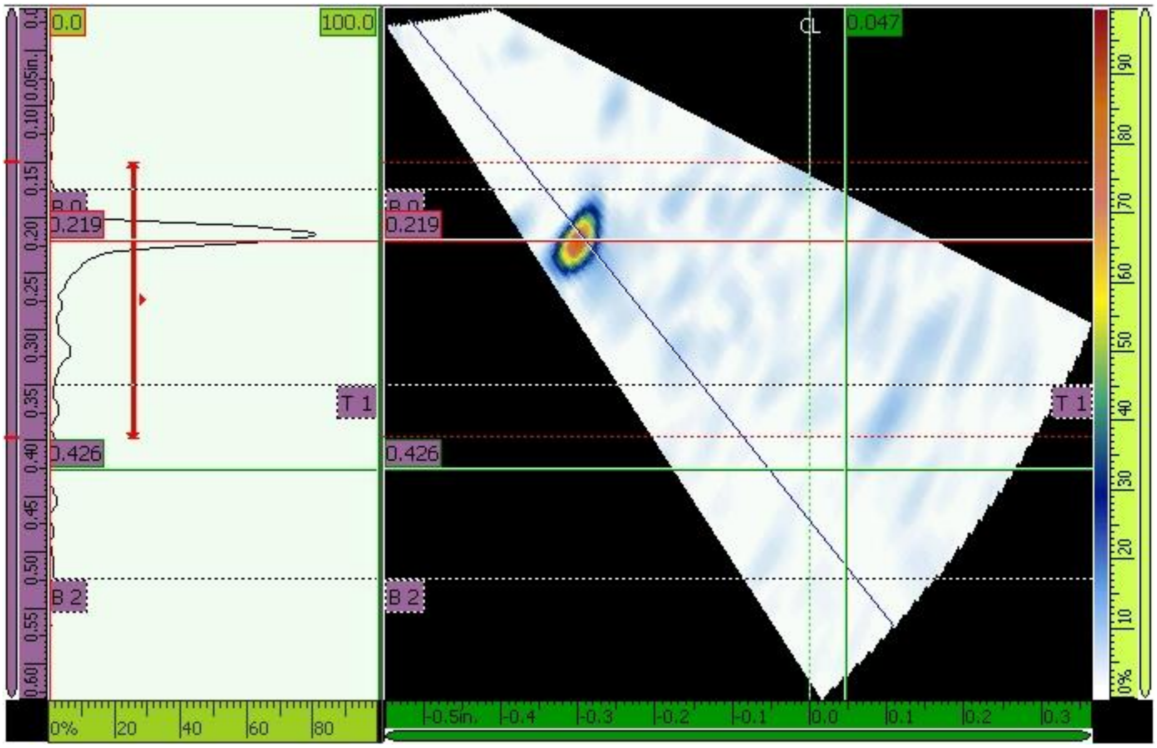
TechKnowServ™
TECHNOLOGY, KNOWLEDGE, SERVICE

Technical Report: Fort Peck Butterfly Valve#5 Inspection Report

FT. PECK PH#2 BUTTERFLY VALVE NDT
Req. # W59XQG92289457

Date: 5/5/2020



Prepared for: U.S. ARMY CORPS OF ENGINEERS OMAHA DIST.
CONTRACTING OFFICE
1616 CAPITOL AVENUE
OMAHA NE 68102-4901

Inspected by: Thomas R. Hay, P.E., ASNT Level 3#107162
TECHKNOWSERV CORP.
2134 Sandy Dr., Suite 14
State College PA, 16803
(814) 237-0144

TechKnowServ™ TECHNOLOGY, KNOWLEDGE, SERVICE

Executive Summary

Butterfly valve #5 was inspected in accordance with the statement of work (SOW) using visual inspection (VT), magnetic particle testing (MT), and phased array ultrasonic testing (PAUT).

In general, it was possible to prepare the surfaces of the of the upstream and downstream welds adequately to assess the condition of the welds with visual testing (VT), magnetic particle (MT) testing, and phased array ultrasonic testing (PAUT).

The exception was the circumferential weld that joined the two disc halves. The surface corrosion on this weld prevented VT, MT, and PAUT over almost the entire weld. In addition to the surface of the circumferential welds, the advanced corrosion and coating blistering was observed up to 6 inches into the shell surface. Upon conclusion of the Butterfly Valve # 5 inspection, the condition of the circumferential weld is largely unknown and may pose the most risk to the continued safe operation of the valve due to this uncertainty. Only a total of 177" of the circumferential weld were scanned with PAUT. Discontinuities over approximately 21" of this area that were not attributable to an inherent feature from the valve drawing. The discontinuities were approximately 1.25" deep from the skin surface. The indications were representative of a lamination or other planar defect parallel skin surface. The remainder of the circumferential weld was not inspected due to advanced corrosion and surface roughness.

The upstream and downstream valve welds were inspected visually for fabrication related cracks, weld/base metal fusion, craters, undercut and porosity. No observable fabrication related defects were noted. The upstream and downstream valve welds were inspected for in-service fatigue and corrosion related defects. No in-service related fatigue cracks were detected. One visual indication on the upstream weld had a linear indication that was followed up with MT to determine if it was a crack. The MT follow-up confirmed no crack was present.

The upstream and downstream valves were inspected with PAUT per the statement of work. Most areas that were scanned had tightly adhered coating that permitted adequate transfer of ultrasound into the valve shell. A fracture mechanics-based weld discontinuity evaluation was performed in accordance with ASME BPVC Mandatory Appendix VIII – Ultrasonic Examination Requirements for Fracture-Mechanics-Based Acceptance Criteria. All weld discontinuities sized using the 6 dB sizing technique in the length and height direction.

The upstream side contained 1 weld discontinuity longer than 1" and 3 weld discontinuities with a height greater than 0.375". The most severe discontinuity was found in weld S6b with a length of 11.100" and a height of 0.603 In addition, a possible in-service crack was detected at the root of weld S3b 0.917" long and 0.284" high.

The downstream side contained 6 weld discontinuities longer than 1" and 1 weld discontinuities with a height greater than 0.375". The most severe discontinuity was found in H2 with a length of 5.963" and a height of 0.301".

The following recommendations are presented for the next major valve maintenance event:

1. **Circumferential weld:** Remove lead paint with industry standard practices, blast to bare metal, and clean the circumferential weld and shell to at least 6 inches radially from the valve OD. Perform detailed VT, MT, and PAUT. Apply new coating system to these areas after inspection.

   Particular attention should be dedicated to the two areas, C1 and C2, in which discontinuities were detected with PAUT. If the USACE elects to blast and clean the circumferential welds, the surface should be inspected for geometric features at 1.25" from the skin surface. C1 and C2 were located 30-45" and 60-66", respectively, from Weld V2 in the clockwise direction looking at the downstream face.

2. **Upstream Side Weld S3b**: A possible in-service fatigue crack was detected in Weld S3b at the weld root. It is recommended to remove lead paint with industry standard practices, blast to bare metal, and clean the weld area for follow-up inspection at the next maintenance event.

3. **Welds and shell with corrosion and blistering:** Remove lead paint with industry standard practices, blast to bare metal, and clean all welds on which coating breakdown and corrosion were observed and perform a detailed inspection in accordance with AWS D1.1. Additional welds may need to be considered at the time of the maintenance event. Apply new coating system to these areas after inspection.

4. **Re-asses risk matrix color-coded red welds after abatement, blasting, and cleaning:** Perform encoded PAUT to more accurately locate and size the weld discontinuities. Apply new coating system to these areas after inspection. Re-assess possible repair action after new sizing data is made available. Determine if discontinuity has grown and, if so, repair immediately.

5. **For all welds with intermittent weld discontinuities:** Remove lead paint with industry standard practices, blast to bare metal, and clean the weld surfaces 6" back from the toe. Perform encoded PAUT to determine if intermittent weld discontinuities detected are indeed intermittent or instead a longer continuous weld discontinuity.

The objective of abatement, blasting to bare metal, cleaning, and applying the new coating system to the valve surfaces, where necessary, is to prolong the fatigue life of the valve components by reducing stress concentrations and the likelihood of slip by dislocation movements at the corroded surfaces. Fatigue related slip and dislocation movement are more likely to occur at corroded versus smooth surfaces.

The objective of PAUT scanning on abated, cleaned and blasted surface is fourfold.

1. It will eliminate and false positives that may occur due to surface conditions. Rough and uneven surfaces may cause false indications that appear in the welds tested.

2. The size and location of the weld discontinuities will be more accurate for potential repair action.

3. It will determine if flaw is active and growing or inactive and stable.

4. Thirdly, it will determine it if many of the smaller intermittent weld discontinuities detected are indeed intermittent or indicative of longer continuous weld discontinuities that were not detected due to surface roughness and data loss.

Some comments on lessons learned:

- The USACE's objective to evaluate the welds in accordance with the SOW was largely successful with the exception of the circumferential weld and limited horizontal splice welds, vertical welds joining disc plate to disc hub, horizontal welds joining disc plate to disc hub, diagonal welds, and O welds that exhibited blistering and surface corrosion that prevented inspection.

