Ultrasonic Inspection of Welds in Flat Plate

Introduction

This is the first in a series of notes related to weld inspection, one of the key applications of non-destructive inspection. They are not intended as a tuition course in how to use the equipment, although a few relevant aspects may be highlighted. Proper NDT training in accordance with appropriate standards is necessary before testing critical products.

This series currently consists of three documents

- E008, Ultrasonic Inspection of Welds in Flat Plate.
- E009, Ultrasonic Inspection of Welded Pipes and Tubes,
- E010, Ultrasonic Inspection of Welds in Nozzles, Curved Surfaces and TKY Joints

Further notes will discuss other applications using ultrasonic inspection technology.

Contents

Essential Weld Technology

Welding is the process of joining materials together by applying sufficient energy to melt the surface of the material, allowing them to be joined together. Normally this will also involve the application of pressure to force the melted faces together, or the introduction of a similar filler material which melts and forms a 'weld pool' mixing with the materials to be joined.

Welding differs critically from soldering or brazing. In these processes a filler material is introduced which melts at a much lower temperature, forming only a surface bond with the parts. Steel can be brazed at a temperature of around 5-700˚C, whereas melting steel requires temperatures of over 1500˚C.

While there are many welding processes that generate these extremely high temperatures, the most common process for the joints we will consider is electric arc welding. There are three main methods of electric arc welding, each of which has its own characteristic properties and gives rise to its own unique defect types.

In general, this article is assuming that the metal being welded is a type of carbon steel. Welding of other metals is generally similar, but there may be minor differences in approach.

Metal – Inert gas (MIG) welding

An electric arc is struck between the base metal to be welded and a consumable solid metal wire which is fed in at a controlled rate, and the heat of the electric arc melts the metal which fills the weld preparation. A shielding gas (typically a mix of argon and carbon dioxide) is fed in around the welding electrode to exclude atmospheric oxygen and nitrogen.

Tungsten – Inert gas (TIG) Welding

An electric arc is struck between the base metal to be welded and a solid tungsten electrode. A consumable solid metal filler wire is normally fed in at a controlled rate, and the heat of the electric arc melts the metal which fills the weld preparation. A shielding gas (typically a mix of argon and carbon dioxide) is fed in around the welding electrode to exclude atmospheric oxygen and nitrogen. For thin metals, TIG welding can be used without additional filling – just melting the base metal together – but this is not normally used in settings where ultrasonic testing is applicable.

Submerged arc (SAW) welding

An electric arc is struck between the base metal and a tubular filler wire which is cored with a suitable flux. The flux melts and floats on top of the molten metal, excluding the atmosphere. Alternatively, the welding filler material may be a solid wire or strip with the flux applied separately. Because the welding arc is normally hidden beneath the flux material, SAW welding is frequently an automatically controlled process.

Weld preparation

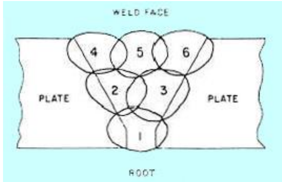


Figure 1: Building up weld layers

Regardless of process, a weld will normally be built up in multiple passes as shown in Figure 1. The initial 'root pass' (1) holds the joint together; in most cases the next pass should be done before the weld has cooled significantly, and subsequent passes allow the weld to be built up to its final geometry.

To create an effective and strong weld, it is normally necessary to prepare the edges to be joined. This performs a dual function: cleaning the site of any oxide or contamination and shaping the edges to allow the weld to be built up in a way that provides the maximum strength. Where maximum joint strength is not critical, simple fillet welds with minimal preparation are possible as shown in Figure 2.

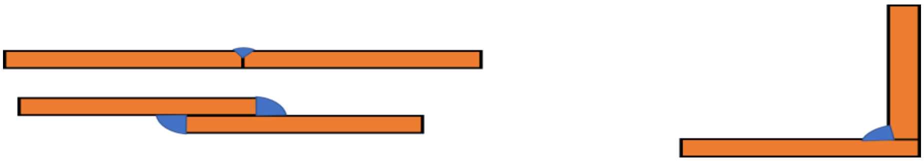


Figure 2: Fillet Welds

Fillet welds contain large areas of adjacent metal surfaces that are not welded. This makes them difficult to test ultrasonically, as we are trying to distinguish between slightly different echoes in similar locations. It is much easier in a solid weld, where any echo in the region of interest is likely to be a defect. Fortunately, fillet welds are seldom used in critical applications where NDT is required.

Groove welds

In critical welds, material will be removed for the full depth of the metal plate, allowing the weld to be evenly built up throughout the full thickness. Typically in thinner plates (maybe less than 25 millimetres) this will be done from one side; for thicker materials, it is normal if possible to build up the weld evenly from both sides, to minimise stress and to remove as little material as possible.

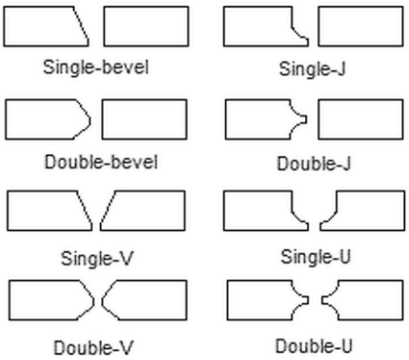


Figure 3: Typical Weld preparations

Typical weld preparation configurations are shown in Figure 3. Perhaps the most common weld configuration is a single-V preparation, with the faces prepared by grinding to 30 degrees from vertical. Thicker materials, especially where access is only possible from one side, may use relatively narrow U or J preparations. This minimises the amount of material removed and the amount of weld filler metal that must be used.

Modern ultrasonic instrumentation typically allows the weld configuration (or at least the material thickness) to be entered, to aid the operator in identifying where indications have come from. This can be critical in analysing the likely source of the reflection; for example, any indication in the centre region of the weld is likely to be a defect, but indications from one side of the material or the other might be due to the material geometry. It is important that the operator has the necessary skills to understand which is which.

Typical weld defects

Some defect types are specific to particular weld processes, but not all. Some common defect types are:

A. Geometric defects:

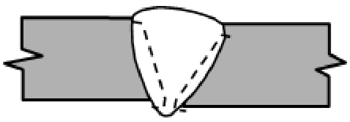


Figure 4: Misalignment

The metal on one side of the weld is higher than the other. This is often caused by careless fit-up of the metal before welding. While it may not necessarily impact the strength of the weld, it can cause problems in ultrasonic inspection and can be confused with other defect types. This type of defect is commonly checked for using a mechanical gauge.

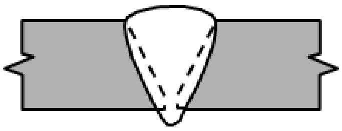


Figure 5: Excessive penetration

Excessive penetration is normally caused by inaccurate weld preparation (e.g. too large a gap) or excessive heat in welding. while this does not reduce the weld strength, it can cause problem in some applications, especially in pipe welds where it can interfere with flow.

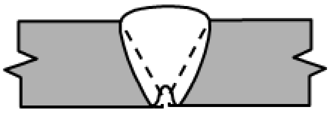


Figure 6: Root concavity

Root concavity (or lack of penetration) can be caused by poor preparation, excessive welding speeds, or excessive heat during the second weld pass melting the root. It may cause the weld to be weaker than expected.

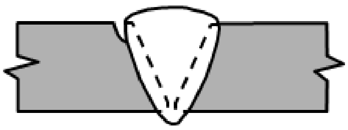


Figure 7: Undercut

An irregular groove at one side of weld is often caused by insufficient fill material or excessive speed. Some level of undercut is usually acceptable.

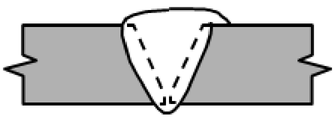


Figure 8: Overlap

Unbonded metal at the side of the weld can be caused by poor technique, such as an excessive weld pool or a cold or contaminated surface.

B. Porosity and inclusions

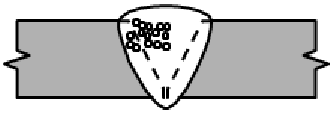


Figure 9: Porosity

Porosity is caused by gas being trapped in the weld. This may come from a variety of sources, such as contamination of the weld or base metal, moisture, or poorly controlled shielding gas. Porosity can be random or evenly distributed and can involve large pores or a cluster of small ones.

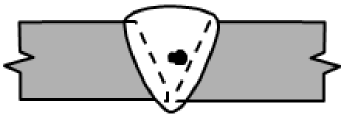


Figure 10: Inclusions

Solid material in the weld can come from a variety of sources, often characterized by the weld process. A SAW process might have inclusions of slag or flux, while damaged TIG welding tips might lead to tungsten inclusions. Oxide inclusions are often more irregularly-shaped than pores, which tend to be 'bubbles'.

C. Lack of fusion defects

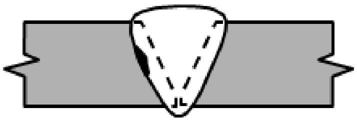


Figure 11: Lack of side-wall fusion

Lack of fusion can appear anywhere in the weld, but root and side-wall fusion defects are the most common. They can be caused by poor control of the welding process, by contamination, or by poor preparation of the base metal. Because defects on the 'fusion face' can leave a flat reflecting surface, it is often critical to design an inspection approach that can detect it.

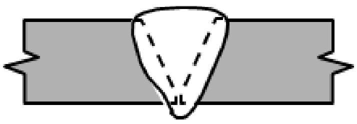


Figure 12: Lack of root fusion

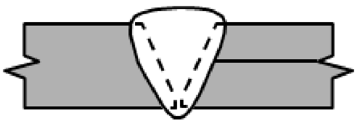


Figure 13: Delamination

Not a weld defect as such, delaminations are caused by a lack of fusion within the base metal – commonly by slag inclusions which have been rolled very flat. Not only do they weaken the joint region, they may prevent proper ultrasonic examination: sound will be reflected within the top part of the material, and no energy will reach the lower part of the weld. This can result in a false negative, with serious defects being unreported. It is therefore normal to do a lamination check with a zero-degree probe, to ensure the metal registers the expected thickness before the weld is scanned.

D. Cracks

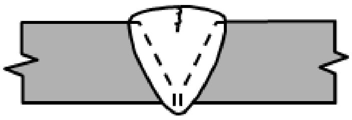


Figure 14: Longitudinal crack

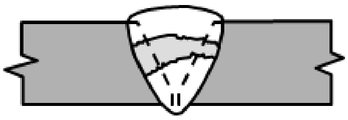


Figure 15: Transverse crack

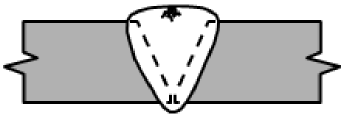


Figure 16: Crater crack

Cracks can be produced during the welding process, or later due to stresses. Cracks of any size are normally unacceptable because they tend to concentrate stress and propagate easily.

Cracks can frequently be caused by cooling the weld too fast after the welding process, or by incorrect heating before or after the welding process. Transverse cracks are normally the result of longitudinal stresses in the weld. Crater cracks (or star cracks) can initiate from an abrupt weld termination / restart.

Cracks can often occur in the heat-affected zone (HAZ) near the weld.

