the weld quality level, and it is generally reasonable to assume that the uninspected areas will have roughly the same proportion of unacceptable levels of indications as is found in the inspected locations. Indications beyond acceptable levels reflect a level of workmanship lower than the expected quality, and do not indicate a relationship to structural integrity, in that, for the reason previously noted, the allowable discontinuity sizes were not determined by fracture mechanic analysis. The following considerations should also be taken into account:

*i)* Important welds in special application and other important structure which are inaccessible or very difficult to inspect in service are to be subjected to an increased level of nondestructive inspection during construction. This provision may be relaxed for automated welds for which quality assurance techniques indicate consistent satisfactory quality.

*ii)* Field erected welds are to be subjected to an increased level of nondestructive inspection.

*iii)* As indicated in 3-2-7/5 of the *Mobile Offshore Drilling Unit Rules*, welds which impose high residual stresses perpendicular to the member thickness ("Z-direction loading") should be ultrasonically inspected to an extent that will provide the Surveyor assurance of freedom from lamellar tearing after welding.

*iv)* Extent of inspection is at the discretion of the Surveyor depending on the type of structure, the material and welding procedures involved and the quality control procedures employed.

*v)* If the proportion of unacceptable weld quality becomes abnormally high, the frequency of inspection is to be increased.

*vi)* ABS does recognize and take into account Owner and designer specifications which are in excess of ABS requirements and may require 100% inspection of certain connections. When such additional inspection is conducted by RT or UT, unless approved otherwise, the following is applicable:

- *Full Penetration Butt Welds.* For locations where inspection is specified on the approval plan or required by the Surveyor, the acceptance standards of the *NDT Guide* appropriate to the structure involved are applicable. For other locations where inspection was not required by ABS, the guidance of Appendix 4 is applicable.

- *Full Penetration Tee or Corner Welds.* The guidance of Appendix 2 is applicable.

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# APPENDIX 2 Guidance for Ultrasonic Inspection of Full Penetration Tee and Corner Welds

## 1 Ultrasonic Inspection of Full Penetration Tee and Corner Welds

ABS *Guide for Nondestructive Inspection of Hull Welds* contain requirements for ultrasonic inspection of full penetration butt welds for ships and other marine structures. Some approved plans for offshore mobile and fixed structures may specially require ultrasonic inspection in way of critical full penetration tee and corner connections to verify weld soundness. In other cases, ultrasonic inspection of these connections may be required in the course of a periodic or damage survey. This Appendix is intended to provide guidance for such inspections.

### 1.1 General

Except for scanning methods and acceptance standards, the provisions of the ABS *NDT Guide* relative to ultrasonic inspection are applicable.

### 1.3 Inspection of Plate Prior to Welding

It is advisable to inspect plates in way of full penetration tee and corner welds prior to welding to avoid plate discontinuities in the joint area, which could interfere with the final ultrasonic inspection. Such plate discontinuities found during this examination should be recorded and evaluated on a case-by-case basis.

### 1.5 Ultrasonic Testing Procedure After Welding

The inspection procedure for verification of weld soundness is to be as follows:

*i)* Shear wave technique is to be employed.

*ii)* Surfaces A and B are to be scanned as indicated in Appendix 2, Figure 1 to an extent which would provide the inspection of the complete weld area.

*iii)* At the discretion of the Surveyor, surface C or corner welds may be required to be scanned as indicated in Appendix 2, Figure 1 to an extent which would provide detection of lamellar tearing.

### 1.7 Plate Discontinuities Detected After Welding

In the course of weld inspection, indications may be obtained from plate discontinuities either pre-existing or developed as a result of welding. In some cases, the latter may be lamellar tearing caused by high residual weld stresses. Indications which are attributable to discontinuities in plates in way of the weld may be considered acceptable if they are in accordance with the Class B standards of the *NDT Guide*. Pre-existing indications observed in welded plate should be disregarded where there is no indication of propagation. Consideration as to the need, if any, for corrective measures should be based on the acceptability of the indications obtained, the functional requirements of the joint, as well as the practical level of workmanship quality which can be obtained.

### 1.9 Acceptance Criteria

The Class A acceptance standard specified in the *NDT Guide* is to apply, except for the root area of those welds for which design drawings provide less than full penetration welds. Indications of lamellar tearing beyond that permitted in A2/1.7 above are to be treated on a case-by-case basis, taking into account the applications and circumstances involved.