- In general, the coating on the butterfly valve tightly adhered to the shell surface and permitted ultrasound transfer into the test piece to produce weld discontinuity reflection at adequate signal-to-noise ratios. For future inspections, this demonstrated that PAUT inspection is possible on coated surfaces.

- The surface conditions had more of an impact on inspection sensitivity than originally expected. While the scan plan cited +6dB scanning gain it was determined that up to 20 dB was needed in some cases to scan at sensitivity level that was judged adequate by the inspector. For this reason, it would be advisable to have a PAUT contractor on-site prior to and during future repairs if deemed necessary.

- Does the value added by abatement and blasting on the PAUT results justify performing these steps before the non-destructive testing? The overall coverage and performance of all NDT processes would be enhanced if abatement and blasting were performed beforehand. The cost of the abatement and blasting, however, my be leveraged into a longer fatigue service life through minimization of corrosion related fatigue phenomena.

- The butterfly valve was built in 1960 to neither ASME Boiler and Pressure Vessel Code or AWS D1.1 code, but rather Williamette Iron and Steel Company Welding Procedure A-3385. Stress relief was carried out to ASME VIII. The statement of work required inspection to ASME BPVC Sec. V. The welds inspected with PAUT were non-traditional in terms of the current ASME BPVC PAUT inspection market which are largely larger circumferential girth and seam welds compare to the T- and corner style welds on the valve. Therefore, if it was the goal of the USACE to adopt a standard to which this valve should be inspected, it may be more advisable to adopt AWS D1.1 due to the style of welds. However, a fracture mechanics approach may be more advisable so that analyses can focus on targeted flaw sizes and desired safety factors specific to the butterfly valve.

Table of Contents

1 Introduction

Butterfly valve weld # 5 was inspected in accordance with the statement of work (SOW) using visual inspection (VT), magnetic particle testing (MT), and phased array ultrasonic testing (PAUT). For reporting purposes, the upstream and downstream weld identification schemes shown in Figure 1.1 and 1.2 were used.

Figure 1.1 is the upstream view of the butterfly valve showing the location and IDs of the horizontal splice welds joining disc plates to the ribs (S1-S13), vertical welds joining disc plate to disc hub (V1-V8), and horizontal welds joining disc plate to disc hub (H1-H2).

Figure 1.2 is the downstream view of the butterfly valve showing the location and IDs of, vertical welds joining disc plate to disc hub (V1-V4), and horizontal welds joining disc plate to disc hub (H1-H2), diagonal welds (X1-X4), and O welds (O1-O4).

.

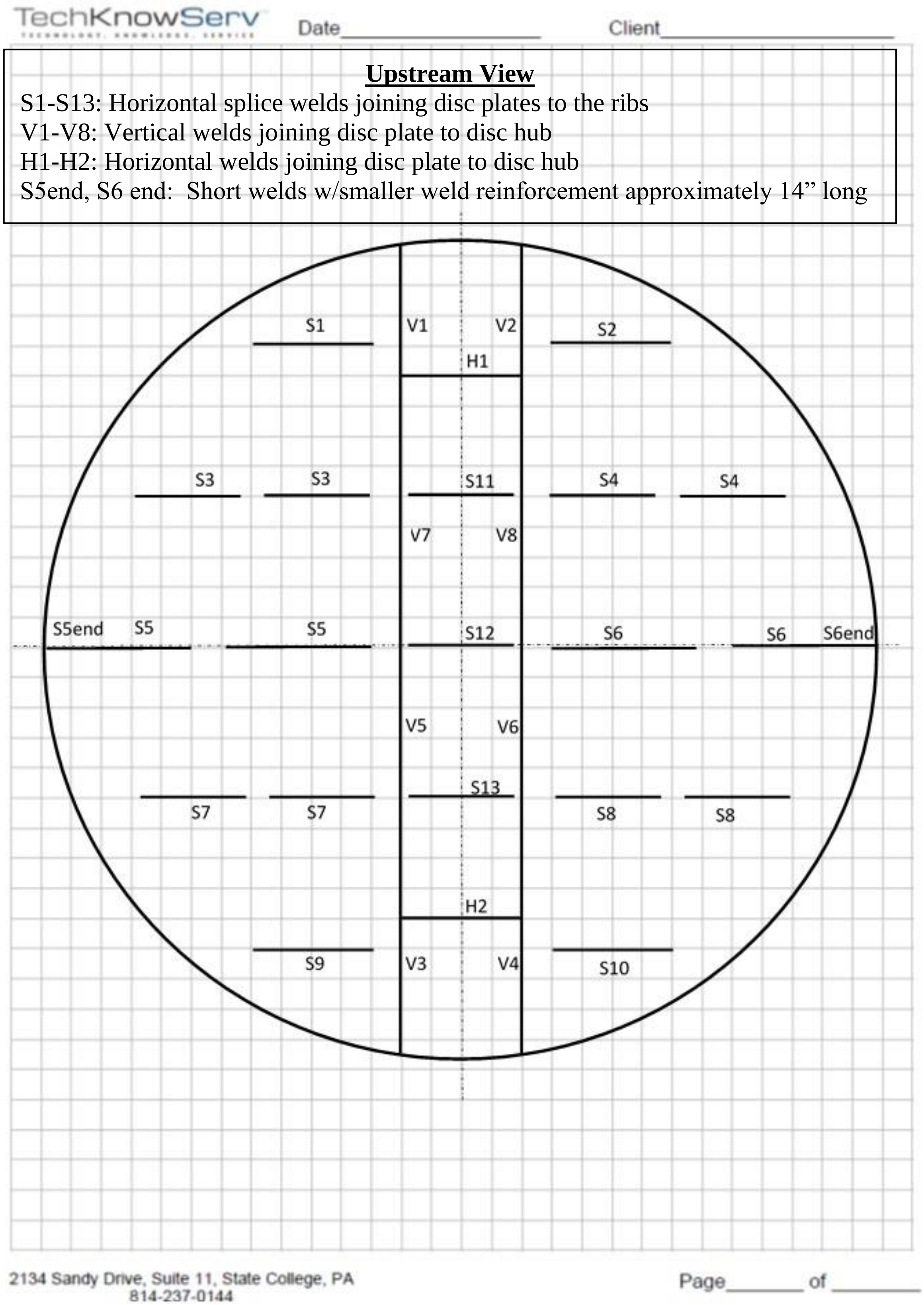


Figure 1.1: Butterfly valve # 5 upstream view.