Normally cracks of any kind must be ground or gouged out and rewelded.

Key points about ultrasonic inspection of plate welds

It is important to understand the following points:

- Most, if not all, welding inspection standards require that the operator identify the type, size and severity of defect according to appropriate criteria, thus accurate measurements and calibration are essential.
- It is important that the inspector understands the weld geometry and technology, to allow the best possible assessment of defect type, and to identify 'artefacts' – reflections from the geometry of the weld or structure.
- Sometimes ultrasonic inspection alone will not give a definite assessment of defect type; for example, a lack of root fusion and a root crack can look similar and may have to be assessed as a 'root defect'. Defects on the top surface may be hard to distinguish from irregularities in the weld crown. It is quite common for ultrasonic inspection to be combined with other methods.

  A full visual examination and the use of appropriate measuring gauges to identify issues such as misalignment should always be carried out before the ultrasonic examination.

- As mentioned earlier, delaminations in the base metal plate can prevent the sound from reaching part of the weld area. This is not always obvious. It is standard practice to carry out a zero-degree inspection to confirm the metal thickness and identify any delaminations (which will cause the metal to appear much thinner).
- Inspection of welds which have been in service is quite different from inspection of new welds. Normally, one should be able to assume that any

manufacturing defects such as lack of fusion, porosity or inclusions will have been found when the weld was originally inspected, so these defects should not be present. In-service inspection will usually be looking for cracking or corrosion defects. In many cases, other NDT methods such as magnetic particle inspection or electromagnetic techniques (eddy current or ACFM) may be more appropriate.

- Normally a weld should be inspected from both sides, as the orientation of defects may make them difficult or impossible to detect from one side. A structure that does not allow this may make it impossible to eliminate the possibility of some orientations / positions of defects, so this should be considered at the design phase. An example with a pipe flange is shown in Figure 17.

  Note that this was less of an issue when using X-ray inspection, and hence some existing designs with flanges and elbows are unsuitable. Phased array inspection will often give a better probability of identifying defects in 'unfavourable' locations because an image is produced.

  To reduce this problem, fittings (such as flanges) are often made with a sufficient length of 'stub' to create a gap between the weld and the fitting.

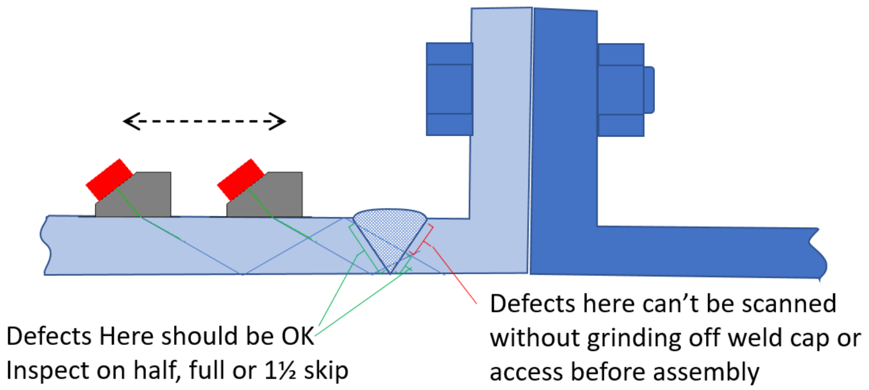


Figure 17: Example of weld location making inspection difficult

- Cracks may also occur in the heat-affected zone (HAZ) either side of the weld, particularly if it is subjected to stress while cooling. Normally an inspection should cover a region several millimetres beyond the melting zone of the weld.

Standards

Many standards organizations issue documents applicable to ultrasonic weld inspection.

Appendix A shows a list of the BS/EN/ISO standards applicable to this in the UK. There are many other organizations who also issue standards. Individual industries or companies may also use their own internal standards.

There are several different types of relevant standards which can be loosely categorized as:

- 'Background standards' – equipment characterization, operator qualification, terminology etc.
- 'Instructional standards' – general guidance on how to carry out a particular inspection technique.
- 'Acceptance standards' – what defects must be rejected to use a welded structure for a particular application. These requirements may often be contained within general material or product standards, rather than being NDT standards as such. Standards sometimes combine details of the method to be used with acceptance criteria

A particular standard that will be frequently met, and is discussed later, is the American Welding Society (AWS) Structural Welding Code for Steel, AWS D1.1. This gives great detail about acceptable design and construction of welded structures, of which ultrasonic NDT is only a very small part. The NDT procedures are very prescriptive as to what equipment is used, how indications are evaluated and how they are reported. Modern equipment typically provides software tools to assist with evaluation and reporting according to the AWS requirements. For more information, refer to the standard and to specific equipment manuals.

A common standard for weld inspection is ISO 17640, most recently updated in 2018. This replaces the older EN 1714, which itself replaced the German standard DIN 54125 and the British standard BS 3923.

It references the following standards:

- ISO 5577, Non-destructive testing — Ultrasonic testing — Vocabulary
- ISO 9712, Non-destructive testing — Qualification and certification of NDT personnel
- ISO 11666, Non-destructive testing of welds — Ultrasonic testing— Acceptance levels
- ISO 16810, Non-destructive testing — Ultrasonic testing — General principles
- ISO 16811, Non-destructive testing — Ultrasonic testing — Sensitivity and range setting

- ISO 16826, Non-destructive testing — Ultrasonic testing — Examination for discontinuities perpendicular to the surface
- ISO 17635, Non-destructive testing of welds — General rules for metallic materials
- ISO 23279, Non-destructive testing of welds — Ultrasonic testing — Characterization of discontinuities in welds
- EN 12668 (all parts), Non-destructive testing — Characterization and verification of ultrasonic examination equipment

Clearly, a lot of reading can be required to establish what is needed for a particular application, although in practice there is a lot of duplication between these standards.

Evaluation methods and criteria

Weld defects may be evaluated either using an amplitude-based method (such as comparing the strength of reflection to a standard reference reflector such as a hole of known diameter), or by direct dimensional measurement using a technique such as TOFD. Typically, acceptance standards specify a maximum length (which may be zero, meaning no defects acceptable) for defects of a particular type and size / reflection strength.

Amplitude-based methods require compensation for the reduction in signal with distance.

This is a result of two distinct factors:

a) Geometric spread of energy; close to the probe this is determined by the probe size and frequency, and at a distance the response approximates to an inverse square law.
b) The loss of energy within the material itself, primarily due to scattering effects. This normally increases greatly at higher frequencies.

The idea is to compensate so that the measured severity (the strength of the reflection) correlates to the size. This compensation may be done in several ways.

DAC

To create a DAC (Distance amplitude correction) curve, the strength of an echo from reflectors of the same size at different distances is measured and a curve fitted. Most modern equipment contains software to enable this. Historically, it was achieved by drawing on the flaw detector display using a Chinagraph pencil.

Once the curve has been calculated, the software can also create subsidiary curves, drawn at a certain dB ratio above or below it. This allows the use of different thresholds for calibration and inspection.

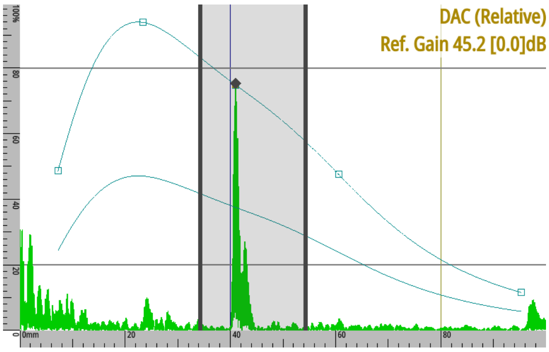


Figure 18: Creation of a DAC curve

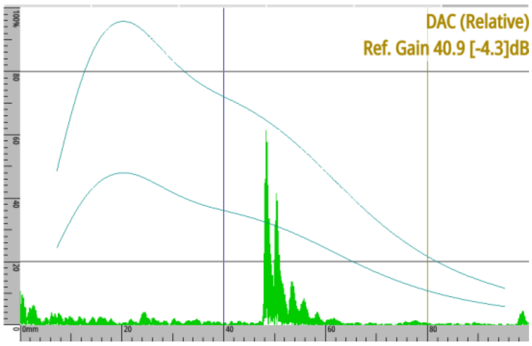


Figure 19: DAC curve used for echo amplitude evaluation.

TCG

TCG (Time controlled gain) achieves the same result as DAC, by rapidly varying the gain of the equipment so that reflections at different distances are corrected to have the same amplitude. Many modern instruments can convert between DAC and TCG without recalibration.

TCG has the advantages that it is easier to interpret small signals, which with DAC might be only a few percent of screen height. TCG is also the only method that can be easily applied where defect detection is done automatically, or by conversion to a colour palette, this includes B-Scan equipment, C-scan equipment and various phased array displays.
Figure 20 shows TCG in use on a Sonatest Wave instrument, Note that:

a) The curve shows the gain change; unlike with DAC or DGS, it does not represent a threshold.
b) The noise level will increase toward the right side of the screen because the gain is higher.

DGS

DGS (Distance-Gain-Size, also known by its German acronym AVG) is a special type of calculated DAC curve, based on a theoretical prediction of echo amplitudes from the probe, based on its near-field length and effective diameter. It has the advantage that the operator only needs to calibrate at a single amplitude point (typically a back-wall echo or side-drilled hole), so does not need to carry around heavy test pieces.

The DGS method has the disadvantage that it can only be used with a small range of 'well-behaved' probes, where the sound field pattern is consistent and matches the theoretical model. Issues such as transfer loss due to rough surfaces and material attenuation must also be well understood if accurate evaluation is to be obtained.

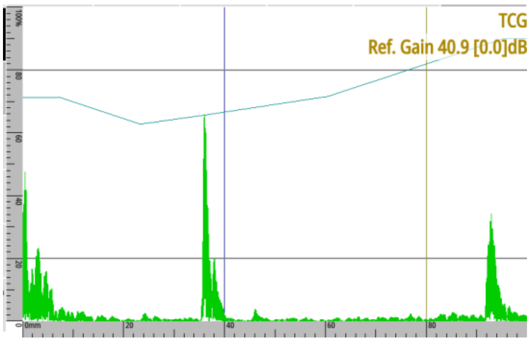


Figure 20: TCG in use.

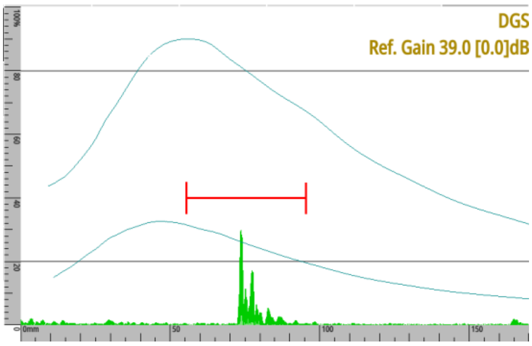


Figure 21: DGS in use

Procedure specific methods

A typical example here would be the AWS D1.1 defect evaluation approach. This uses a very prescribed setup, and then applies an attenuation factor in dB proportional to the sound path length. This is simple to apply on basic equipment and requires limited calibration. Most modern equipment can calculate the AWS 'indication rating' automatically.

