ULTRASONIC TESTING OF WELDED JOINTS IN ACCORDANCE WITH ASME V 2021

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1. PURPOSE AND SCOPE

This procedure defines the methods of performing Manual Contact Ultrasonic Testing on full penetration weld configurations and parent material on steel, to detect subsurface indications using the manual pulse echo technique in material with a thickness range from 6mm to 90mm, by personnel for or on behalf of the employer.
Typical weld configurations include:

- Plate – single and double V, J, U weld preparations. This includes vessels and piping with a diameter more than 508mm.
- Corner joints – full and partial penetration welds.
- Special applications include plate welded to castings.

All inspection shall be done according to an approved technique sheet.

2. REFERENCE DOCUMENTS

ASME V Article 4 & 23: 2021 Ultrasonic Examination Methods for Materials
ASME VIII Division 1 App 12:2021 Acceptance Standards
ASME VIII Division 2 Part 7. ULTRASONIC EXAMINATION
ASME IX:2021 Welding and Brazing Qualifications

Undated reference documents refer to the latest available edition.

Work Instructions. WI. Work instructions are instructions, which stem from requirements in the Quality Management System

Forms Forms provide the structure by which records are completed
Records Records are data, arising from activities and implemented of the QMS and provides an audit trail
QMS Quality Management System
PWHT Post Weld Heat Treatment
WPS Welding Procedure Specification
QC Quality Control
NCR Non-conformance
NDE/ NDT Non-destructive Examination/ Test

Manual scanning: Manual displacement of the probe on the scanning surface
Amplitude: Maximum value of the motion or pressure of a sound wave (echo-height)
Dead zone: Zone adjacent to the scanning surface within which reflectors of interest are not revealed.
FSH: Full Screen Height
dB: Decibel
Probe index: Intersection point of the sound beam axis with the probe surface.
DAC: Distance Amplitude Curve
DGS-diagram: Series of curves (manual / electronical which shows relationship between distance along a beam and gain in dB for an infinity reflector and different sizes of disc shaped reflectors.
Back wall echo: Pulse reflected from a boundary surface which is perpendicular to the sound beam axis.
6 dB-drop technique: Method for defect size assessment, where the probe is moved from a position showing maximum reflection amplitude until the echo has decreased to its half-value (by 6dB)

Primary Gain: The gain noted when constructing the DAC using the reference block
Corrected Primary Gain: Primary Gain plus transfer correction
S: Skip distance
FBH: Flat Bottom Hole
SDH: Side Drilled Hole.

3. PERSONNEL QUALIFICATION AND CERTIFICATION

The examination shall only be carried out by personnel certified in accordance with the employer’s Written Practice & SNT-TC-1A. Evaluation of inspection results may only be conducted by certified Level II and Level III personnel. When required, blind trials may be used to review personnel performance.

Personnel who perform non-destructive examination of welds shall be qualified and certified for each examination method in accordance with a program established by the employer of the personnel being certified, which shall be based on the following minimum requirements:

4. SURFACE CONDITION

The test surface shall be free from loose scale or dirt or any surface contaminant that may influence the scan.
Any surface on which scanning cannot be performed shall be regarded as a limitation and it shall be recorded on the relevant report as such. A sketch showing the limitations relevant to the weld and the length of the limitation relevant to the zero-datum mark is required.
Calibrations shall be performed from the surface (clad or unclad; convex or concave) corresponding to the surface of the component from which the examination will be performed.

5. EQUIPMENT REQUIREMENTS

The flaw detecting instrument shall be of the pulse echo type and have A-Scope presentation capable of operating between 1 – 5 Mhz. The instrument shall be equipped with a calibrated gain control adjustable in increments of 2 dB or less.

If the unit is equipped with a “reject” control, it shall be in the “off” Position at all times, unless it can be demonstrated that it does not affect the linearity of the examination.
The instrument shall have a send and receive jack for operation with twin crystal transducers. The nominal probe frequency shall be from 1 to 5Mhz.