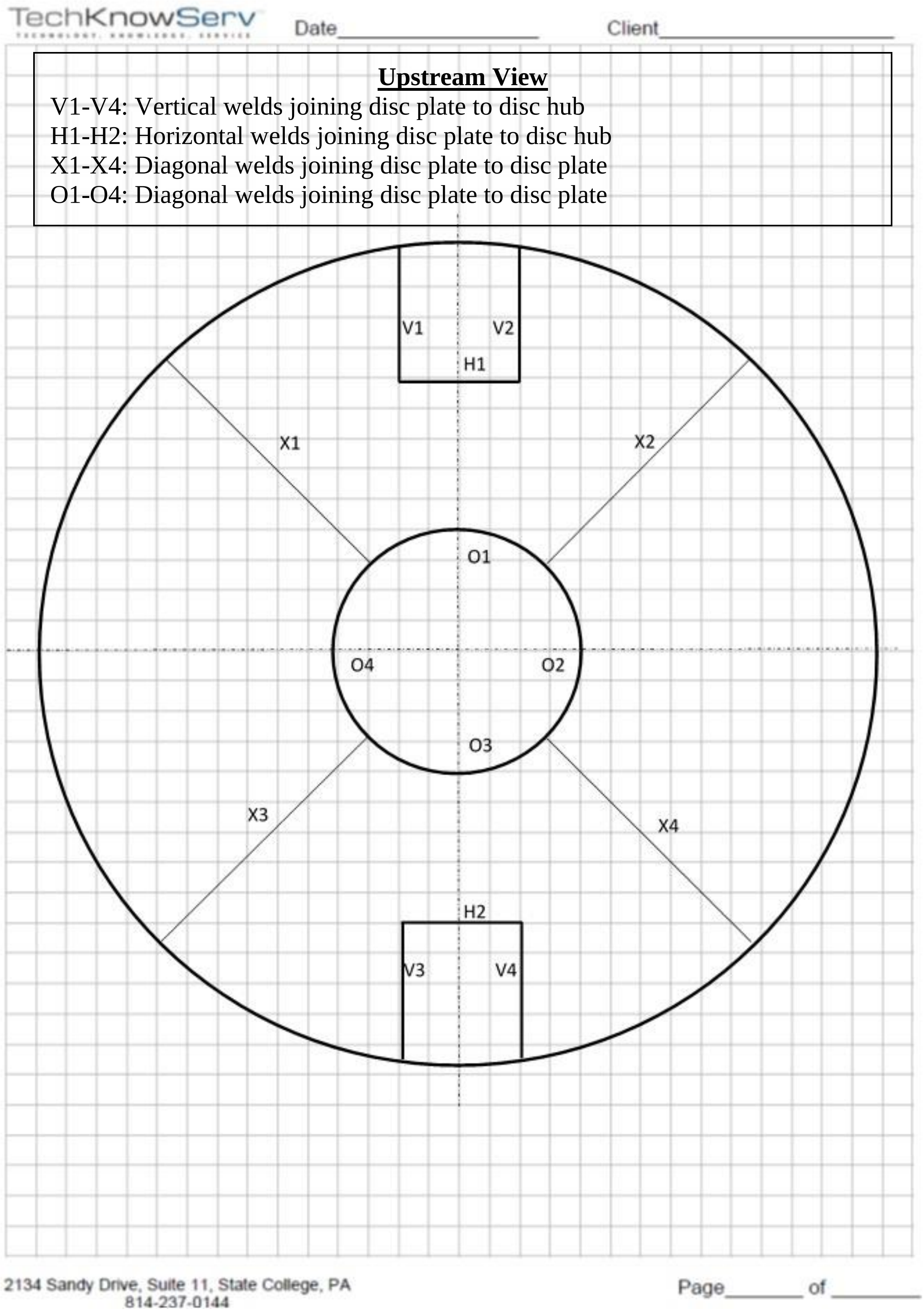


Figure 1.2: Butterfly valve # 5 downstream view.

2 Visual Inspection

A visual inspection of Butterfly Valve 5 was performed on 10/03/19 – 10/08/19 in accordance with ASME BPVC Sec. V. AWS D1.1 Table 6.1 Visual Inspection Acceptance Criteria and ASME BPVC VIII Table 7.6 Visual Examination Acceptance Criteria for fabrication related weld defects were considered during the inspection and reporting process. The AWS D1.1 and ASME BPVC acceptance criteria are presented in Figures 2.1 and 2.2. A summary of the inspection results relative to AWS D1.1 and ASME BPVC VII Table 7.6 are shown in Tables 2.1 and 2.2.

Table 2.1: Summary of AWS D1.1 Table 6.1 Visual Inspection Criteria

Weld Defect Type	**Status**	**Comments**
Crack Prohibition	Pass	
Weld/Base Metal Fusion	Pass	
Crater Cross-section	Pass	
Weld profiles	N/A	Weld profiles not measured
Undersized welds	N/A	Fillet welds only
Undercut	Pass	
Porosity	Pass	

Table 2.2: Summary of ASME BPCV VIII Table 7.6 Visual Examination Acceptance Criteria

Weld Defect Type	**Status**	**Comments**
Gas Cavity/Shrinkage Cavity	Pass	
Inclusions	Pass	
Incomplete fusion	Pass	
Lack if penetration	Pass	
Weld reinforcement	N/A	Weld profiles not measured
Undercut	Pass	
Porosity	Pass	

Upstream weld S3a had a 1.5" linear indication along the bottom of the weld toe was followed up with MT to determine if it was a crack. The MT follow-up confirmed no crack was present.

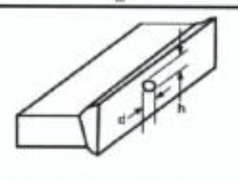
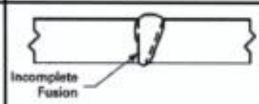
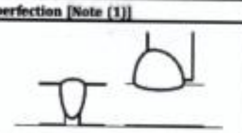
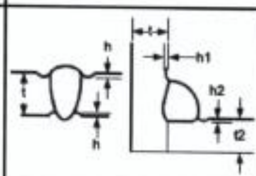
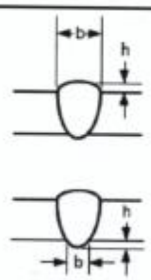
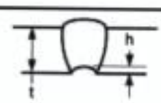
Table 6.1
Visual Inspection Acceptance Criteria (see 6.9)

Discontinuity Category and Inspection Criteria	Statically Loaded Nontubular Connections	Cyclically Loaded Nontubular Connections	Tubular Connections (All Loads)
(1) Crack Prohibition Any crack shall be unacceptable, regardless of size or location.	X	X	X
(2) Weld/Base-Metal Fusion Complete fusion shall exist between adjacent layers of weld metal and between weld metal and base metal.	X	X	X
(3) Crater Cross Section All craters shall be filled to provide the specified weld size, except for the ends of intermittent fillet welds outside of their effective length.	X	X	X
(4) Weld Profiles Weld profiles shall be in conformance with 5.24.	X	X	X
(5) Time of Inspection Visual inspection of welds in all steels may begin immediately after the completed welds have cooled to ambient temperature. Acceptance criteria for ASTM A 514, A 517, and A 709 Grade 100 and 100 W steels shall be based on visual inspection performed not less than 48 hours after completion of the weld.	X	X	X
(6) Undersized Welds The size of a fillet weld in any continuous weld may be less than the specified nominal size (L) without correction by the following amounts (U): L, specified nominal weld size, in [mm] — U, allowable decrease from L, in [mm] ≤ 3/16 [5] — ≤ 1/16 [2] 1/4 [6] — ≤ 3/32 [2.5] ≥ 5/16 [8] — ≤ 1/8 [3] In all cases, the undersize portion of the weld shall not exceed 10% of the weld length. On web-to-flange welds on girders, underrun shall be prohibited at the ends for a length equal to twice the width of the flange.	X	X	X
(7) Undercut (A) For material less than 1 in [25 mm] thick, undercut shall not exceed 1/32 in [1 mm], with the following exception: undercut shall not exceed 1/16 in [2 mm] for any accumulated length up to 2 in [50 mm] in any 12 in [300 mm]. For material equal to or greater than 1 in [25 mm] thick, undercut shall not exceed 1/16 in [2 mm] for any length of weld.	X		
(B) In primary members, undercut shall be no more than 0.01 in [0.25 mm] deep when the weld is transverse to tensile stress under any design loading condition. Undercut shall be no more than 1/32 in [1 mm] deep for all other cases.		X	X
(8) Porosity (A) CJP groove welds in butt joints transverse to the direction of computed tensile stress shall have no visible piping porosity. For all other groove welds and for fillet welds, the sum of the visible piping porosity 1/32 in [1 mm] or greater in diameter shall not exceed 3/8 in [10 mm] in any linear inch of weld and shall not exceed 3/4 in [20 mm] in any 12 in [300 mm] length of weld.	X		
(B) The frequency of piping porosity in fillet welds shall not exceed one in each 4 in [100 mm] of weld length and the maximum diameter shall not exceed 3/32 in [2.5 mm]. Exception: for fillet welds connecting stiffeners to web, the sum of the diameters of piping porosity shall not exceed 3/8 in [10 mm] in any linear inch of weld and shall not exceed 3/4 in [20 mm] in any 12 in [300 mm] length of weld.		X	X
(C) CJP groove welds in butt joints transverse to the direction of computed tensile stress shall have no piping porosity. For all other groove welds, the frequency of piping porosity shall not exceed one in 4 in [100 mm] of length and the maximum diameter shall not exceed 3/32 in [2.5 mm].		X	X

Note: An "X" indicates applicability for the connection type; a shaded area indicates non-applicability.

Figure 2.1: AWS D1.1 Table 6.1 Visual Inspection Acceptance Criteria

Table 7.6
Visual Examination Acceptance Criteria

No.	Type of Imperfection [Note (1)]		Acceptance Criteria
1	Cracks (all)	...	Not permitted.
2	Gas cavity (all) Shrinkage cavity (all)		Not permitted.
3	Slag inclusions (all) Flux inclusions (all) Oxide inclusions (all) Metallic inclusions (all)	...	Not permitted when occurring at the surface [Note (2)].
4	Incomplete fusion (all)		Not permitted.
5	Lack of penetration		Not permitted if a complete penetration weld is required.
6	Undercut		Refer to 6.2.4.1(b)(2) for acceptable undercut. Requirements in 7.5.3.2 to permit proper interpretation of radiography shall also be satisfied.
7	Weld reinforcement		Acceptable weld reinforcement in butt welding joints shall be in accordance with 6.2.4.1(d). A smooth transition is required.
8	Joint offset	...	Refer to 6.1.6 for acceptable offset in butt-welded joints.
9	Peaking	...	Refer to 6.1.6 for acceptable peaking in butt welding joints.
10	Stray flash or arc strike	...	Not permitted [Note (2)].
11	Spatter	...	Spatter shall be minimized [Note (2)].
12	Torn surface Grinding mark Chipping mark	...	Not permitted [Note (2)].
13	Concavity		Refer to 6.2.4.1(d) for acceptable concavity.

NOTES:
(1) The following symbols are used in this Table:

a = nominal fillet weld throat thickness
b = width of weld reinforcement
d = diameter of pore
h = height of imperfections
t = wall or plate thickness

(2) These imperfections may be removed by blend grinding.