- Covers groove welds in material with thickness between 8mm and 200mm inclusive
- Angle beam transducers must be 2 to 2.5MHz, 15 to 25mm long, 15 to 20mm high. A 5/8in (16mm) square is most used
- Calibrate using the 1.6mm hole in an IIW block– gain required is recorded as (b)
- Adjust gain on defect indication – gain required is (a)
- Calculate the attenuation factor (c), which is sound path distance in inches, minus one, multiplied by two
- Then calculate an indication rating (d) , which is a – b – c
- Measure length indication and evaluate according to an appropriate table
- Refer to the AWS standard for full details

Table 6.2
UT Acceptance-Rejection Criteria (Statically Loaded Nontubular Connections) (see 6.13.1)

Discontinuity Severity Class	Weld Size* in in. [mm] and Search Unit Angle										
	5/16 through 3/4 [8–20]	> 3/4 through 1-1/2 [20–38]	> 1-1/2 through 2-1/2 [38–65]			> 2-1/2 through 4 [65–100]			> 4 through 8 [100–200]		
	70°	70°	70°	60°	45°	70°	60°	45°	70°	60°	45°
Class A	+5 & lower	+2 & lower	−2 & lower	+1 & lower	+3 & lower	−5 & lower	−2 & lower	0 & lower	−7 & lower	−4 & lower	−1 & lower
Class B	+6	+3	−1 0	+2 +3	+4 +5	−4 −3	−1 0	+1 +2	−6 −5	−3 −2	0 +1
Class C	+7	+4	+1 +2	+4 +5	+6 +7	−2 to +2	+1 +2	+3 +4	−4 to +2	−1 to +2	+2 +3
Class D	+8 & up	+5 & up	+3 & up	+6 & up	+8 & up	+3 & up	+3 & up	+5 & up	+3 & up	+3 & up	+4 & up

* Weld size in butt joints shall be the nominal thickness of the thinner of the two parts being joined.

Notes:
1. Class B and C discontinuities shall be separated by at least 2L, L being the length of the longer discontinuity, except that when two or more such discontinuities are not separated by at least 2L, but the combined length of discontinuities and their separation distance is equal to or less than the maximum allowable length under the provisions of Class B or C, the discontinuity shall be considered a single acceptable discontinuity.
2. Class B and C discontinuities shall not begin at a distance less than 2L from weld ends carrying primary tensile stress, L being the discontinuity length.
3. Discontinuities detected at "scanning level" in the root face area of CJP double groove weld joints shall be evaluated using an indicating rating 4 dB more sensitive than described in 6.26.6.5 when such welds are designated as "tension welds" on the drawing (subtract 4 dB from the indication rating "d"). This shall not apply if the weld joint is backgouged to sound metal to remove the root face and MT used to verify that the root face has been removed.
4. ESW or EGW: Discontinuities detected at "scanning level" which exceed 2 in. [50 mm] in length shall be suspected as being piping porosity and shall be further evaluated with radiography.
5. For indications that remain on the display as the search unit is moved, refer to 6.13.1.

Class A (large discontinuities)
Any indication in this category shall be rejected (regardless of length).

Class B (medium discontinuities)
Any indication in this category having a length greater than 3/4 in. [20 mm] shall be rejected.

Class C (small discontinuities)
Any indication in this category having a length greater than 2 in. [50 mm] shall be rejected.

Class D (minor discontinuities)
Any indication in this category shall be accepted regardless of length or location in the weld.

Scanning Levels

Sound path[b] in in. [mm]	Above Zero Reference, dB
through 2-1/2 [65 mm]	14
> 2-1/2 through 5 [65–125 mm]	19
> 5 through 10 [125–250 mm]	29
> 10 through 15 [250–380 mm]	39

[b] This column refers to sound path distance; NOT material thickness.

Figure 22: AWS D1.1 for angle beam testing in brief

Inspection of welds using mono-element ultrasonic flaw detectors

Once mechanical checks and a delamination check have been carried out, an ultrasonic weld inspection will usually be conducted in several stages:

Critical root scan

Defects at the root of a weld – such as cracks, lack of penetration or 'undercut' – can very quickly propagate and weaken a structure. They must therefore be found with a high reliability. They may also be difficult to distinguish from the 'normal' reflection from the weld bead. A careful scan with a shear wave probe at a fixed distance (a magnetic ruler or similar guide is helpful) from the weld will allow root defects, which normally show up 'ahead' of the root signal, to be distinguished. Often the weld bead signal will be small, but this cannot be assumed.

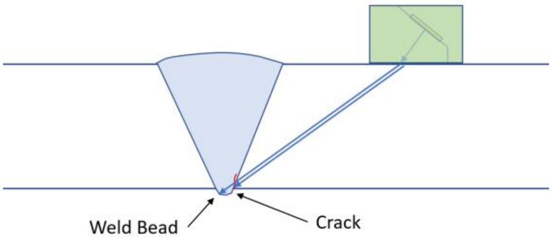


Figure 23: A critical root scan

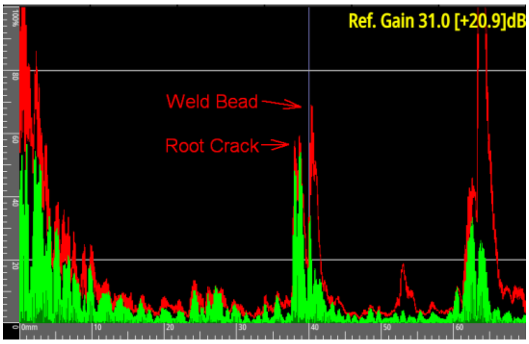


Figure 24: Weld bead and root crack indications on the WAVE

Inspection from both sides will normally assist the inspector in distinguishing between cracks and other issues such as lack of penetration. With a crack the root bead will be seen from one side, with lack of penetration the signal should be similar from either side.

Weld body/fusion face Inspection

Normally, the weld body and the fusion face will be inspected by moving the probe between the position used for root defect inspection and the position at which the 'full skip' (i.e. reflected once from the lower surface of the plate) beam intersects the top of the fusion face. The probe angle used should match the weld bevel angle (so a 60 degree probe should be used for a 30 degree weld angle). This should find defects in the body of the weld and in the 'near' fusion face.

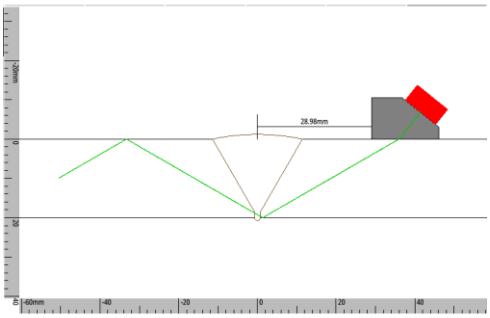


Figure 25: Scan at root

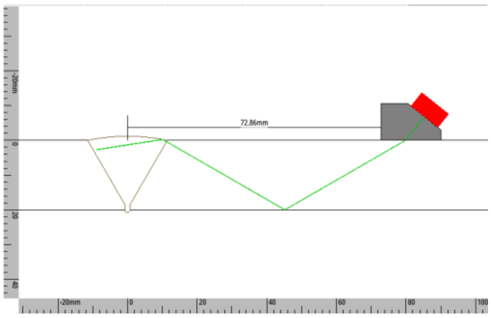


Figure 26: Scan at edge of weld cap.

Note that, because of the unfavourable angle, this will not give a strong signal (if any) from a lack of fusion on the far fusion face. The inspection should always be repeated from the far side. A 'half-skip' or 'third-leg' inspection may give partial coverage of this region, but this is not recommended if alternatives exist. Reflections from the weld crown will be erratic unless it has been ground flat.

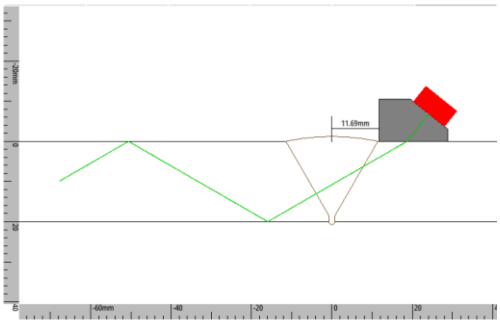


Figure 27: Scan of 'far side' extent limited by weld cap

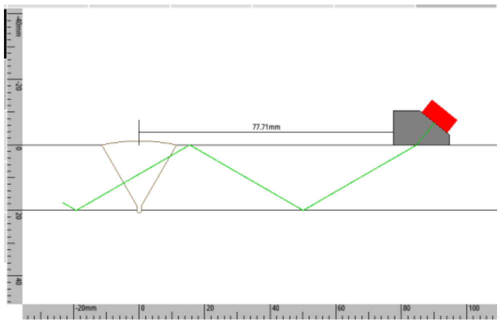


Figure 28: 'Third-leg' scan - only a bit further up

To scan a weld, the probe should be moved between these two positions in a 'zig-zag' or 'raster' pattern along the weld. Doing this consistently takes skill and practice.

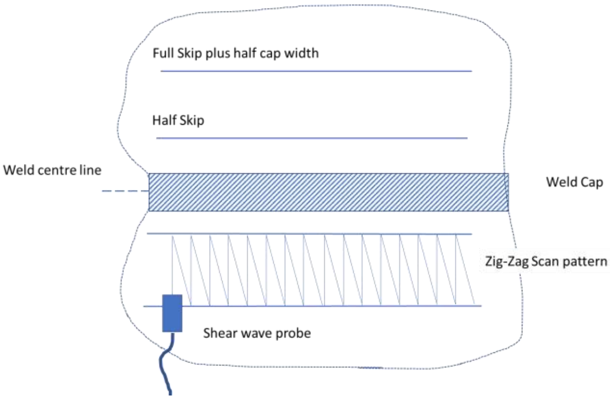


Figure 29: Typical scanning pattern for weld

Scan for transverse defects

Where the weld cap has been ground flat, this can be done using a single probe scanned along the weld centreline. Where the weld has not been ground, the probe should be scanned along to one side – or two probes, one either side, used in a 'pitch-catch' configuration The scan should be done from both directions and, in the case of a single probe from the side, both sides.

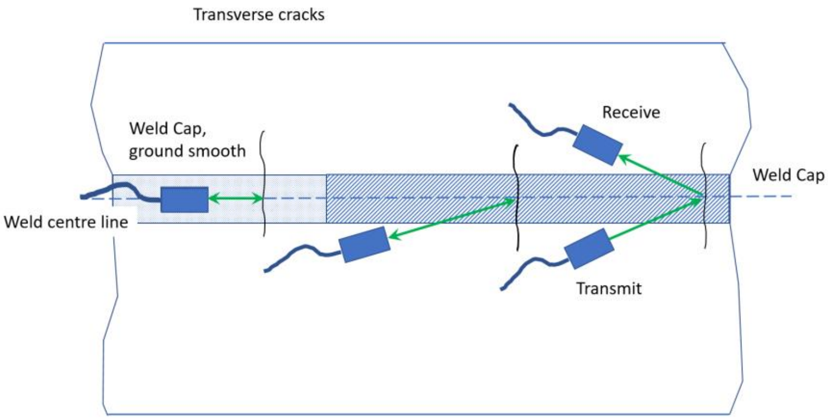


Figure 30: Inspection options for transverse cracking

Double-V and more complex shaped welds

The scan distance should cover from the half-skip to centre-line, back to the full skip to edge of the upper weld crown (plus HAZ) as shown in Figures 31 and 32.