Examinations performed on a curved component having a diameter less than 14 in. (350 mm) (at the examination surface) shall be performed using a contoured wedge, to ensure sufficient ultrasonic coupling is achieved and to limit any potential rocking of the search unit as it is moved along the circumference of the component.
(a) Search units shall be contoured as required by the following equation:

\[ D \leq \left[ \frac{A \times A}{2.87 \text{ mm}} \right] \]

where

\( A = \) length of search unit footprint during circumferential scanning or the width when scanning in the axial direction, in. (mm)

\( D = \) the component diameter at inspection surface (I.D./O.D.), in. (mm)

The footprint is defined as the physical dimension of the search unit in the curved direction of the component.

(b) The search unit contoured dimension shall be selected from the tables in (1) and (2) below, and shall be determined using the same component dimension from which the examination is being performed (I.D. or O.D.).

(1) Maximum contour for examinations performed from O.D.

<table>
<thead>
<tr>
<th>Actual Component Outside Diameter, (mm)</th>
<th>Allowable Increase in Contour Diameter Over Component O.D. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;100</td>
<td>&lt;25</td>
</tr>
<tr>
<td>≥100 to 250</td>
<td>&lt;50</td>
</tr>
<tr>
<td>&gt;250</td>
<td>&lt;100</td>
</tr>
</tbody>
</table>

(2) Minimum contour for examinations performed from I.D.

<table>
<thead>
<tr>
<th>Actual Component Inside Diameter, (mm)</th>
<th>Allowable Decrease in Contour Diameter Under Component I.D. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;100</td>
<td>&lt;25</td>
</tr>
<tr>
<td>≥100 to 250</td>
<td>&lt;50</td>
</tr>
<tr>
<td>&gt;250</td>
<td>&lt;100</td>
</tr>
</tbody>
</table>

Probes and cables used shall be compatible with the flaw detector in use.

**Couplants** shall be compatible with the material to be examined and shall remain constant throughout calibration of equipment and the examination. The couplant, including additives, shall not be detrimental to the material being examined. Couplants used on nickel base alloys shall contain no more than 250 ppm of sulphur, and couplants used on austenitic stainless steels or titanium shall contain no more than 250 ppm of halides. The equipment’s screen height and amplifier linearity shall be evaluated at intervals not to exceed three months for analogue type instruments and one year for digital type instruments, or prior to first use thereafter.

All equipment shall comply with relevant International standards and shall fulfil the requirements of Equipment Inspection and Verification.
6. CALIBRATION AND REFERENCE BLOCKS

- IIW V1 & V2 calibration block range calibration blocks.
- Reference Standard Blocks with specified reflectors, covering the radii of the pipes wall and plate thicknesses, over which subsequent testing will be conducted.
- Side drilled holes, flat bottom holes and notches shall be used to establish primary reference responses of the equipment.
- The material from which the calibration / reference block is fabricated shall be of the same product form, material specification, heat treatment, surface condition and shall have the same acoustic properties as the product to be examined.
- The finish on the scanning surfaces of the block shall be representative of the scanning surface finishes on the component to be examined.
- Materials with Diameters Greater Than 20 in. (500 mm). For examinations in materials where the examination surface diameter is greater than 20 in. (500 mm), a block of essentially the same curvature, or alternatively, a flat basic calibration block, may be used.
- For examinations in materials where the examination surface diameter is equal to or less than 20 in. (500 mm), a curved block shall be used. A single curved basic calibration block may be used for examinations in the range of curvature from 0.9 to 1.5 times the basic calibration block diameter. The curvature ranges from 0.94 in. to 20 in. (24 mm to 500 mm) in diameter requires six curved blocks as shown in Figure 3 for any thickness range.
- For contact examination, the temperature differential between the calibration block and examination surfaces shall be within 14°C.
- For similar metal welds, the material from which the block is fabricated shall be of the same product form and material specification.
- For dissimilar metal welds, the material selection shall 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 shall be provided in both materials.
- Prior to fabrication, the block material shall be completely examined with a straight beam search unit. Areas that contain an indication exceeding the remaining back-wall reflection shall be excluded from the beam paths required to reach the various calibration reflectors.