Figure 2.2: ASME BPVC VIII Table 7.6 Visual Examination Acceptance Criteria

2.1 Weld Preparation

In accordance with the SOW, the welded region was cleaned for visual inspection and base metal inspection. The base metal was cleaned to approximately 6” from the weld toe. To remove the organic film and surface scale the following procedure was used:

- Scrub surface with an industrial grade plastic bristle scrub brush and water
- Scrub surface with steel wire brush surface to loosen organic film
- Rinse and clean surface with an industrial grade plastic bristle scrub brush and water
- Wipe down with rag and assess surface quality
- Repeat previous steps as required

Lead paint was not removed from the surface during this process.

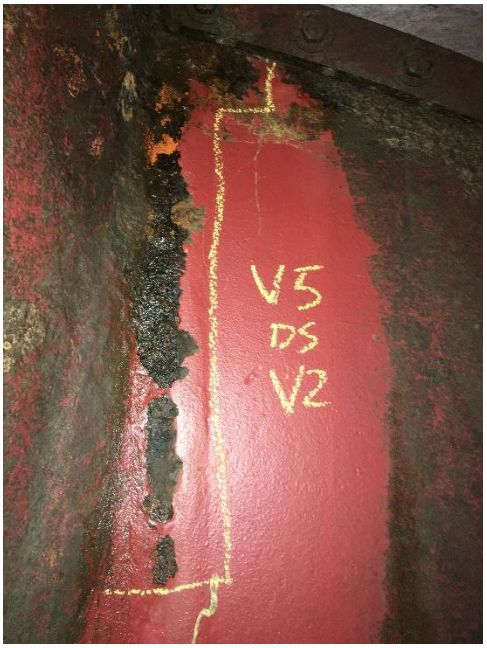


Figure 2.3: Example cleaned surfaces on Valve 5 downstream weld V2.

2.2 Weld Visual Inspection Results

The locations of the notable coating breakdown and surface corrosion on the upstream and downstream sides are shown in Figures 2.4 and 2.5, respectively, via the yellow areas superimposed onto the valve welds. Details on each weld are presented in Table 2.3.

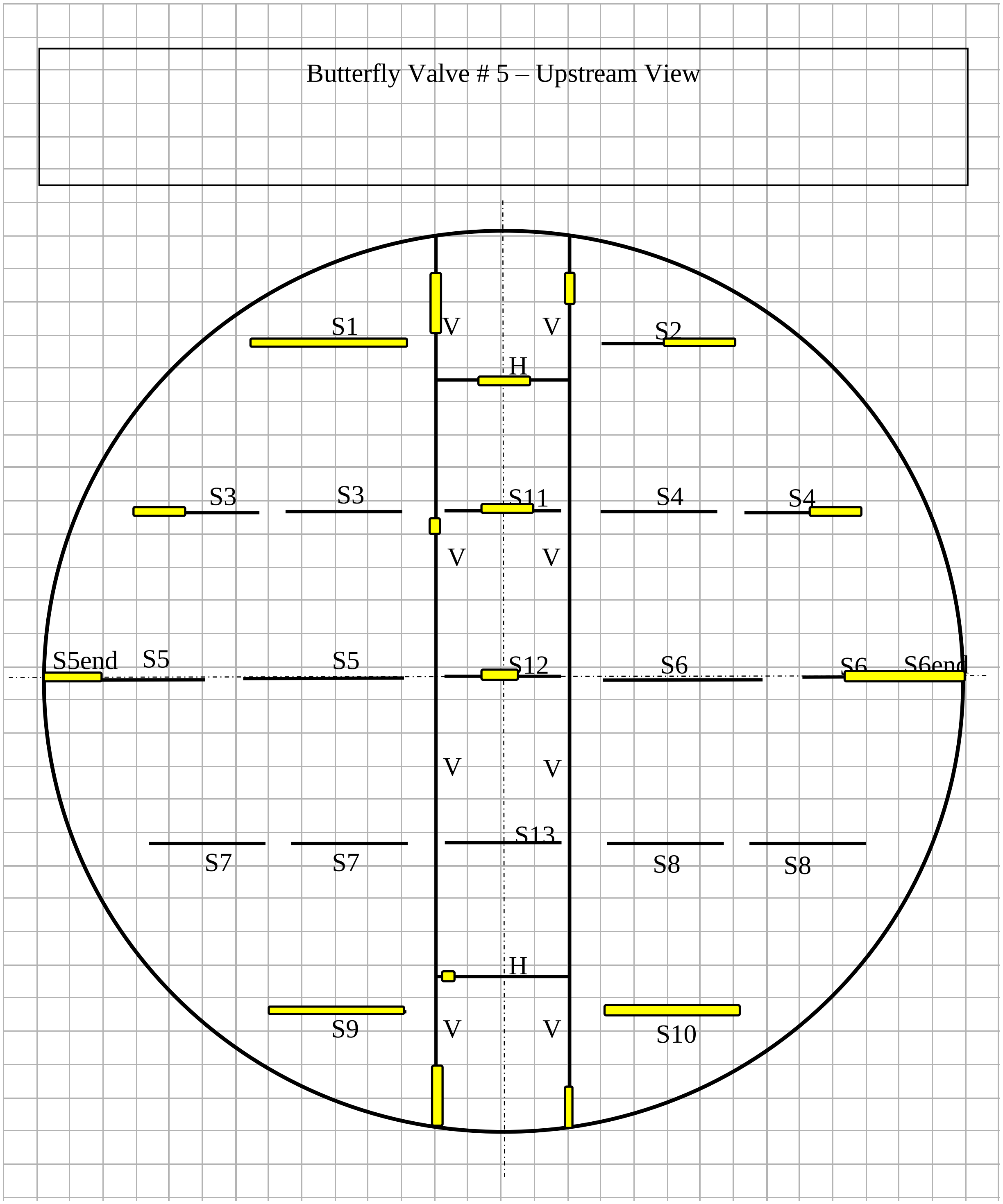


Figure 2.4: Locations of coating breakdown and surface corrosion on Valve 5 upstream side.

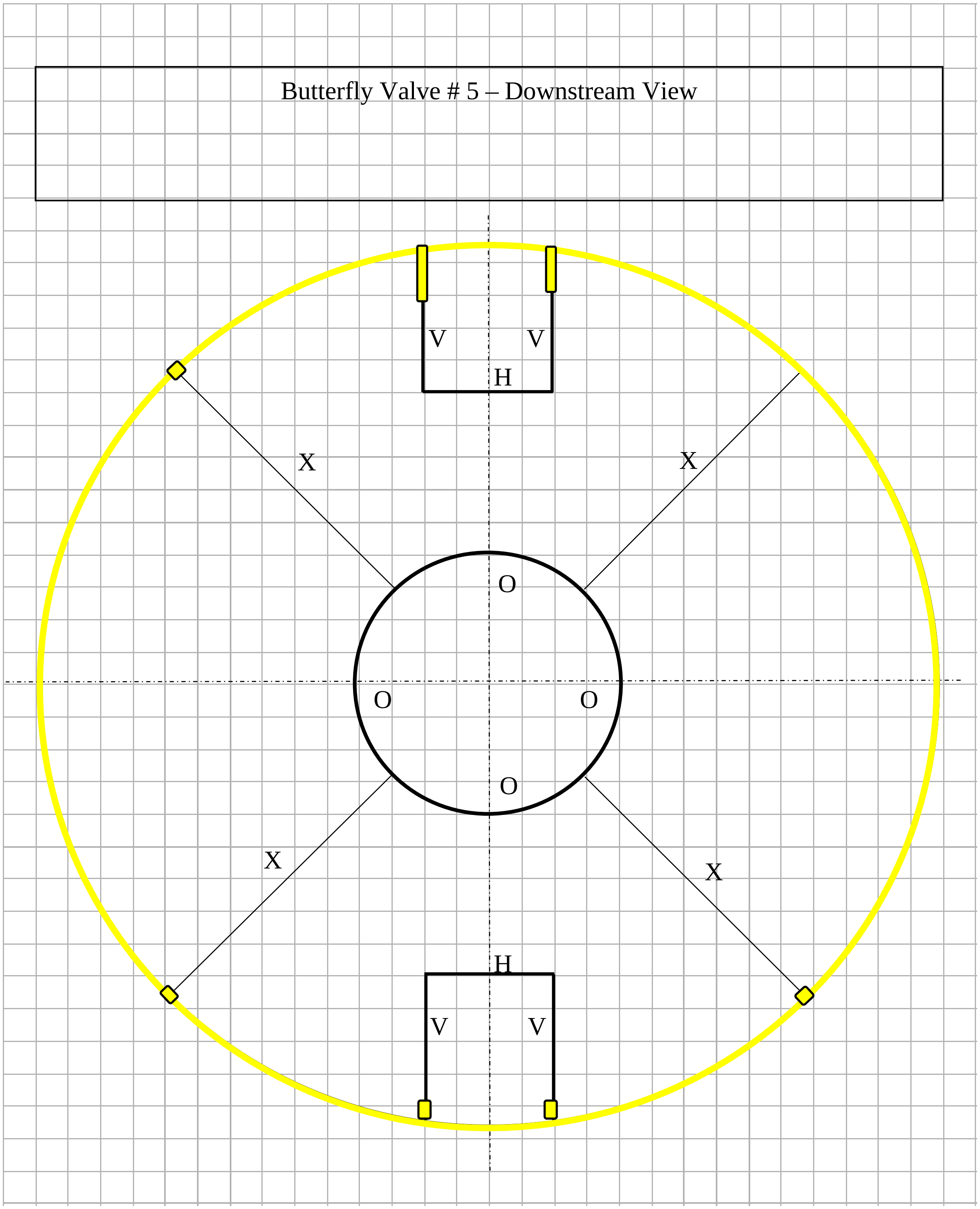


Figure 2.5: Locations of coating breakdown and surface corrosion on Valve 5 downstream side.