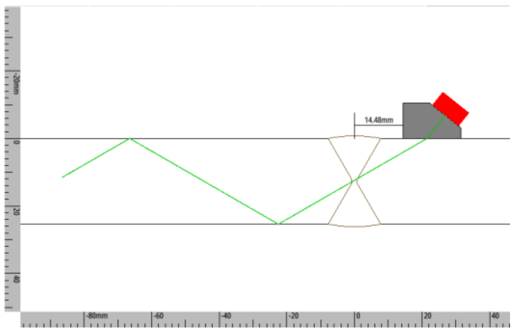


Figure 31: Nearest scan extent for double-V weld

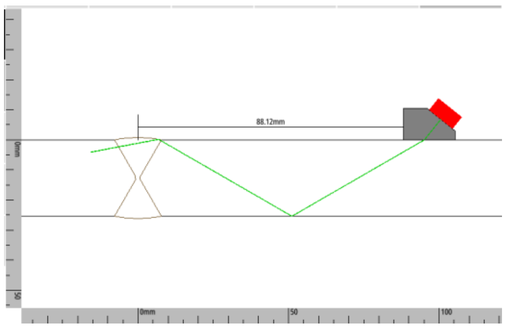


Figure 32: Furthest scan extent for double-V weld

Special attention should be paid to the weld centre region; in particular, if the preparation has a significant vertical region (shown slightly exaggerated in Figure 33), this should be tested with a high angle (70 or 80 degree) probe, or ideally with a tandem probe arrangement. The tandem setup will normally need a suitable fixture to keep the probes at the correct distance.

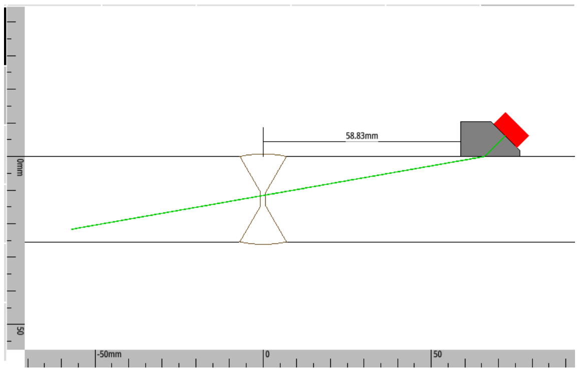


Figure 33: Single probe inspection for root defects

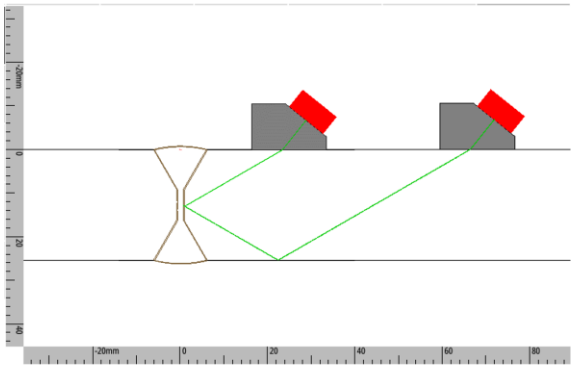


Figure 34: Tandem probe inspection for root defects

Complex weld shapes need to be evaluated on a case-by-case basis, ensuring that the full body of the weld is inspected and that the probe angle is suitable for location of smooth lack of fusion defects.

Compression mode probes

For carbon steel, inspection is almost always done using a shear wave mode probe. For some materials, particularly austenitic steels, shear waves do not propagate very well; for these, a longitudinal mode (compression wave) probe will give better results. To improve signal to noise ratio, a dual element probe is often used.

Figure 35: Twin crystal compression angle probe

Inspection of welds using TOFD

TOFD (Time of Flight-Diffraction) is a geometric diffraction technique. The time taken by the signal diffracted from the tips of a discontinuity is measured; this allows calculation of the path length, and thus, by trigonometry, the depth.

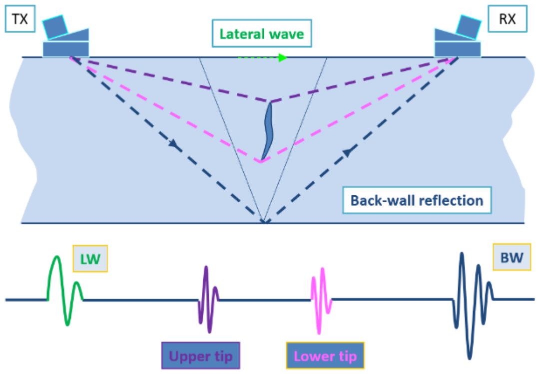


Figure 36: TOFD measurement

Key points about TOFD:

- We are primarily looking at diffracted signals, rather than reflected ones. These signals are much weaker and as long as they can be detected, the amplitude is not important – only the timing.
- The probes are designed to give a wide spread of energy to cover the area of interest, rather than a narrow beam, and they are typically much smaller in diameter than other probe types. A 5MHz 6mm probe, or a 10MHz 3mm diameter probe, are typical. Probes are usually supplied with separate wedges, allowing the correct frequency/diameter/angle combination to be selected.
- Since the signals are small – both because they are diffracted, and because a wide beam is used – high gain is needed, and often a preamplifier will be required.
- To cover thick materials, the beam spread and sensitivity of a single probe pair may still not be enough to give optimal results. For material thicker than 30mm or so (depending on the standard applied), two or more probe pairs at different frequencies or angles may be required.
- All Sonatest phased array instruments (Prisma, veo, veo+) can be configured to carry out two simultaneous TOFD scans. The instruments include tools for setting up the scan (see Figure 37) as well as for measurement / evaluation of indications.
- Because we are making accurate measurements, precision is essential. The probes must be held in a rigid support, with position tracked by an encoder.
- Offline assessment is normally required.
- Hyperbolic cursors on the instrument assist in measuring the precise dimensions of the indication, allowing assessment.

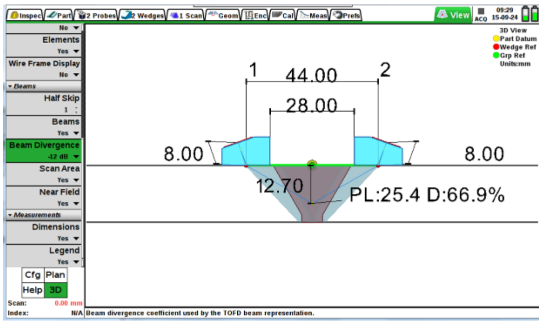


Figure 37: Setting up a TOFD scan on the veo

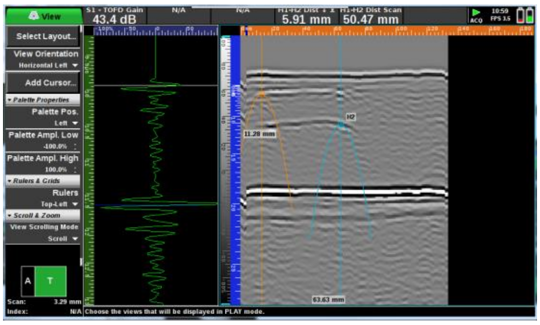


Figure 38: Indication measurement using hyperbolic cursors

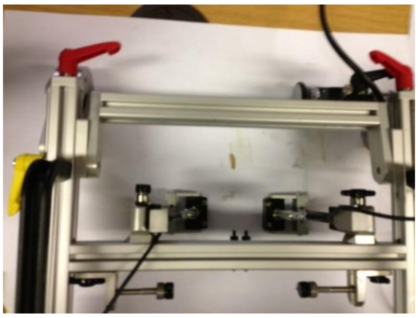


Figure 39: Scanner with TOFD probes

Detailed use of TOFD and evaluation of indications is outside the scope of this document.

Please refer to appropriate standards and training materials.

Inspection of welds using phased array instruments

The term 'phased array' (PA) is used to refer to several different related techniques:

1. 'Standard' beamforming phased array, where probe element firing delays are used to create an ultrasonic beam with a specific angle, position, and focus. This can be rapidly changed to create a sequence of scans, which can be assembled to form a 'picture'.
2. Full Matrix Capture (FMC), where the sequence fires one element at a time, collecting data on all the other elements. This data can then be combined to produce an image using a variety of approaches. Most commonly, the Total Focusing Method (TFM) is used, which as the name implies, creates an image that is 'in focus' at all points. One of the key advantages of FMC/TFM is that discontinuities are interrogated from a variety of directions. This allows a more accurate representation of the shape and orientation of defects to be determined. The main disadvantages are that it tends to be slower and that it collects massive quantities of data.
3. 'Real time' TFM, where the above process is done live. This can give quick and accurate results but relies on the operator selecting the correct image reconstruction options at the time of testing. There is normally no ability to 're-analyse' with different options.

This document will primarily deal with beamforming PA, which is well established as an inspection method. At present, the process of developing agreed standards for TFM methods has only just started.

Key points about phased array for weld inspection:

a) The physics of PA inspection are identical to mono-element ultrasonic inspection. The advantages are:
    a. Ability to produce multiple angles.
    b. Speed – it can usually replace or reduce the need for scanning at multiple distances from the weld. Often, a single scan along a weld at several centimetres per second is acceptable.
    c. Ability to save data and produce reports with images is included in most equipment
    d. Because of the imaging capability, interpretation can be easier.
b) A sound beam still needs to be produced at a suitable angle to get a reflection back to the probe from possible defects.
c) Phased array probes tend to be larger, so in some cases there is a compromise between access and the ideal probe characteristics. Probes similar in size to conventional ultrasonic probes are available,
d) The use of a scanner / encoder setup is strongly recommended. It is possible to scan manually and investigate indications manually – and this can still gain a speed advantage over manual UT – but most of the potential advantages of phased array require precise logging of position.

Approaches to phased array scanning

1. **Single sector scan**

The simple sector scan, with a single scan setup covering a range of angles, is shown in Figure 40. This image is created using the UT studio+ software, supplied with all Sonatest phased array instruments.

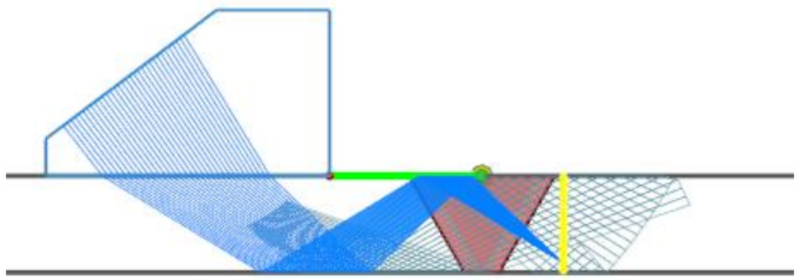


Figure 40: Phased array sector scan of weld

In Figure 40 we see beams at a range of angles (from 50 to 70 degrees at 1-degree increments), with the element contributions to the 50-degree beam. The yellow line shows the focus for each beam angle. Here we have placed the focus just beyond the heat affected zone (shown in red).