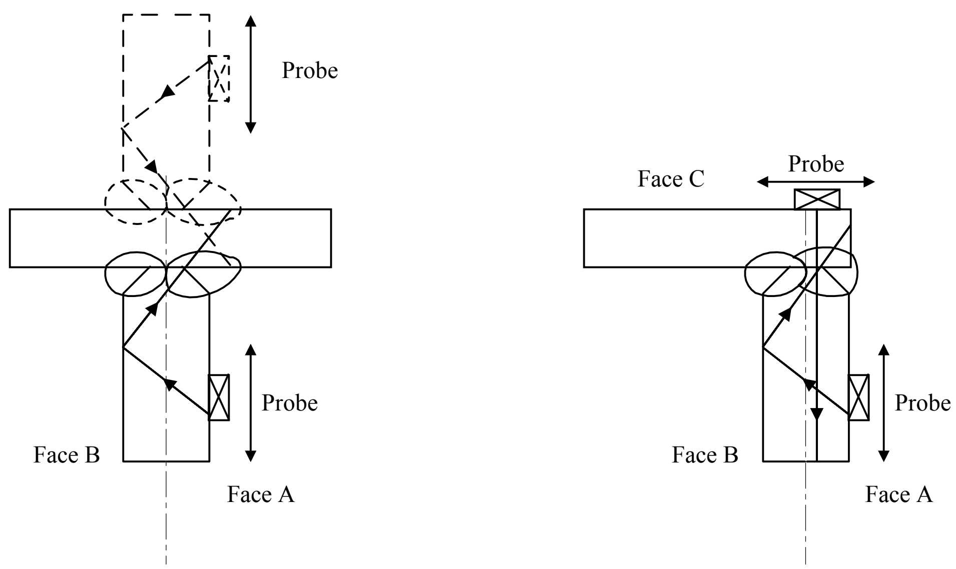
### 1.11 Alternate Acceptance Criteria

Acceptance criteria submitted by the fabricator which are satisfactory to the designer/Owner may also be applied.

### 1.13 Applicability of Acceptance Criteria

The acceptance criteria of A2/1.9 or A2/1.11 above are only applicable to the specific locations indicated in the approved plans or as required by the Surveyor. Acceptance criteria for locations other than those required by ABS are considered as agreed upon between fabricator and Owner.

## FIGURE 1
## Ultrasonic Inspection of Tee and Corner Welds



# APPENDIX 3 Guidance for Monitoring Underwater Inspections

## 1 General (See Appendix 3, Figures 1 and 2)

This Appendix is intended for guidance for underwater inspection for ships in lieu of drydocking, mobile or fixed offshore units and other marine structures. In all cases, the Rules pertinent to the structure and applicable regulations are to be consulted.

The Surveyors should be satisfied that the chosen diving inspection company is competent, that the divers and top-side technicians are qualified for the operation and the equipment to be used is appropriate for the particular survey. Appendix 3, Figure 1 is a checklist intended as guidance. The items in the checklist are essentially amplifications of the general remarks contained in the text of this Appendix.

The diving company should have a well-defined cleaning/inspection procedure available, as well as an inspection schedule, and should specify the intended nondestructive testing methods, which should be discussed with the Surveyor prior to the inspection. This will reduce the likelihood of misunderstandings during the diving operation and expedite the entire operation.

As a minimum, underwater examination consists of a visual inspection. ABS may on occasion require other nondestructive inspection methods, e.g. magnetic particle testing (MT), ultrasonic testing (UT), for certain joints and designs. Also, an Owner/operator may specify methods other than visual examination. Depending on the intended nondestructive inspection method, the following should be given consideration.

### 1.1 Visual Inspection (see Appendix 3, Figure 3)

When a visual inspection is scheduled, a diver who regularly wears glasses or contact lenses should also wear them when diving. Adequate white light is needed for proper inspection. Water clarity with or without artificial lighting is to be sufficient to allow viewing from approximately 1 m (39 in.) or more.

A suitable closed-circuit television with two-way communication capable of being monitored by the Surveyor and/or a still photographic camera capable of providing good resolution photographs should be used. The methods for identifying the inspected area, acceptable quality of video and still photography and the extent of retaining permanent record is to be established before commencement of inspection.

Proper cleaning equipment must be available (e.g. wire brush, preferably hydraulic powered water blast). When difficult-to-reach areas are required to be cleaned, a needle gun may be used, provided precautions are taken so as not to excessively peen the surface. Please note that the use of pneumatic tools will hinder the view of the diver, as well as what is visible on video, by producing excessive bubbling.

## 1.3 Magnetic Particle Testing (MT) (See Appendix 3, Figure 4)

MT may be required for a particular application or may be specified by the Owner/operator.

If an MT is to be performed, the surfaces to be examined should be cleaned to bare metal in order to provide good contact and sensitivity. However, a thin protective coating on the surface area to be inspected may be acceptable provided the equipment used has good metal to poles contact (bare metal).