Table 2.3: Visual Inspection Summary of Valve #5	
Valve 5 Upstream Side	
Weld	Comments
S1	Advanced blistering and surface corrosion over length of weld. 
S2	Blistering and surface corrosion at 20”- 40” from left to right. Coating in good condition over remainder of weld. 

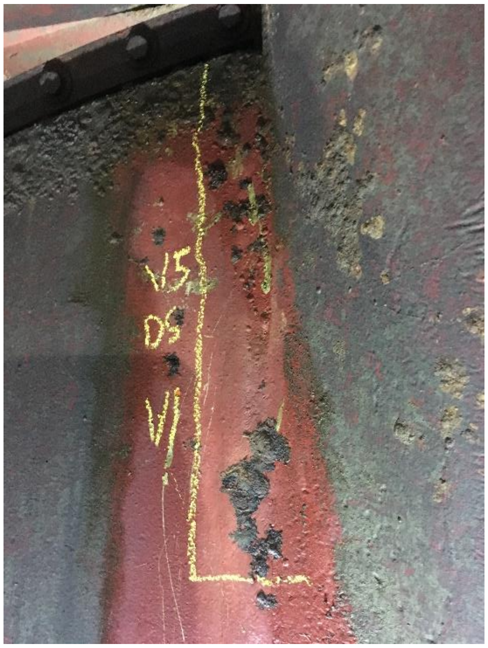
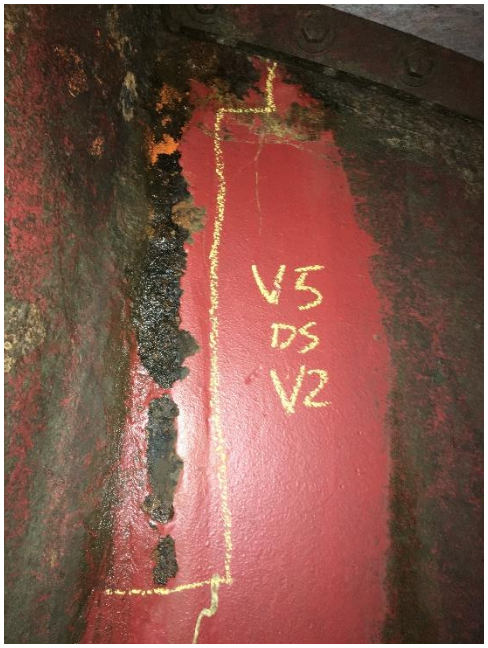
S3	Blistering and surface corrosion at 0”- 10” from left to right. Coating in good condition over remainder of weld. 
S4	Blistering and surface corrosion at 20”- 40” from left to right. Coating in good condition over remainder of weld. 

S5	Blistering and surface corrosion at 0"- 20" from left to right. Coating in good condition over remainder of weld. 
S6	Blistering and surface corrosion at 40" to end of weld from left to right. Coating in good condition over remainder of weld. 
S7	No blistering or surface corrosion, coating in good condition over length of weld.
S8	No blistering or surface corrosion, coating in good condition over length of weld.

S9	Intermittent blistering and surface corrosion over length of weld. 
S10	Intermittent blistering and surface corrosion over length of weld. 

S11	Intermittent blistering and surface corrosion over length of weld. 
S12	Intermittent blistering and surface corrosion 16”-24” from left to right.
S13	No blistering or surface corrosion, coating in good condition over length of weld.
V1	Blistering and surface corrosion at 21”- 41” from top of weld. Coating in good condition over remainder of weld. 

V2	Intermittent blistering and surface corrosion 13”-25” from top of weld. Coating in good condition over remainder of weld. 
V3	24” of blistering and surface corrosion at bottom of weld. Coating in good condition over remainder of weld.
V4	14” of blistering and surface corrosion at bottom of weld. Coating in good condition over remainder of weld.
V5	No blistering or surface corrosion, coating in good condition over length of weld.
V6	No blistering or surface corrosion, coating in good condition over length of weld.
V7	1.5” diameter surface corrosion, 0.040” depth, 12” from top of weld.
V8	No blistering or surface corrosion, coating in good condition over length of weld.
H1	Intermittent blistering and surface corrosion over length of weld. 
H2	0.25” diameter pitting, 0.0625” depth on left side of weld, Coating in good condition over remainder of weld.

Valve 5 Downstream Side	
V1	23” of blistering and surface corrosion from top of weld. Coating in good condition over remainder of weld. 
V2	21” of blistering and surface corrosion from top of weld. Coating in good condition over remainder of weld. 
V3	8” of blistering and surface corrosion at bottom of weld. Coating in good condition over remainder of weld.

V4	8” of blistering and surface corrosion at bottom of weld. Coating in good condition over remainder of weld. 
X1	6” of blistering and surface corrosion at end of weld towards OD. Coating in good condition over remainder of weld. See X2 picture for reference.
X2	5” of blistering and surface corrosion at end of weld towards OD. Coating in good condition over remainder of weld. 

X3	6" of blistering and surface corrosion at end of weld towards OD. Coating in good condition over remainder of weld. See X2 picture for reference.
X4	6"of blistering and surface corrosion at end of weld towards OD. Coating in good condition over remainder of weld. See X2 picture for reference.
O1	No blistering or surface corrosion, coating in good condition over length of weld.
O2	No blistering or surface corrosion, coating in good condition over length of weld.
O3	No blistering or surface corrosion, coating in good condition over length of weld.
O4	No blistering or surface corrosion, coating in good condition over length of weld.

Circumferential Weld	
Circ	Weld showed advanced blistering and surface corrosion over entire circumference. 

2.3 Visual Inspection Summary

The upstream and downstream valve welds were inspected for fabrication related cracks, weld/base metal fusion, craters, undercut and porosity. No observable fabrication related defects were noted.

The upstream and downstream valve welds were inspected for in-service fatigue and corrosion related defects. No in-service related fatigue cracks were detected. Numerous areas of coating breakdown and surface corrosion and/or on-set of surface corrosion were observed on upstream and downstream welds. The entire circumferential weld joining disc halves showed advanced corrosion and coating breakdown.

Magnetic particle testing (MT) was performed on the upstream and downstream sides of butterfly valve in accordance with the statement-of-work. There were no cracks detected with MT.

WFMT was not performed on the circumferential weld joining the disc halves due to the surface conditions described in the visual inspection report.

The following recommendations are presented for the next major valve maintenance event:

1. Remove lead paint with industry standard practices, blast to bare metal, and clean the circumferential weld and shell to at least 6 inches radially from the valve OD. Perform a detailed visual inspection in accordance with AWS D1.1 guideline. Magnetic particle test same areas. Apply new coating system to these areas after inspection.

2. Remove lead paint with industry standard practices, blast to bare metal, and clean all welds on which coating breakdown and corrosion were observed and perform a detailed inspection in accordance with AWS D1.1. Additional welds may need to be considered at the time of the maintenance event. Apply new coating system to these areas after inspection.

3. Remove lead paint with industry standard practices, blast to metal, and clean all shell areas that exhibit coating breakdown and corrosion. Apply new coating system to these areas after inspection.

The objective of abatement, blasting to bare metal, cleaning, and applying the new coating system to the valve surfaces, where necessary, is to prolong the fatigue life of the valve components by reducing stress concentrations and the likelihood of slip by dislocation movements at the corroded surfaces. Fatigue related slip and dislocation movement is more likely to occur at corroded versus smooth surfaces.

3 Magnetic Particle Testing Results

Magnetic particle testing (MT) was performed on the upstream and downstream sides of butterfly valve in accordance with the statement-of-work. There were no cracks detected with MT.

Wet fluorescent magnetic particle testing (WFMT) was performed on 100% of the tension side (downstream side), and 25% of the upstream side, of the vertical and horizontal welds joining the disc plates to the disc hub "casting". (Reference drawing H-4075, assembly side view, Detail J, and Section F-F).

WFMT was performed on at least 50% of all horizontal splice welds (plug and butt type) joining the disc plates to the ribs, on the upstream side and 100% of same welds on the downstream side.

WFMT was not performed on the circumferential weld joining the disc halves due to the surface conditions described in the visual inspection report.