The software allows us to 'unwrap' the part to showing each reflection skip separately as shown in Figure 41. This is often much clearer:

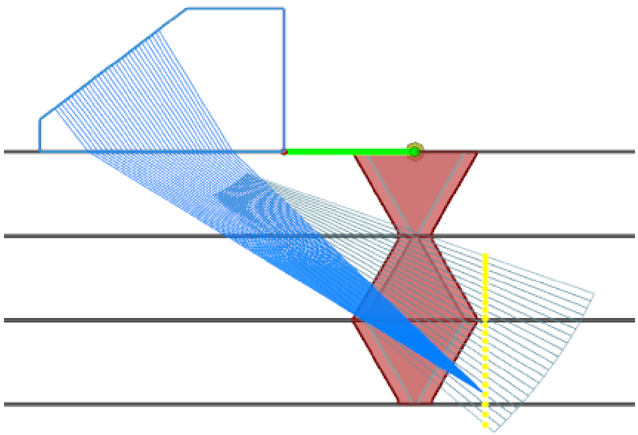


Figure 41: Phased array sector scan as in the previous figure, shown with reflections in part 'unwrapped'

For mono-element ultrasonic testing, a maximum of ±5° off normal to the fusion face is recommended. With phased array the images are clearer, and we can (subject to code) relax this slightly. In Figure 41we see that the beam from 50 to 70 degrees just reaches the extremes of the face at full skip, and again on the 'third leg'.

2. Dual sector scan

As elsewhere, it is recommended that the weld is scanned from both sides. With the veo+, two probes and a suitable scanner, this scan be done in a single pass and the data recorded into a single file, This increases the inspection speed, and allows a single report to combine the scans from either side.

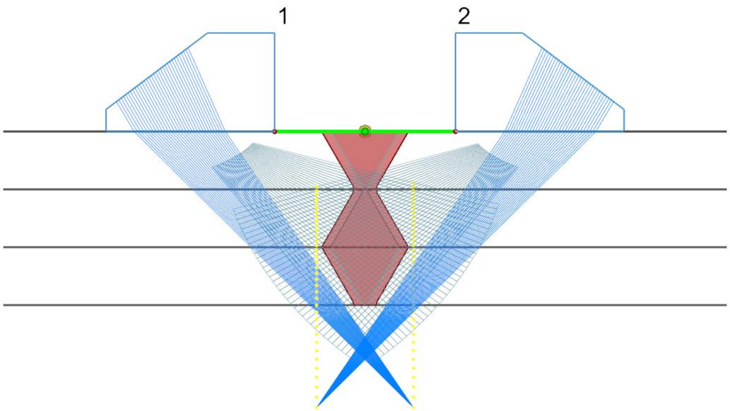


Figure 42: Dual sector scan of weld

3. Linear scan

Alternatively, a linear scan at the weld bevel angle can be used to give an equivalent test to a mono-element raster scan. The disadvantage is that even a standard 64 element (X3 or equivalent) probe may not be long enough to cover the full weld bevel in a single scan. A longer and larger pitch probe can be used, but this may be bulky, and may be less suitable for a sector scan due to its inferior beam steering characteristics.

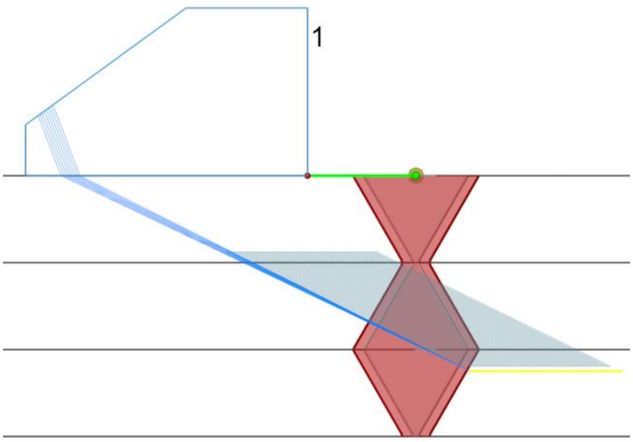


Figure 43: Linear scan of weld

4. Multiple scans

We can use a dual probe setup to carry out simultaneous linear and sector scans, from both sides, providing improved probability of detection into a single record.

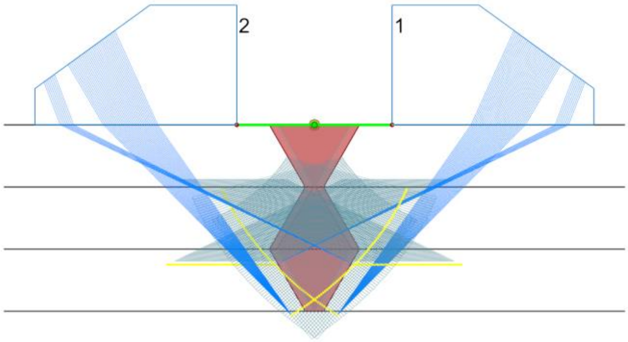


Figure 44: Dual linear and sector scans of a weld

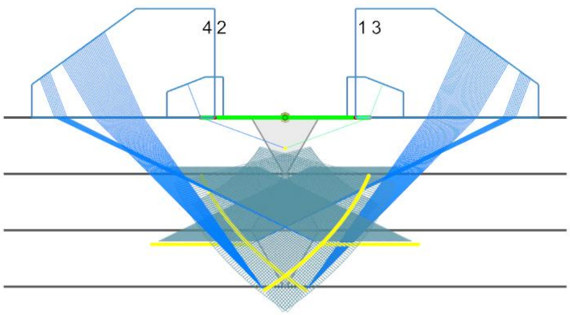
5. Combining phased array and TOFD

Both theoretical and experimental studies show that combining phased array and TOFD scans greatly increases the reliability of weld inspection. This stems from two factors:

a) They are very different methods, so the statistical effects can be treated as independent. For example, if a particular phased array inspection has an 80% probability of detection (so a 20% chance of missing a defect) and a TOFD inspection also has an 80% POD, combining the two means that 20% chance of failure is itself multiplied by 20% - leaving only a 4% chance of missing the defect, and a 96% probability of detection.

b) The weaknesses of the two methods are complementary. For example, where TOFD can miss defects near the surface, PA is good at catching them; and where PA can miss unfavourably oriented defects (which is why we test from both sides), TOFD is in turn stronger.

The veo+ allows us to set up multiple scans. In Figure 45 we show a sector scan and a linear scan from each side, plus a TOFD scan.



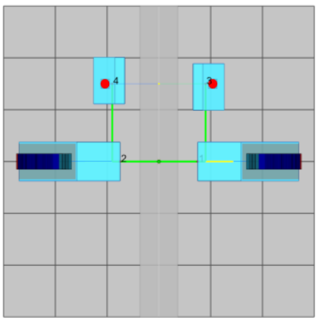


Figure 45: Combining Phased array and TOFD; top view of typical probe arrangement shown

While this might be considered overkill and running five scans simultaneously can reduce the maximum acquisition speed, it is an appropriate compromise for critical applications.

6. Check scans

With a multiple probe setup, it can be useful, especially for automated scans, to add a simple zero degree scan to check the back wall location and coupling. An additional scan can be allocated to this on each probe; generally, this can be a very coarse scan, so that it uses minimal extra scanning time.

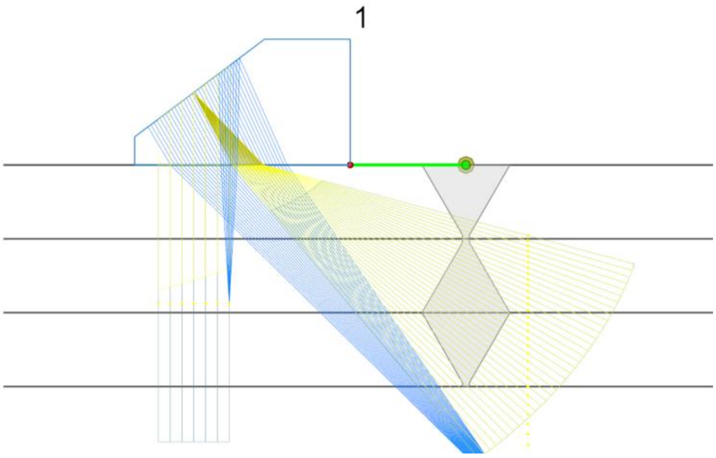


Figure 46: Use of a coupling check scan

While creating a zero-degree scan using a high angle wedge is far from optimal, the performance is sufficient to provide a coupling check and verification of back wall for quality control purposes.

Data acquisition

As mentioned earlier, to collect acceptable data it is essential that the instrument is set up correctly and the probe is manipulated correctly.

If the intention is to do a simple good/bad scan and mark defects for later action, a manual scan without encoding or recording may be acceptable. The practice here is to scan carefully along the weld, normally with a magnetic ruler or similar for guidance; indications are marked for investigation and, after scanning a length, the individual defect indications are investigated, measured, marked, and written down.

When submitting reports of critical welds for a customer or client, best practice is to supply images and possibly datafiles of relevant scans, even where no defects are found. The veo series allows the client to use the free UTstudio viewer software to review files if desired.

Prior to making any recording the following approach should be taken:

- Ensure the equipment is set up properly; ensure all probes are in good condition, check coupling in any wedges etc.

- Check calibration on all channels.

- Set the instrument display to give at least one scan which shows any missing data points (usually a top view or B-scan). Missing data is normally a sign that the probe is being moved erratically or at excessive speed. Check also that the pulse repetition frequency (PRF) on one or more channels is not set too low, causing that scan to take too long. Missing data will only be visible if an encoder is used.

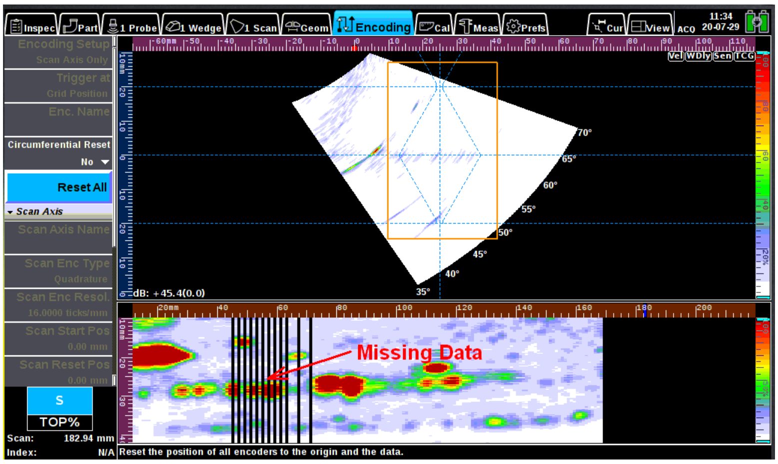


Figure 47: Missing data due to fast or erratic probe movement

- Collect a test scan over a suitable area of the weld. It may be helpful to increase the gain, to confirm that weld beads and any other geometric features appear where expected.