7. IDENTIFICATION OF WELD EXAMINATION AREAS

- **Weld locations**: Weld locations and their identifications shall be recorded on a weld map or an identification plan.
- **Marking**: If welds are to be permanently marked, low stress stamps may be used. Markings applied after final stress relief of the component shall not be any deeper than 1.2mm.
- **Reference System**: Each weld shall be located and identified by a system of reference points. The system shall permit identification of each weld centre line. These requirements shall be strictly adhered to as this provides the basis for further inspection i.e. monitoring of indications, propagation of cracks etc.

8. CALIBRATION
Compression Probe
Calibrate on an IIW Calibration Block for distance of the thickness of test to be conducted.
Distance Amplitude Correction Set Up Fig: 6

- Position the search unit for the maximum indication from the SDH, which gives the highest indication.
- Adjust the sensitivity (gain) control to provide an 80% (±5%) of FSH indication. This is the primary reference level. Mark the peak of this indication on the screen.
- Position the search unit for maximum indication from another SDH.
- Mark the peak of the indication on the screen.
- Position the search unit for maximum indication from the third SDH and mark the peak on the screen.
- Connect the screen marks for the SDHs and extend through the thickness to provide the distance–amplitude curve.

![Sensitivity and Distance–Amplitude Correction](image)

Figure 6

Shear Wave Probe
Calibration on an IIW Calibration Block Calibration shall facilitate the entire beam path length of every angle beam probe to be used. See section 6
Distance Amplitude Correction Set up Fig: 7 and 8

- The angle beam shall be directed toward the calibration reflector that yields the maximum response in the area of interest.
- The gain control shall be set so that this response is 80% ± 5% of full screen height. This shall be the primary reference level.
- The search unit shall then be manipulated, without changing instrument settings, to obtain the maximum responses from the other calibration reflectors at their beam paths to generate the distance-amplitude correction (DAC) curve.
- These calibrations shall establish both the distance range calibration and the distance amplitude correction.
• No point on the DAC curve shall be lower than 20% FSH. When any point on a DAC falls below 20% a split DAC shall be used. The first point on the second DAC will start at 80% +/- 5% FSH at the same BPL as the last point on the first DAC.

• Where the signal to noise ratio precludes the effective indication evaluation and classification, a split DAC will not be used.

When an electronic distance-amplitude correction device is used, the primary reference responses from the basic calibration block shall be equalized over the distance range to be employed in the examination. The response equalization line shall be at a screen height of 40% to 80% of full screen height.

Sensitivity and Distance–Amplitude Correction (Side-Drilled Holes)

Fig 7: DAC Side Drilled Holes.

Sensitivity and Distance–Amplitude Correction (Notches)

Fig 8: DAC Notches

CALIBRATION FOR NOZZLE SIDE WELD FUSION ZONE AND/OR ADJACENT NOZZLE PARENT METAL

• The number of calibration holes used depends upon the requirements for the examination. If only the nozzle side fusion zone is to be examined, then only a single side drilled hole at the nozzle wall thickness needs to be used.

(a) Single Hole. The response from a single side drilled hole shall be set at 80% ± 5% of full screen height. This is the primary reference level.

(b) Multiple Holes. The straight beam shall be directed toward the calibration reflector that yields the maximum response. The gain control shall be set so that this response is 80% ± 5% of full screen height. This shall be the primary reference level. The search unit shall then be manipulated, without changing instrument settings, to obtain the
maximum responses from the other hole position(s) to generate a distance-amplitude correction (DAC) curve.

![Fig 9 Spilt DAC](image)

9. CALIBRATION CONFIRMATION

When any part of the examination system is changed, a calibration check must be made on the basic calibration block to verify that range points or sensitivity settings are maintained.

Any changes exceeding 5% of the sweep (range) or 2dB in amplitude will result in the re-examination of all components since the last valid calibration or calibration check and the data changed or re-recorded.