WFMT was performed on approximately 95% of the he "X" and "O" splice welds located on the upstream side of the disc weldment. All X-welds exhibited blistering and surface corrosion towards the ends of the weld at the valve OD. These areas were not inspected.

The performance of the total WFMT system was confirmed on-site using a Quantitative Quality Shim (QQI) shim with a 0.0006" deep EDM notch. The horizontal indication generated with the MT yoke, wet bath, and UV light is shown in Figure 3.1.

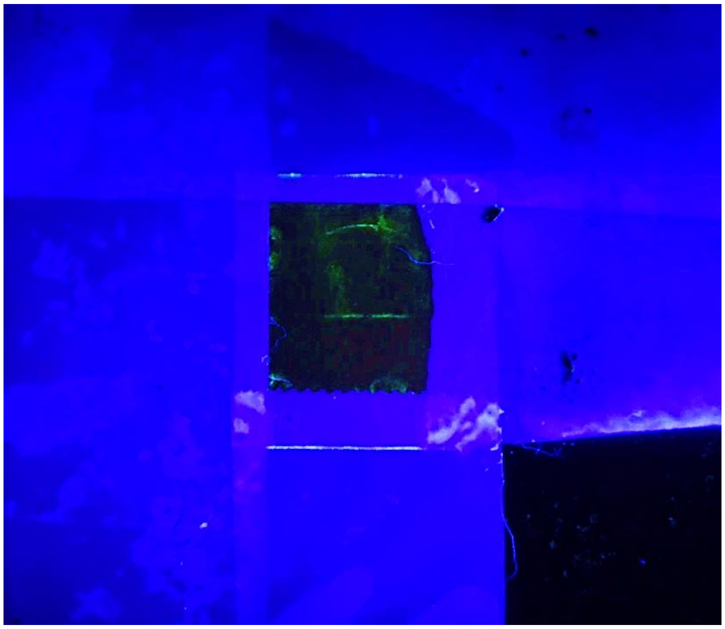


Figure 3.1: WFMT indication on from QQI shim.

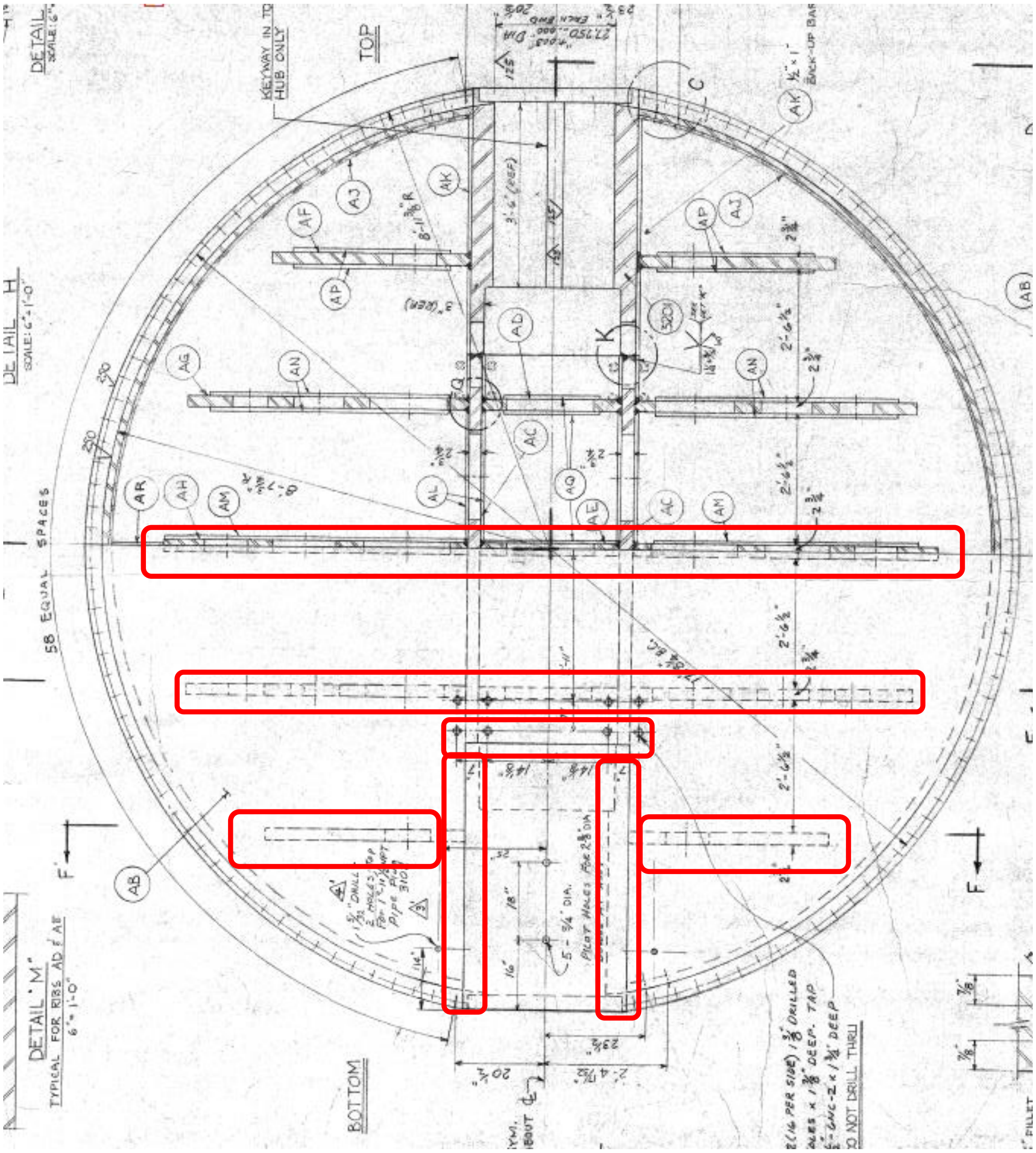


Figure 3.2: WFMT welds on upstream valve side.

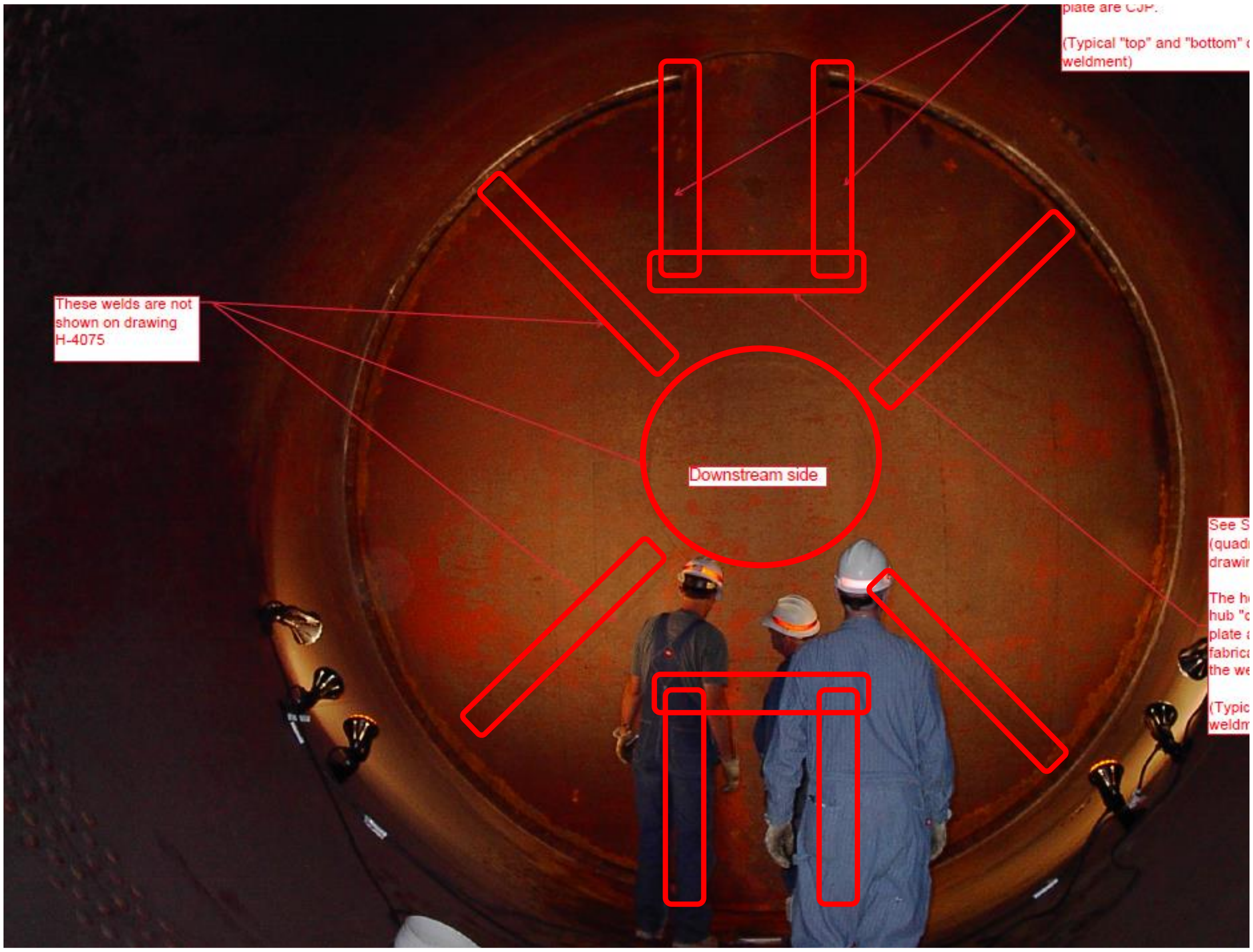


Figure 3.3: WFMT welds on downstream valve side.