- If everything is satisfactory collect the scans and analyse as required.

Reporting

Once an inspection has been performed most applications require a report to be issued. Usually this will be in a format agreed between the inspector and client, and will contain the following items:

- Details of the customer, part ID, location etc.
- The date and time of inspection.
- Details of the equipment used – instruments, probes, scanners etc., along with serial numbers and calibration status.
- A listing of any defects found (or confirmation that none were found). As a minimum, this should include location, size/severity, and type of defect where possible.
- Where appropriate, images of the part and one or more ultrasonic images of the part and or defects.

The Sonatest mono-element flaw detectors do not attempt to produce full reports but do provide the ability to store and recall screen images for use in reporting. Several examples are shown earlier in this report.

With the Sonatest phased array products (Prisma, veo, veo+) and the attendant UTstudio software, there are a number of options:

1. The instrument itself can produce a PDF report based on the current display and selected parameters.
2. The UTstudio+ software can produce a PDF report based on the current display (which is highly configurable), plus selected parameters and an annotation table.
3. Individual 'windows' can be extracted from UTstudio via drag and drop into a suitable word processor document.

Examples of this are shown in Appendix B.

Appendix A:
Partial list of ultrasonic standards applicable for weld inspection

All revisions noted are current as of 2020, most of these standards are revised or reconfirmed periodically

	BS, EN, BS EN and BS ISO (For EN and ISO standards, other national/ translated implementations should be identical)
General provisions	ISO 10375:1997 Non-destructive testing – Ultrasonic inspection – Characterisation of search unit and sound field
	BS EN ISO 16810:2014 Non-destructive testing – Ultrasonic testing – General principles
Training	BS EN ISO 9712:2012 " Non-destructive testing. Qualification and certification of NDT personnel
Equipment and tools	BS EN ISO 2400:2012 Non-destructive testing – Ultrasonic testing – Specification for calibration block No 1
	BS EN ISO 7963:2010 Non-destructive testing – Ultrasonic testing – Specification for calibration block No 2
	BS EN 12668-1:2010 Non-destructive testing – Characterisation and verification of ultrasonic examination equipment – Part 1: Instruments
	BS EN 12668-2:2010 Non-destructive testing – Characterisation and verification of ultrasonic examination equipment – Part 2: Probes
	BS EN 12668-3:2013 Non-destructive testing – Characterisation and verification of ultrasonic examination equipment – Part 3: Combined equipment
	ISO 12710:2002 Non-destructive testing – Ultrasonic inspection – Evaluating electronic characteristics of ultrasonic test instruments
	ISO 12715:2014 Non-destructive testing – Ultrasonic testing – Reference blocks and test procedures for the characterisation of contact probe sound beams
	ISO 18175:2004 Non-destructive testing – Evaluating performance characteristics of ultrasonic pulse-echo testing systems without the use of electronic measurement instruments
	BS EN ISO 18563-1:2015 Non-destructive testing – Characterisation and verification of ultrasonic phased array equipment – Part 1: Instruments
	BS EN ISO 18563-2:2017 Non-destructive testing – Characterisation and verification of ultrasonic phased array equipment – Part 2: Probes
	BS EN ISO 18563-3:2015 Non-destructive testing – Characterisation and verification of ultrasonic phased array equipment – Part 3: Combined systems
	BS ISO 19675:2017 Non-destructive testing – Ultrasonic testing – Specification for a calibration block for phased array (PAUT)
Techniques	BS EN ISO 15626:2018 Non-destructive testing of welds – Time-of-flight diffraction technique (TOFD) – Acceptance levels
	BS EN ISO 16811:2014 Non-destructive testing – Ultrasonic testing – Sensitivity and range setting
	BS EN ISO 16826:2014 Non-destructive testing – Ultrasonic testing – Examination for discontinuities perpendicular to the surface
	BS EN ISO 16827:2014 Non-destructive testing – Ultrasonic testing – Characterisation and sizing of discontinuities

Special techniques	BS EN ISO 16828:2014 Non-destructive testing – Ultrasonic testing – Time-of-flight diffraction technique as a method for detection and sizing of discontinuities
	BS EN ISO 10863:2011 Non-destructive testing of welds – Ultrasonic testing – Use of time-of-flight diffraction technique (TOFD)
	BS EN ISO 15626:2013 Non-destructive testing of welds – Time-of-flight diffraction technique (TOFD) – Acceptance levels
	BS EN ISO 13588:2019 Non-destructive testing of welds – Ultrasonic testing – Use of automated phased array technology
Welds (w)	BS EN ISO 17640:2018 Non-destructive testing of welds – Ultrasonic testing – Techniques, testing levels and assessment
	BS EN ISO 22825:2017 Non-destructive testing of welds – Ultrasonic testing – Testing of welds in austenitic steels and nickel-based alloys
	BS EN ISO 23279:2017 Non-destructive testing of welds – Ultrasonic testing – Characterisation of indications in welds
	BS EN ISO 11666:2018 Non-destructive testing of welds – Ultrasonic testing – Acceptance levels
	ISO 19285:2017 Non-destructive testing of welds - Phased array ultrasonic testing (PAUT) - Acceptance levels
Tubes and pipes (t)	BS EN ISO 10893-8:2011 Non-destructive testing of steel tubes – Part 8: Automated ultrasonic testing of seamless and welded steel tubes for the detection of laminar imperfections
	BS EN ISO 10893-9:2011 Non-destructive testing of steel tubes – Part 9: Automated ultrasonic testing for the detection of laminar imperfections in strip/plate used for the manufacture of welded steel tubes
	BS EN ISO 10893-10:2011 Non-destructive testing of steel tubes – Part 10: Automated full peripheral ultrasonic testing of seamless and welded (except submerged arc-welded) steel tubes for the detection of longitudinal and/or transverse imperfections
	BS EN ISO 10893-11:2011 Non-destructive testing of steel tubes – Part 11: Automated ultrasonic testing of the weld seam of welded steel tubes for the detection of longitudinal and/or transverse imperfections
	BS EN ISO 10893-12:2011 Non-destructive testing of steel tubes – Part 12: Automated full peripheral ultrasonic thickness testing of seamless and welded (except submerged arc-welded) steel tubes
	BS ISO 10332:2010 Non-destructive testing of steel tubes – Automated ultrasonic testing of seamless and welded (except submerged arc-welded) steel tubes for verification of hydraulic leak-tightness
Terminology	BS EN ISO 5577:2017 Non-destructive testing – Ultrasonic testing – Vocabulary
	BS EN 16018:2011 Non-destructive testing – Terminology – Terms used in ultrasonic testing with phased arrays

Main US Standards
ASTM E114-15 Practice for Ultrasonic Pulse-Echo Straight-Beam Examination by the Contact Method
ASTM E164-19 Standard Practice for Contact Ultrasonic Testing of Weldments
ASTM E 317-16, Standard Practice for Evaluating Performance Characteristics of Ultrasonic Pulse- Echo Examination Instruments and Systems Without the Use of Electronic Measurement Instruments

ASTM E 494-15, Standard Practice for Measuring Ultrasonic Velocity in Materials.
ASTM E 543-15 Specification for Agencies Performing Nondestructive Testing
ASTM E 587-15(2020) , Standard Practice for Ultrasonic Angle-Beam Examination by the Contact Method.
ASTM E1316-20 Standard Terminology for Nondestructive Examinations
ASTM E1324-16 Guide for Measuring Some Electronic Characteristics of Ultrasonic Testing Instruments
ASTM E 1961-16 , Standard Practice for Mechanized Ultrasonic Examination of Girth Welds Using Zonal Discrimination with Focused Search Units.
ASTM E2373 / E2373M-19 Standard Practice for Use of the Ultrasonic Time of Flight Diffraction (TOFD) Technique
ASTM E2700-20 Standard Practice for Contact Ultrasonic Testing of Welds Using Phased Arrays
ASME Boiler and Pressure Vessel Code, Section V , 2019 – Nondestructive Examination
AWS D1.1: Structural Welding Code - Steel
API 1104: Welding of Pipelines and Related Facilities

Appendix B: Veo+ reporting

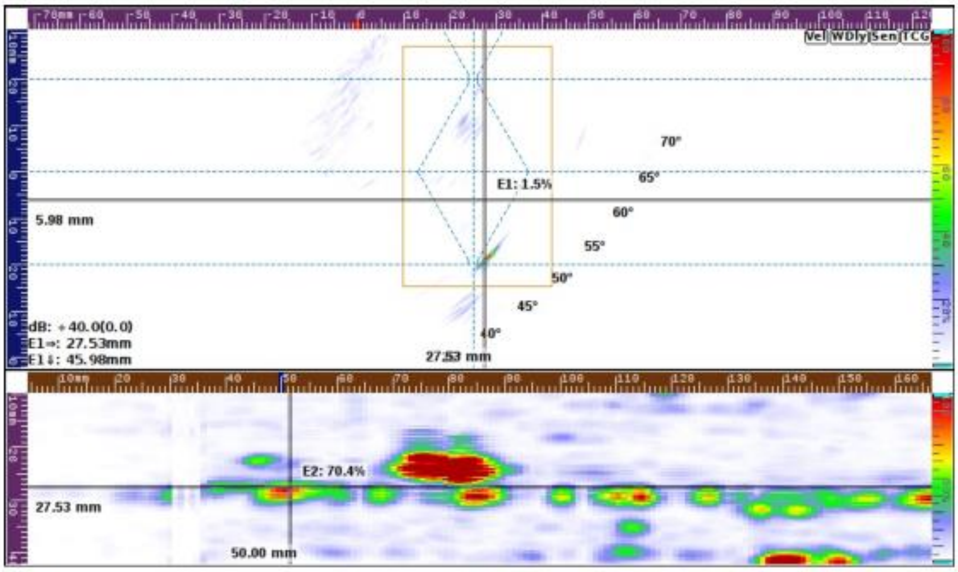
Direct pdf report from veo+

Veo+ Inspection Report

Software: blueorigin, Unit serial #: I016353

Component	Config File Name	File Vers.	Data File Vers.	Operator	Procedure Ref	Inspection Date
	single v weld _0004.utdata	11	1			2020-07-27 14:48:38

S1 - Sectorial PE Gain	N/A	N/A	N/A	N/A	N/A
40.0 dB					



Legend :

Abbrev.	Description
BPL	Path Length
D	Depth
SD	Surface Dist.
A	Amplitude
L	Length
DLT	Delta

*[Smoothing, Sub-Sampling]

Inspection	Info
Voltage Ar.	50 V
Probe 1 [Freq, Model]	5.00 MHz, X3A-5M64E-0.6x10
Wedge 1 [Velo, Model]	2.337 mm/µs, X3AW-N55S

Encoder Info	
Encoding Setup	Scan Axis Only
Enc. Name	N/A
Scan Enc Resol.	16.0000 ticks/mm

Part	Info
Material	Steel
Velocity [LW/SW]	5.890 mm/µs, 3.240 mm/µs
Part Geometry	Plate
Thickness	20.00 mm
Weld	Single V