10. TRANSFER CORRECTIONS

A transfer correction shall be carried out between the DAC block and test material using two 45° probes on the reference block at one full beam path length / distance and two Full beam path lengths / distances, repeat the check on test surface and record dB difference (i.e. DAC + 4dB).

A transfer loss of + or -2dB does not require transfer correction to be done.

Add or subtract this correction factor to the DAC curve when there is more than 2dB difference.

11. INSTRUMENT CALIBRATION

**Screen Height Linearity.** The ultrasonic instrument shall provide linear vertical presentation within 65% of the full screen height for at least 80% of the calibrated screen height [base line to maximum calibrated screen point(s)].

To verify the ability of the ultrasonic instrument to meet the linearity requirement, position an angle beam search unit as shown in Fig. 10 so that indications can be observed from both the 1/2 and 3/4T holes in a basic calibration block.

Adjust the search unit position to give a 2:1 ratio of amplitudes between the two indications, with the larger set at 80% of full screen height. Without moving the search unit, adjust sensitivity (gain) to successively set the larger indication from 100% to 20% of full screen height, in 10% increments (or 2 dB steps if a fine control is not available), and read the smaller indication at each setting. The reading must be 50% of the larger amplitude, within 5% of full screen height.
The settings and readings must be estimated to the nearest 1% of full screen. Alternatively, a straight beam search unit may be used on any calibration block which will provide amplitude differences, with sufficient signal separation to prevent overlapping of the two signals.

**Amplitude Control Linearity.** The ultrasonic instrument shall utilize an amplitude control, accurate over its useful range to ±20% of the nominal amplitude ratio, to allow measurement of indications beyond the linear range of the vertical display on the screen. To verify the accuracy of the amplitude control of the ultrasonic instrument, position an angle beam search unit as shown in Fig.10 so that the indication from the 1/2T hole in a basic calibration block is peaked on the screen.

With the increases and decreases in attenuation shown in the following table, the indication must fall within the specified limits. Other convenient reflectors from any calibration block may be used with angle or straight beam search units.

<table>
<thead>
<tr>
<th>Indication Set at % of Full Screen</th>
<th>dB Control Change</th>
<th>Indication Limits % of Full Screen</th>
</tr>
</thead>
<tbody>
<tr>
<td>80%</td>
<td>-6 dB</td>
<td>35% to 45%</td>
</tr>
<tr>
<td>80%</td>
<td>-12 dB</td>
<td>15% to 25%</td>
</tr>
<tr>
<td>40%</td>
<td>+6 dB</td>
<td>65% to 95%</td>
</tr>
<tr>
<td>20%</td>
<td>+12 dB</td>
<td>65% to 95%</td>
</tr>
</tbody>
</table>

The settings and readings must be estimated to the nearest 1% of full screen.

*Fig 10 Linearity*

![](Linearity.png)

**12. SCANNING SENSITIVITY**

The scanning sensitivity level shall be set a minimum of 6 dB higher than the reference level gain setting when using DAC.
13. PARENT MATERIAL INSPECTION & THICKNESS MEASUREMENT

Parent material shall be inspected with a compression wave probe to locate any imperfections such as laminations, confirm the material thickness and velocity. Note any attenuation variations. The area both sides of the weld, including full skip for the shallowest angle probe to be used.

Where imperfections are found, their influence on the inspection the weld shall be assessed. The technique for scanning may have to be adjusted to ensure the maximum possible local coverage of the full cross section of the weld. The speed of probe movement shall not exceed 150mm/s and have at least 10% probe overlap.

On curved surfaces, rotate the probe through 90 degrees to establish the lowest stable reading. Record the lowest reading.

Calculations:

\[
\text{\% material loss} = \frac{\text{original thickness} - \text{remaining thickness}}{\text{Original thickness}} \times 100\%
\]

\[
\text{Unknown mat Velocity} = \left( \text{Calibrated Velocity \times} \frac{\text{Physical thickness of unknown material}}{\text{Apparent thickness (instrument reading) from the unknown material}} \right)
\]
14. WELD INSPECTION

The area of interest for welds will be 100% of the weld and HAZ.