Prior to diving, the proper working conditions of the MT equipment should be verified by the Surveyor. If DC current or permanent magnets are used, the equipment should be demonstrated as capable of lifting 40 lbs in air, 10 lbs if AC current is used. Fixed electromagnetic yokes and permanent magnet yokes do not lend themselves to all geometries encountered and particular attention should be paid to the connection geometry vis-à-vis the surface contact provided by the yokes. For example, although all the MT methods mentioned earlier are generally acceptable for detection of cracks in ferromagnetic materials, the AC method has been proven to be the most sensitive for detection of cracks open to the surface. When using the coil method, amperage is to be in accordance with ASTM E709 or its equivalent.

In addition, the concentration of the testing medium should be checked by use of a magnetic field indicator when utilizing a squirt bottle and with a centrifuge tube when an agitated tank is used. A magnetic field indicator is a pocket tool containing simulated cracks.

When the divers can clearly discern particles deposited and remaining on the magnetic field indicator along the appropriate linear direction, all of the following conditions are satisfactory:

*i)* Adequacy of particle concentration

*ii)* Adequacy of field strength

*iii)* Field direction or orientation of detectable discontinuities

*iv)* Adequacy of working conditions (e.g. visibility, turbulence)

The diver should carry the magnetic field indicator with him while diving to enable him to verify the adequacy of these conditions regularly.

Depending on the type of magnetic particles (visible or fluorescent) the Surveyor should be satisfied that the proper lighting condition is available: when using visible dye, the conditions should generally be the same as for visual inspection; when using a fluorescent dye, 125 foot-candles at 15 inches (equivalent to 120 $\mu W/cm^2$ at 38 cm) from the ultraviolet light source is considered adequate. Fluorescent indications should be readily discernable on the magnetic field indicator from approximately 1 m (39 in.).

## 1.5 Alternative and Supplementary NDT Methods

Under some conditions, alternative inspection methods to supplement MT, e.g., eddy current, may be used. Any new technique must work side-by-side with MT until such time as it is proven to the Surveyor's satisfaction that it is equally effective in detecting discontinuities under the conditions encountered with the inspection under consideration. A reasonable amount of MT is to be conducted periodically to verify the supplementary method. In addition, if an alternate method to MT is used, the proposed method and procedure is subject to special approval by the Surveyor.

Ultrasonic examination may be used for crack depth determination provided that MT or an equivalent approved surface crack detection method is used to locate the crack and to verify that it has been removed.

### 1.7 Ultrasonic Thickness Gauging

When thickness gauging is to be performed using ultrasonic methods, the surfaces of the part to be measured should be cleaned to bright metal to provide a good probe-to-metal contact. Utilized equipment should be calibrated both topside and below the waterline at the inspection depth. Recognized standard blocks should be used for this calibration.

### 1.9 Alternating Current Field Measurement (See Appendix 3, Figures 6 and 7)

When Alternating Current Field Measurement testing is to be performed, the surface is to be cleaned to allow smooth probe travel, which requires removal of hard marine fouling for underwater inspection. The required surface condition is similar to that required for eddy current inspection. Hand cleaning with a scraper is normally sufficient. No coating removal is required as long as it is not more than 6.25 mm (0.25 or $^1/_4$ in.) thick and is non-conducting. The system operator is to confirm that the surface condition is acceptable prior to carrying out the inspection. It must be ensured that the surface being inspected is in an unmagnetized state. Therefore, the procedure followed with any previous magnetic technique deployed must include demagnetization of the surface.

An operational check is to be carried out as described in Subsection 4/5, "Alternating Current Field Measurement." The results are to be presented as shown in Appendix 3, Figure 6. The probe operator is to be briefed in accordance with the procedure in Appendix 3, Figure 7.

### 1.11 Reporting

Reporting is to be as per existing practice. Appropriate figures of this Appendix may be used for guidance.

# FIGURE 1
# Checklist for Underwater Inspection

**General**

Date ________________

Vessel ________________________________________________________________

Location ________________________________________________________________

Inspection Company ________________________________________________________

Address ________________________________________________________________

________________________________________________________________________

Telephone ______________________________________________________________

Head of diving/inspection operation _________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

Persons contacted (including Owner reps., Government agencies, etc.)