3.1 Magnetic Particle Testing Parameters

Surface preparation:	Plastic brush, steel wire brush, plastic brush, repeat as necessary. See visual inspection surface cleaning description.
MT Method Used:	☒ Wet ☐ Dry ☐ Black/White Contrast ☒ Fluorescent
Particle Suspension:	Water
Magnetizing Current:	☒ AC ☐ DC ☐ HWDC
Applicable Method:	☒ Residual ☒ Continuous
Field Direction:	☐ Circular ☒ Longitudinal
Equipment Used:	☐ Coil ☒ Yoke ☐ Other

Coil Serial #:	N/A	Calibration Due Date:	N/A
Yoke Coil Serial #:	26322 and 20702	Date Calibrated:	11/30/2018
Black Light Intensity:	>1000 mW/cm2	Black Light Serial #:	2157677
Light Meter Serial #:	N/A: Confirmed on-site using shim	Calibration Due Date:	N/A: Confirmed on-site using shim

Particle Concentration:	0.2-0.4 ml per 100 ml
Acceptance Criteria:	No cracks allowed

MPI Inspector:	Seth Bonar	TKS SNT-TC-1A	Seth Bonar	10/21/19
	Name	Certification #	Signature	Date

3.2 Magnetic Particle Testing Summary

The follow-up magnetic particle inspection recommendations are consistent with those summarized in the Visual inspection Summary.

1. Remove lead paint with industry standard practices, blast to bare metal, and clean the circumferential weld and shell to at least 6 inches radially from the valve OD. Magnetic particle test same areas. Apply new coating system to these areas after inspection.

4 Phased Array Testing Results

The phased array testing was performed in accordance with the statement of work and the Final Scan Plan which was approved 10/01/2019. The scan plan was part of the original submittals and is not included in the technical report.

A fracture mechanics-based weld discontinuity evaluation was performed in accordance with ASME BPVC Mandatory Appendix VIII – Ultrasonic Examination Requirements for Fracture-Mechanics-Based Acceptance Criteria.

All weld discontinuities were sized using the 6-dB sizing technique in the length and height direction. The dimensions of the flaw are determined by the rectangle that fully contains the area of the flaw.

The length of the flaw shall be the dimension of the rectangle that is parallel to the weld center line.

The height of the flaw shall be the dimension of the rectangle in the thickness direction of the shell thickness.

TechKnowServ™
TECHNOLOGY, KNOWLEDGE, SERVICE

4.1 How to Interpret PAUT Results

Butterfly Valve # 5 – Upstream View

The following reference system was used to locate weld indications on the valve. For horizontal welds, the flaws indications are located from left to right. The scan origin is the left most edge of the weld. Vertical welds on the top half of the valve are referenced from the bottom up. Vertical welds on the bottom half of the valve are referenced from the top down

- Scan Origin Index (X = 0) O
- Scan Directional Indication ---->

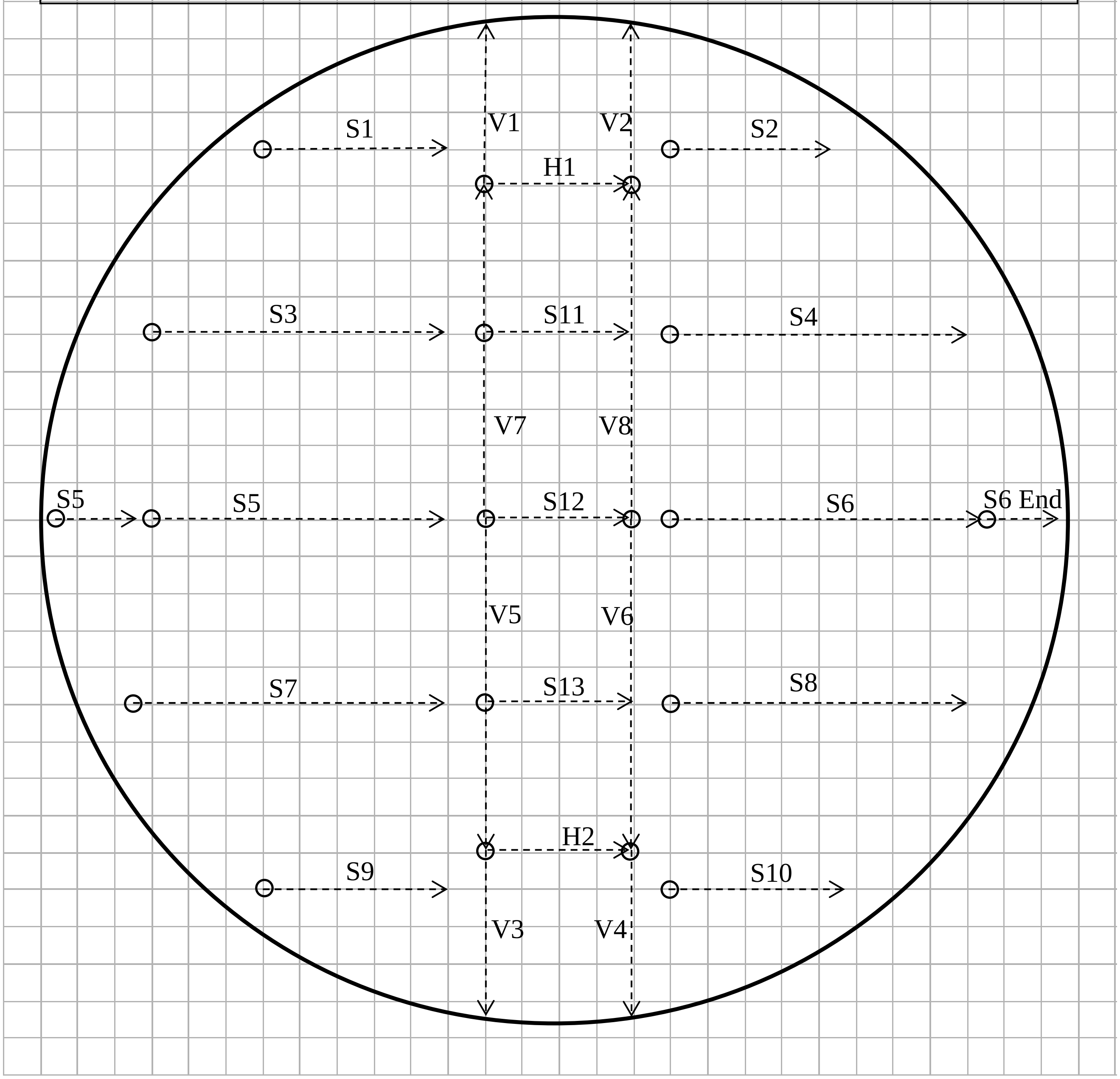


Figure 4.1: PAUT scan origin (reference point) and scan direction for Valve 5 Upstream side.

Butterfly Valve # 5 – Downstream View

The following reference system was used to locate weld indications on the valve. For horizontal welds, the flaws indications are located from left to right. The scan origin is the left most edge of the weld. Vertical welds on the top half of the valve are referenced from the bottom up. Vertical welds on the bottom half of the valve are referenced from the top down.