**Beam Angle.** The search unit and beam angle selected shall be appropriate for the configuration being examined and shall be capable of detecting the calibration reflectors, over the required angle beam path (as per scan plan appendix 2)

**Reflectors Parallel to the Weld Seam.** The angle beam shall be directed at approximate right angles to the weld axis from both sides of the weld (i.e., from two directions) on the same surface when possible. The search unit shall be manipulated so that the ultrasonic energy passes through the required volume of weld and adjacent base material.

**Reflectors Transverse to the Weld Seam.** The angle beam shall be directed essentially parallel to the weld axis. The search unit shall be manipulated so that the ultrasonic energy passes through the required volume of weld and adjacent base material. The search unit shall be rotated 180 deg and the examination repeated.

If the weld cap is not machined or ground flat, the examination shall be performed from the base metal on both sides of the weld cap in both weld axis directions.

(a) **Scanning with Weld Reinforcement.** If the weld cap is not machined or ground flat, the examination shall be performed from the base material on both sides of the weld cap. While scanning parallel to the weld axis, the angle beam shall be directed from 0 deg to 60 deg with respect to the weld axis in both axial directions, with the angle beam passing through the required examination volume.

(b) **Scanning Without Weld Reinforcement.** If the weld cap is machined or ground flat, the examination shall be performed on the weld. While scanning, the angle beam shall be directed essentially parallel to the weld axis in both axial directions. The search unit shall be manipulated so that the angle beam passes through the required examination volume.

**Restricted Access Welds.** Welds that cannot be fully examined from two directions using the angle beam technique (e.g., corner and tee joints) shall also be examined, if possible, with a straight beam technique. These areas of restricted access shall be noted in the examination report.

**Inaccessible Welds.** Welds that cannot be examined from at least one side (edge) using the angle beam technique shall be noted in the examination report. For flange welds, the weld may be examined with a straight beam or low angle longitudinal waves from the flange face provided the examination volume can be covered.
**NOZZLE SIDE WELD FUSION ZONE AND/ OR ADJACENT NOZZLE PARENT METAL**

Should it be specified that an ultrasonic examination be performed to examine either the nozzle side weld fusion zone and/or the adjacent nozzle parent metal, a straight beam examination shall be conducted from the inside nozzle surface.

The full circumference of the nozzle shall be scanned to cover the entire nozzle side fusion zone of the weld plus 25 mm beyond the weld toes. The search unit may be moved either circumferentially around or axially across the examination zone.

The screen range shall cover as a minimum, 1.1 times the full thickness of the nozzle wall. Nozzles that cannot be fully examined (e.g., restricted access that prevents hand placement of the search unit) shall be noted in the examination report.

**15. EVALUATION**

**Classification of geometric indications**

It is recognized that not all ultrasonic reflectors indicate flaws, since certain metallurgical discontinuities and geometric conditions may produce indications that are not relevant.

Included in this category are plate segregates in the heat-affected zone that become reflective after fabrication.

Under straight beam examination, these may appear as spot or line indications. Under angle beam examination, indications that are determined to originate from surface conditions (such as weld root geometry) or variations in metallurgical structure in austenitic materials (such as the automatic-to-manual weld clad interface) may be classified as geometric indications.

The identity, maximum amplitude, location, and extent of reflector causing a geometric indication shall be recorded. [For example: internal attachment, 200% DAC, 1 in. (25 mm) above weld centre line, on the inside surface, from 90 deg to 95 deg] The following steps shall be taken to classify an indication as geometric:

- Interpret the area containing the reflector in accordance with the applicable examination procedure.
- Plot and verify the reflector coordinates. Prepare a cross-sectional sketch showing the reflector position and surface discontinuities such as root and counter bore.
- Review fabrication or weld preparation drawings.

Other ultrasonic techniques or non-destructive examination methods may be helpful in determining a reflector’s true position, size, and orientation.