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

ABS Surveyors ___________________________________________________________

________________________________________________________________________

________________________________________________________________________

Method(s) of inspection to be used on this survey

__________________________ Visual

__________________________ Magnetic particle

__________________________ Ultrasonic thickness

__________________________ Other ________________________________________
Specify

# FIGURE 2
# Preplanning

**Personnel**

Top-side technicians

Names____________________________________________

________________________________________________

________________________________________________

NDT method(s) and qualification level

________________________________________________

________________________________________________

________________________________________________

Diver/inspector

Names____________________________________________

________________________________________________

________________________________________________

NDT method(s) and qualification level

________________________________________________

________________________________________________

________________________________________________

| | | |
|---|---|---|
| Inspection procedure on board? | Yes __________ | No __________ |
| Procedure reviewed by Surveyor? | Yes __________ | No __________ |
| Personnel files of divers and top-side technicians have been reviewed by Surveyor? | Yes __________ | No __________ |
| Do divers and top-side technicians have proof of level of certification? | Yes __________ | No __________ |
| Is there a procedure to clearly locate and identify the inspection area? | Yes __________ | No __________ |

# FIGURE 3
# Visual Inspection

Procedure no. ______________________________

**Diving conditions** (describe)

Weather ______________________________

Water surge ______________________________

Water visibility ______________________________

Depth ______________________________

**Inspection equipment used** (describe)

Video ______________________________

Still photography ______________________________

Oral communication ______________________________

Lighting ______________________________

Measuring tape ______________________________

Fillet gauge ______________________________

Pit gauge ______________________________

Other ______________________________
Specify

**Cleaning equipment used** (describe)

Water blast _________ Water blast with grit _________ Needle gun _________

Wire brush: pneumatic _________ hydraulic _________ Other ______________________________
Specify

# FIGURE 4
# Magnetic Particle Testing (MT)

Procedure no.______________________________________________

**Magnetic particle method and equipment** (check)

Yoke type ______fixed _____ articulated

Current ______AC _____ DC

Permanent magnets ______

Coils (AC/DC) ______

**Magnetic particle type** (check)

Visible (powder color) ________________ Fluorescent _________

**Lighting used**

White light__________ Black light (UV) ________

**Calibration equipment** (check)

Ammeter _________ Magnetic field indicator _________ Centrifuge tube__________

10-lb weight__________ 40-lb weight _________ Other _________________________________

Specify

**Cleaning equipment used** (check)

Water blast__________ Water blast with grit_________ Needle gun__________

Wire brush: pneumatic _________ hydraulic ________ Other ____________________________

Specify

# FIGURE 5
# Ultrasonic Thickness Gauging

Procedure no. ____________________________________________

**Diving conditions** (describe)

Weather ____________________________________________

Water surge ____________________________________________

Water visibility ____________________________________________

Depth ____________________________________________

**Equipment**

Make and model ____________________________________________

Date of calibration ____________________________________________

Transducer: make, size and frequency ______________________________

**Calibration equipment**

IIW block _________ Other ______________________________
Specify

**Cleaning equipment used** (check)

Water blast _________ Water blast with grit _________ Needle gun _________

Wire brush: pneumatic _________ hydraulic _________ Other ____________________
Specify

## FIGURE 6
## Reporting Requirements

The data report sheets generated by the alternating current field measurement examination will be specifically designed with the system and current examination requirements in mind. The essential information contained on a data sheet will include:

**General Information**

Date
Operator's Name
Probe Operator
Component ID Number
File Number
Equipment Used

**Scanning Data**

Filename
Page Number
Position on Weld
Probe Number
Probe Direction
Tape Position
Examination Summary

**Detailed Record of Indications/Anomalies**

Filename
Page Number
Position on Weld
Start of Flaw (Tape reference)
End of Flaw (Tape reference)
Length of Flaw (millimeters/inches)
Remarks
Diagram/Drawing of component under examination

# FIGURE 7
# Alternating Current Field Measurement Report Form

| | | |
|---|---|---|
| Date:<br>Time: | Location: | Sketch of geometry: |
| Operator: | Probe Op: | |
| Component ID: | | |
| Summary of indications: | | |
| Filename: | | |
| Probe Number: | | Probe File: |

| Distance from Datum | Direction of travel | Weld Position | Page | Examination report/comments |
|---|---|---|---|---|
| | | | | |
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# APPENDIX 4 Guidance Criteria for Nondestructive Tests not Required by ABS

## 1 General

In the course of new construction or after various periods of service, an Owner or shipyard, on their own initiative, may conduct radiographic or ultrasonic inspections of welds in addition to those specified in the *NDT Guide* or required by the Surveyor. Although such inspections of welds are not required by ABS, there are circumstances under which guidance is desired as to an appropriate acceptance criteria. In some instances, the guidance in the table below indicates criteria that have been used by some shipyards and Owners.

| | *Location* | *Intersections* | *Butts between intersections* | *Seams between intersection* |
|---|---|---|---|---|
| Outer hull | Midship 0.6*L* | Class A | Twice Class A | Twice Class B |
| | Outside midship 0.6*L* | Class B | Twice Class B | Twice Class B |
| Longitudinal and transverse bulkheads and analogous internal structures | Midship 0.6*L* | Class A | Twice Class B | Twice Class B |
| | Outside midship 0.6*L* | Class B | Twice Class B | Twice Class B |

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