Scan / Cursor	Value1	Value2	Value3	Value4
S1 S-Scan/E1	BPL 73.42 mm	D 45.98 mm	SD 27.53 mm	51.50°
S1 S-Scan/CH1	BPL 0.00 mm	D 80.68 mm	SD -52.32 mm	0.00°
S1 Top View/E2	---	---	SD 27.53 mm	S.Axis 50.00 mm
S1 Top View/CH2	---	---	SD 9.77 mm	S.Axis 6.64 mm

Scan S1 - Sectorial PE	Value
Signal Processing*	High, Auto: 1:4
Filters	Auto: wide high
Software Gain	0.0 dB
Gain , Ref	40.0 dB, 0.0 dB
Focal [Type, Dist]	Constant Path, 90.00 mm
Start/Stop Path	30.00 mm, 95.00 mm
Start/Stop Angle	35.00°, 70.00°
Acq. Freq.	125 MHz

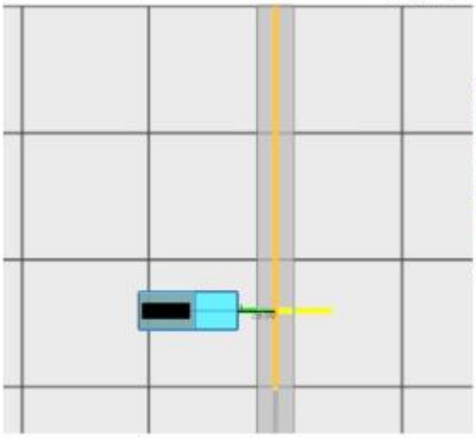
single v weld _0004_0001.pdf

Page 1

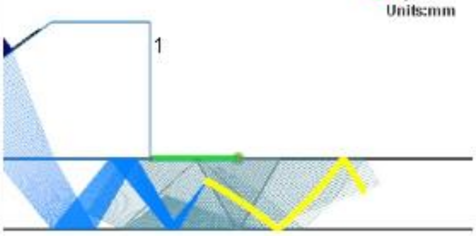
Veo+ Inspection Report

Software: blueorigin, Unit serial #: I016353

PLAN View
Units:mm



3D View
Part Datum
Wedge Ref
Grp Ref
Units:mm



Inspection					
Probe Qty	1	Encoded Axis Ref.	Wedge Reference	Qualification	N/A
Scan Qty	1	Job/Customer	N/A	Procedure Ref	N/A
Voltage Ar.	50 V	Site	N/A	Couplant	N/A
Alarms	Off	Operator	N/A		

Part					
Material	Steel	Velocity LW	5.890 mm/µs	Weld Root Gap	2.00 mm
Condition	N/A	Velocity SW	3.240 mm/µs	Weld Top Bevel Width	24.00 mm
Temperature	0.0°C	Cal. Block Serial #	N/A	Weld Face Left	0.95 mm
Component	N/A	Cal. Block Type	N/A	Weld Top Left Width	12.00 mm
Serial #	N/A	Cal. Block Sensibility Ref.	N/A	Weld Top Left Angle	30.00°
Location Ref	N/A	Rejection Criteria	N/A	Weld Top Left Height	19.05 mm
Part Geometry	Plate	Velocity SW	3.240 mm/µs		
Thickness	20.00 mm	Weld	Single V		

Probe P1 - Array 1D					
Probe Type	Array 1D	Elmt Size Dim 1	0.50 mm	Elmt Pitch Dim 1	0.60 mm
Manufacturer	Sonatest	Pulse Type	Square-Wave	Elmt Offset Dim 1	3.35 mm
Model #	X3A-5M64E-0.6x10	Pulse Width	100.00 ns	Elmt Offset Dim 2	6.50 mm
Serial #	N/A	First Elmt Pin #	1	Element Layout	Bottom Left Row
Frequency	5.00 MHz	Nb Elmt Dim 1	64	Elmt Size Dim 2	10.00 mm

Wedge P1 - Array 1D					
Type	Angular	Back Height	11.70 mm	Roof Angle	0.00°
Manufacturer	Sonatest	Cut Angle	36.00°	Probe Back Dist	0.00 mm
Model #	X3AW-N55S	Front Height	38.60 mm	Probe Side Dist	1.00 mm
Serial #	N/A	Width	25.00 mm	Probe Inset	0.00 mm
Contact Surface	Planar	Length	65.00 mm	Wedge Velocity LW	2.337 mm/µs

single v weld _0004_0001.pdf

Page 2

Veo+ Inspection Report

Software: blueorigin, Unit serial #: I016353

Scan S1 - Sectorial PE					
Type	Sectorial PE	Focal Mode	Constant Path	nbElementsUsedTx	32
Gain , Ref	40.0 dB, 0.0 dB	Focal Dist	90.00 mm	First Elmt RX	17
Software Gain	0.0 dB	Signal Rectification	Full	Last Elmt RX	48
Resolution	0.50°	Filters	Auto: wide high	Beam Qty.	71
Start Angle	35.00°	Sub-Sampling	Auto: 1:4	Sample Qty.	1256
Stop Angle	70.00°	Rejection	Disabled	Path Res.	19.3 spl/mm
Start Path	30.00 mm	Smoothing	High	Acq. Freq.	125 MHz
Range Path	65.00 mm	Contouring	No	Velocity Cal Status	None
Stop Path	95.00 mm	Probe TX/RX	P1 - Array 1D	Wedge Delay Cal Status	None
Zero	0.00 µs	Probe RX	P1 - Array 1D	Sensitivity Cal Status	None
Wave Mode	SW 3.240 mm/µs	First Elmt TX	17	Amp Tolerance	5.00%
Travel Mode	Half Path	Last Elmt TX	48		

Geometry					
W1 Index Off.	-25.00 mm	W1 Rotation	90.0°	Encoder Area CL Offset	0.00 mm
W1 Scan Off.	0.00 mm	Encoder Area CL Pos	0.00 mm	Encoder Area Rotation	0.00°

Encoder parameters					
Encoding Setup	Scan Axis Only	Scan Enc Resol.	16.0000 ticks/mm	Scan Step	1.00 mm
Enc. Name	N/A	Scan Start Pos	0.00 mm	Scan Invert Dir	Yes
Scan Axis Name	N/A	Scan Distance	250.00 mm	Data File Size	43.03 MB
Scan Enc Type	Quadrature	Scan Stop Pos	250.00 mm	Max Phys. Enc. Speed	70.4 mm/s

S1 S-Scan	BPL	Depth	SD	Angle	Beam	Peak	Delta
BX1[Top, Left]	---	12.94 mm	9.77 mm	---	---	---	---
BX1[Bot, Right]	---	64.60 mm	42.01 mm	---	---	---	---
Cartesian Extractor 1 (E1)	73.42 mm	45.98 mm	27.53 mm	---	---	1.5%	---

S1 Top View	SD	Scan Axis	Amplitude
Cartesian Extractor 2 (E2)	27.53 mm	50.00 mm	70.4%

Warning Messages	Value
Scan S1 - Sectorial PE	PRF above 1624 Hz may cause phantom echoes.

single v weld _0004_0001.pdf

Page 3 (End)

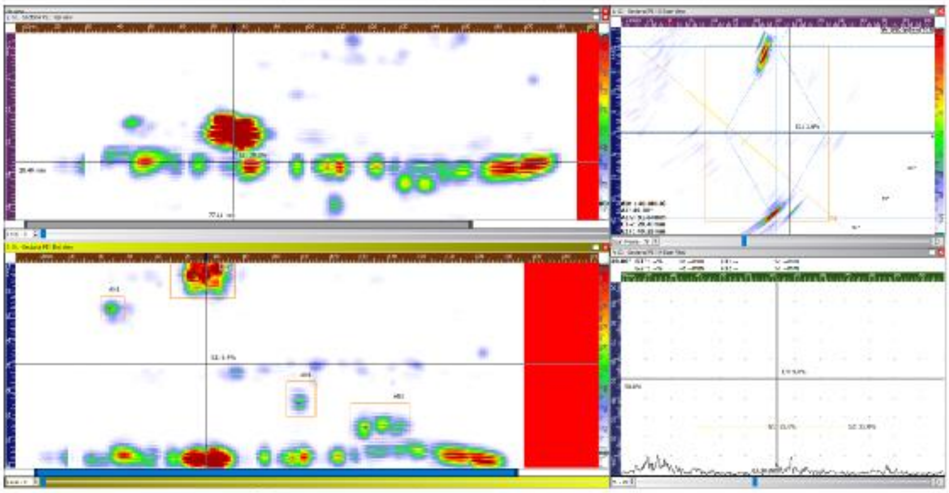
PDF report from UTstudio+

Veo+ Inspection Report

Software: 4.2.3, Unit serial #: I016353

Component	Config File Name	File Vers.	Data File Vers.	Operator	Procedure Ref	Inspection Date
	single v weld _0004.utdata	11	1			2020-07-27 14:48:38

S1 - Sectorial PE Gain	G1 ^ %FSH	G1 ^ [illegible]	G2 ^ %FSH	G2 ^ [illegible]	G1-G2 ^ [illegible]
40.0 dB	--	--	--	--	--



Legend :

Abbrev.	Description
BPL	Path Length
D	Depth
SD	Surface Dist.
A	Amplitude
L	Length
DLT	Delta

*[Smoothing, Sub-Sampling]

Inspection	Info
Voltage Ar.	50 V
Probe 1 [Freq, Model]	5.00 MHz, X3A5M64E-0.6x10
Wedge 1 [Velo, Model]	2.337 mm/µs, X3AW-N55S

Encoder Info	
Encoding Setup	Scan Axis Only
Enc. Name	N/A
Scan Enc Resol.	16.0000 ticks/mm

Part	Info
Material	Steel
Velocity [LW/SW]	5.890 mm/µs, 3.240 mm/µs
Part Geometry	Plate
Thickness	20.00 mm
Weld	Single V

Scan S1 - Sectorial PE	Value
Signal Processing*	High, Auto: 1:4
Filters	Auto: wide high
Software Gain	0.0 dB
Gain , Ref	40.0 dB, 0.0 dB
Focal [Type, Dist]	Constant Path, 90.00 mm
Start/Stop Path	30.00 mm, 95.00 mm
Start/Stop Angle	35.00°, 70.00°
Acq. Freq.	125 MHz

single v weld _0004.pdf

Page 1

Veo+ Inspection Report

Level X NDT

Software: 4.2.3, Unit serial #: I016353

Inspection					
Probe Qty	1	Encoded Axis Ref.	Wedge Reference	Qualification	N/A
Scan Qty	1	Job/Customer	N/A	Procedure Ref	N/A
Voltage Ar.	50 V	Site	N/A	Couplant	N/A
Alarms	Off	Operator	N/A		

Part					
Material	Steel	Velocity LW	5.890 mm/µs	Weld Root Gap	2.00 mm
Condition	N/A	Velocity SW	3.240 mm/µs	Weld Top Bevel Width	24.00 mm
Temperature	0.0°C	Cal. Block Serial #	N/A	Weld Face Left	0.95 mm
Component	N/A	Cal. Block Type	N/A	Weld Top Left Width	12.00 mm
Serial #	N/A	Cal. Block Sensibility Ref.	N/A	Weld Top Left Angle	30.00°
Location Ref	N/A	Rejection Criteria	N/A	Weld Top Left Height	19.05 mm
Part Geometry	Plate	Velocity SW	3.240 mm/µs		
Thickness	20.00 mm	Weld	Single V		