**Evaluation**

All indications greater than 20% of the reference level shall be investigated to the extent that they can be evaluated in terms of the acceptance criteria. All indications shall be sized with the 6 dB drop method unless they are classified as multi-faceted in which case the Maximum amplitude sizing technique shall be implemented.
Recording of indications

Non-rejectable indications shall be recorded as per the referencing code/section. Rejectable indications shall be recorded. As a minimum, the type of indication (i.e., crack, non-fusion, slag, etc.), location, and extent (i.e., length) shall be recorded.
16. RECORDS
For each Ultrasonic Examination, the following information shall be recorded:

- Date of the examination.
- Procedure identification and revision.
- Ultrasonic instrument identification including (manufacturer's) serial number.
- Search unit identification including (manufacturer’s) serial number, frequency and size.
- Beam angles used.
- Couplant used brand name or type and batch number.
- Search unit cables used, type and length. It is recommended to serialise the cables.
- Computerized program identification and revision, when used. For example, Pre-programmed DAC curves.
- Calibration block identification.
- Instrument reference gain level and if used, damping and reject setting.
- Calibration data including reference reflectors, indication amplitude, and distance readings.
- Data correlating simulation blocks or electronic simulators when used with initial calibration.
- Identification and location of weld or volume scanned.
- Surfaces from which examination was conducted.
- Areas of restricted access.
- Examination personnel identity and qualification level.
- Results of the examination

Map-view and side view drawing of the component indicating:

- The reflectors location in relation to a clear reference point.
- The reflectors location in relation to a clear datum point.
- The reflectors distance from the reference or datum point.
- The reflectors length.
- The reflectors orientation – longitudinal or transverse.
- Typical Echo dynamic signal pattern.

17. POST-CLEANING
When post-examination cleaning is required, it should be conducted as soon as practical using a process that does not adversely affect the part.
18. ACCEPTANCE CRITERIA

The acceptance criteria shall be in accordance with the requirement as stipulated by the client in writing and shall be recorded on the report.

In lieu if any acceptance criteria specified by the client in writing the following criteria may be used.

ASME VIII Division 1 App 12.

Imperfections which produce a response greater than 20% of the reference level shall be investigated to the extent that the operator can determine the shape, identity, and location of all such imperfections and evaluate them in terms of the acceptance standards given in (a) and (b) below.

(a) Indications characterized as cracks, lack of fusion, or incomplete penetration are unacceptable regardless of length.

(b) Other imperfections are unacceptable if the indications exceed the reference level amplitude and have lengths which exceed:

1. 1/4 in. (6 mm) for t up to 3/4 in. (19 mm);  
2. 1/3t for t from 3/4 in. to 2 1/4 in. (19 mm to 57 mm);  
3. 3/4 in. (19 mm) for t over 2 1/4 in. (57 mm).

where t is the thickness of the weld excluding any allowable reinforcement. For a butt weld joining two members having different thicknesses at the weld, t is the thinner of these two thicknesses. If a full penetration weld includes a fillet weld, the thickness of the throat of the fillet shall be included in t.

Acceptance Standards. ASME B 31.1.

(b) Acceptance Standards. Welds that are shown by ultrasonic examination to have discontinuities that produce an indication greater than 20% of the reference level shall be investigated to the extent that ultrasonic examination personnel can determine their shape, identity, and location so that they may evaluate each discontinuity for acceptance in accordance with (1) and (2).

1. Discontinuities evaluated as being cracks, lack of fusion, or incomplete penetration are unacceptable regardless of length.

2. Other discontinuities are unacceptable if the indication exceeds the reference level and their length exceeds the following:
   - (a) 1/4 in. (6.0 mm) for t up to 3/4 in. (19.0 mm).  
   - (b) 1/3t for t from 3/4 in. (19.0 mm) to 2 1/4 in. (57.0 mm).  
   - (c) 3/4 in. (19.0 mm) for t over 2 1/4 in. (57.0 mm).

   where t is the thickness of the weld being examined. If the weld joins two members having different thicknesses at the weld, t is the thinner of these two thicknesses.

(c) As an alternative to (b)(1) and (b)(2), the fracture mechanics ultrasonic acceptance criteria in Mandatory Appendix O may be used, provided all of the requirements of Mandatory Appendix O are met.