Geometry					
W1 Index Off.	-25.00 mm	W1 Rotation	90.0°	Encoder Area CL Offset	0.00 mm
W1 Scan Off.	0.00 mm	Encoder Area CL Pos	0.00 mm	Encoder Area Rotation	0.00°

	General		Cursor Position				Cursor Meas...	Defect Measurements		General
Name	View	Type	Δ Scan	Center Scan	Center Index	Center True Depth	Max dB REF	Scan 1	Δ Scan	Comment
AN1	3: S1 - Sectorial PE | End View	Box	8.22 mm	44.82 mm	--	11.03 mm• 2	-43.9 dB	41.73 mm	6.17mm	Porosity
AN2	3: S1 - Sectorial PE | End View	Box	21.73 mm	76.23 mm	--	16.58 mm• 2	-34.5 dB	71.29 mm	11.85mm	Root Crack
AN3	3: S1 - Sectorial PE | End View	Box	20.26 mm	137.16 mm	--	11.59 mm• 3	-41.4 dB	129.05 mm	17.22mm	LoF
AN4	3: S1 - Sectorial PE | End View	Box	10.47 mm	110.02 mm	--	7.28 mm• 3	-44.0 dB	106.88 mm	5.24mm	poss LoF?

single v weld _0004.pdf

Page 2 (End)

Veo+ reporting – relevant images extracted from UTstudio+ into Word

This can be customized in almost any way required. Here, we show the annotation table, the top view and the end view (which separates the suspected defects from the root noise more clearly); then, for each indication, we show a sector scan and the A-scan of the relevant indication.

#Data export from file	single v weld _0004.utdata				
#Application name	UTstudio+				
#Application version	4.2.3				
#Unit serial	I016353				
#UTDataFile	1.1				
#CSV File Version	1.3				
#Annotation Table :					
Name	Center True Depth	Max dB REF	Scan 1	Delta Scan	Comment
AN1	11.03 mm	-43.9 dB	41.73 mm	6.17mm	Porosity
AN2	16.58 mm	-34.5 dB	71.29 mm	11.85mm	Root Crack
AN3	11.59 mm	-41.4 dB	129.05 mm	17.22mm	LoF
AN4	7.28 mm	-44.0 dB	106.88 mm	5.24mm	poss LoF?

Figure 48: Formatted annotation table via Excel– this is saved as a .CSV file

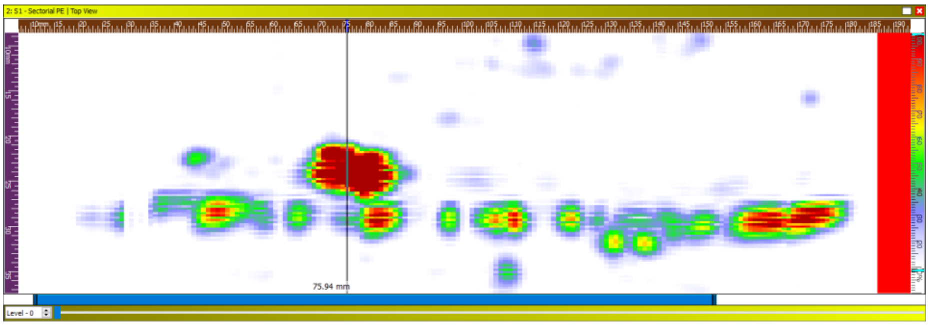


Figure 49: Top view of scanned weld

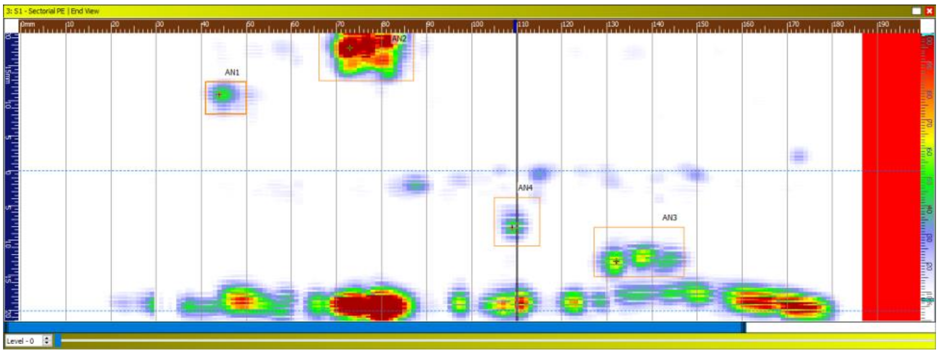
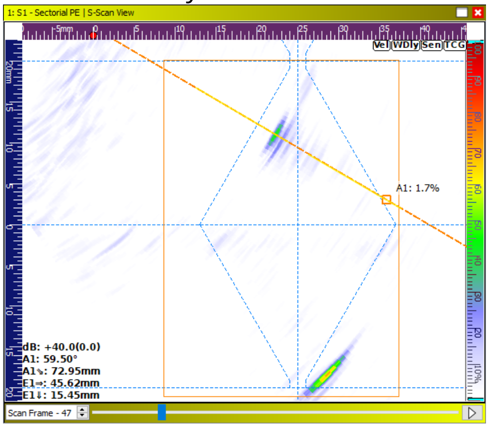


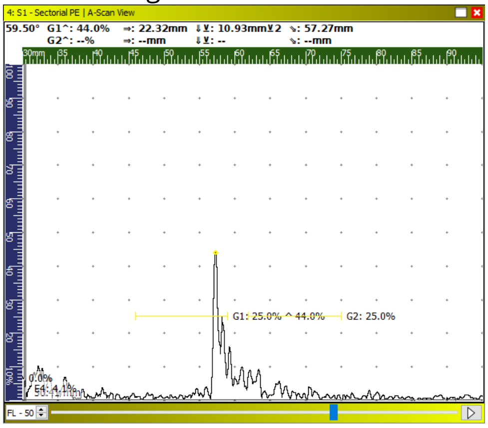
Figure 50: End view of scanned weld. Note that this view shows two 'skips' the weld root is shown at both top and bottom of the image, the weld crown is in the centre (reference line)

Individual defect sector scans and A-scans of defect

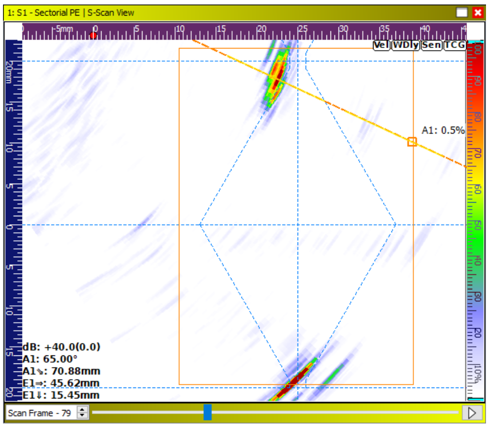
AN01 – Porosity in centre of weld

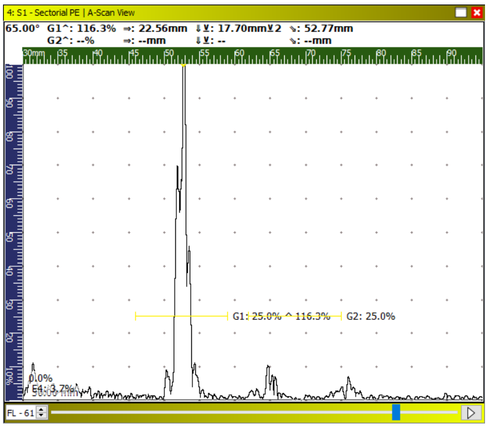


A-scan along extractor line

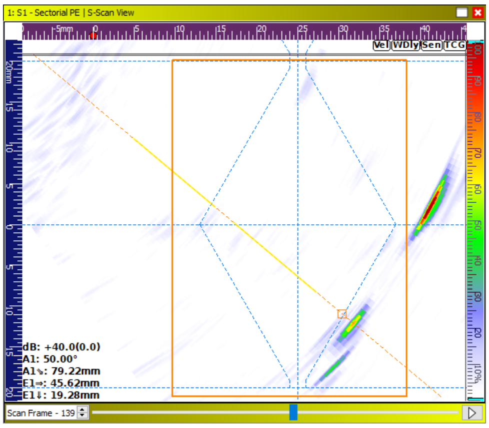


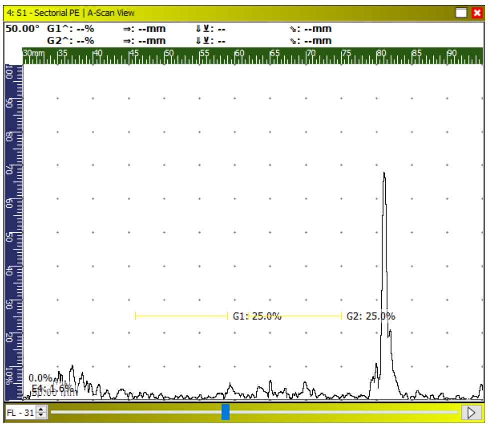
AN02 – Root crack - note that this is 'earlier' than the weld root 'noise'





AN03 - Lack of side wall fusion.





AN04 – Suspected LoF

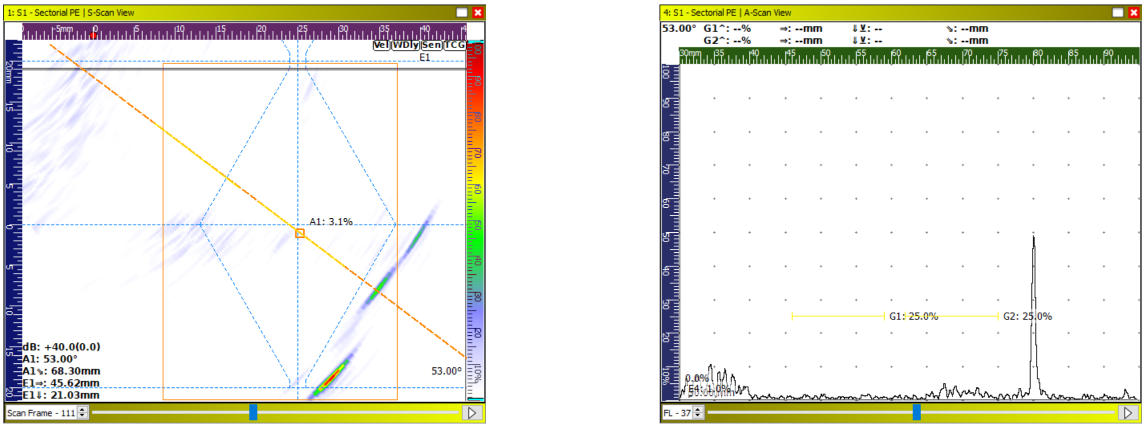


Figure 51: Sector and A-scans for individual indications

Note that these example scan images show indications only from one side; a complete report would, as well as the required inspection information, also show scans from the other side, ideally recorded simultaneously with a second probe in a suitable scanner arrangement.