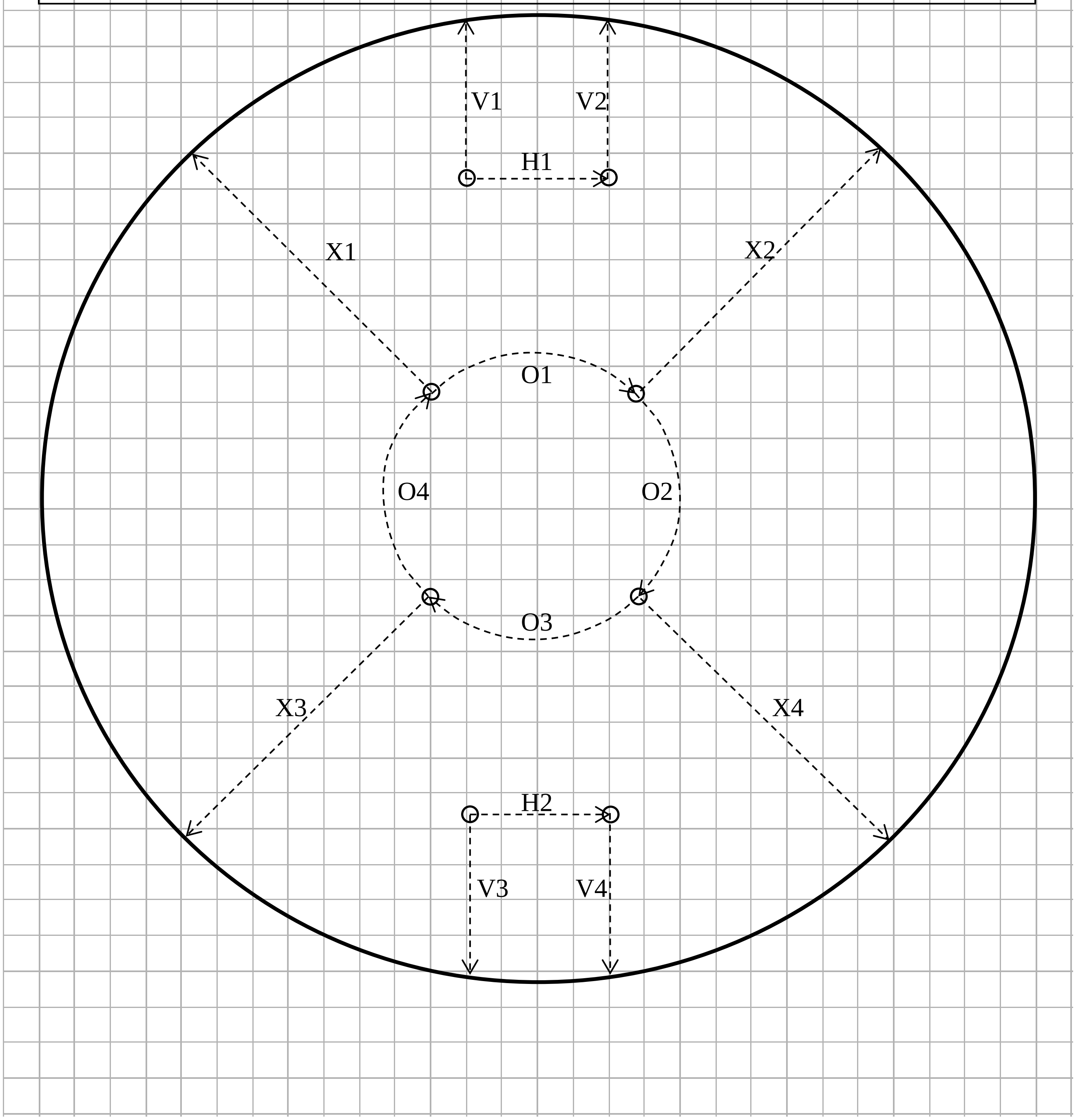


Figure 4.2: PAUT scan origin (reference point) and scan direction for Valve 5 Downstream side.

Figure 4.3 identifies the coordinate system used to for weld indication length (X), location in weld (Y), and depth from exterior surface (Z).

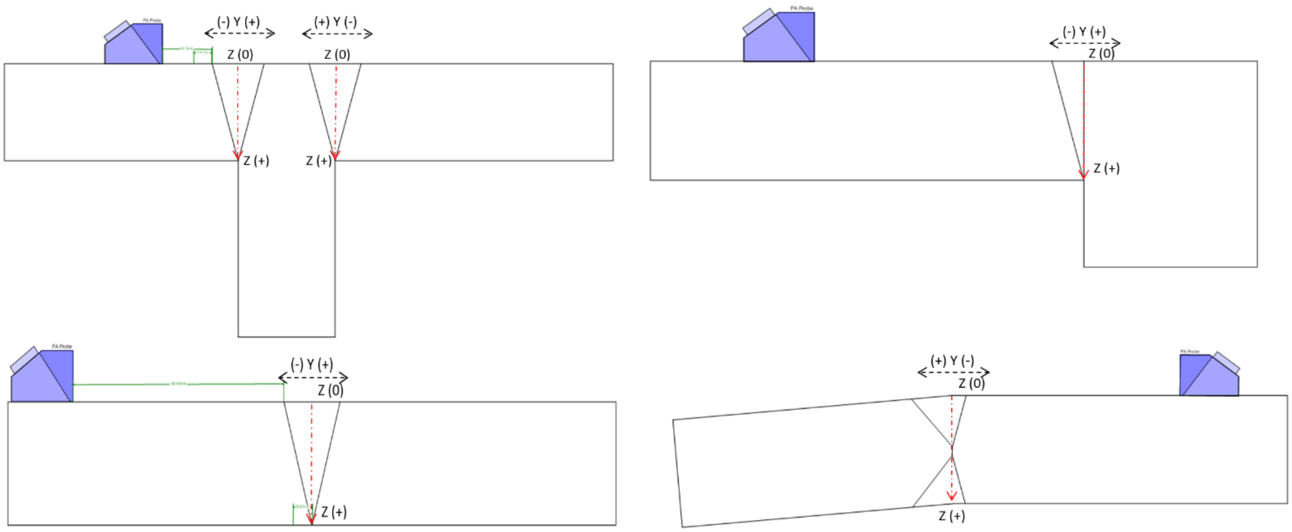


Figure 4.3: X, Y, and Z coordinate system for weld reflector identification. Note that X-direction is into the page.

The size of each reflector are summarized for upstream and downstream welds in Tables 4.1 and 4.2, respectively. The sizes are color coded in a risk matrix based on the following weld flaw dimensions:

Flaw Length	<0.200	0.200-0.500	0.500-1.000	>1.000
Flaw Height	<0.125	0.125-0.250	0.250-0.375	>0.500

The PAUT encoder scan directions and associated data files, for upstream and downstream sides, are shown in Figures 4.6 and 4.8, respectively. The data files were identified by valve#, upstream/downstream, weld ID, and top/bottom or outside/inside. For example, "Valve5uss4a" is the data file name for the scan of Valve #5, up-stream weld s4, top weld. Valve5uss4b would be the bottom weld. The encoder scan directions are identified via the set of perpendicular arrows. The longer arrow is the scan direction, or weld axis, and the short arrow is the direction of the ultrasonic beams as shown in Figure 4.4.

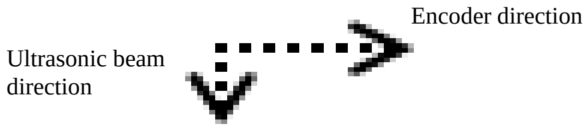


Figure 4.4: Explanation of encoder scan direction and ultrasonic beam directions.

The upstream side contained 1 weld discontinuity longer than 1" as shown in Table 4.1. The upstream side contained 3 weld discontinuities with a height greater than 0.375". The most severe discontinuity was found in weld S6b with a length of 11.100" and a height of 0.603". The PAUT inspection details for all welds inspected is presented in Section 5. The data for Weld S6b, for example, shows that the discontinuity was found mid-wall and was classified as lack of fusion (LOF). In addition, a possible in-service crack was detected at the root of weld S3b 0.917" long and 0.284" high.

Table 4.1: Valve #5 upstream weld discontinuity dimensions.

Valve 5 US Welds	Length S(m-r)	Height U(m-r)	X1 (in)	X2 (in)	Y1 (in)	Y2 (in)	Z1 (in)	Z2 (in)	Thickness (in)	Discontinuity
S2b	0.917	0.195	0.0	1.0	-0.5	-0.4	1.3	1.5	2.75	LOF
S3a	0.439	0.248	54.8	55.2	-1.7	-1.5	2.5	2.7	2.75	LOP
S3b	0.917	0.284	27.2	27.6	0.3	0.5	2.5	2.7	2.75	LOP
S4a	0.266	0.245	1.7	1.9	-0.3	-0.2	2.1	2.4	2.75	ROOT REF.
S4b	0.229	0.142	27.6	27.8	0.7	0.9	2.4	2.7	2.75	ROOT REF.
S5a	0.459	0.337	40.7	41.1	0.0	0.1	2.3	2.6	2.75	ROOT REF.
S5a-End	0.358	0.390	7.5	7.9	-0.2	0.1	1.9	2.3	2.75	LOF
	0.400	0.248	1.5	1.9	-0.3	-0.1	1.9	2.1	2.75	LOF
S6b	11.100	0.603	52.8	64.0	0.4	0.7	1.9	2.5	2.75	LOF
S7a	0.241	0.106	4.0	4.2	-0.6	-0.4	1.6	1.7	2.75	SLAG
S7b	0.344	0.195	13.5	13.8	0.7	0.9	1.4	1.6	2.75	LOF
S8b	0.378	0.195	58.3	58.6	0.4	0.5	1.4	1.6	2.75	LOF
	0.310	0.195	39.6	40.0	0.7	0.9	1.3	1.5	2.75	LOF
	0.241	0.071	45.2	45.4	-0.2	-0.1	1.9	2.0	2.75	LOF
	0.378	0.124	38.1	38.5	0.4	0.5	2.4	2.5	2.75	LOF
S9a	0.454	0.135	18.7	19.2	-0.3	-0.1	1.1	1.2	2.75	POROSITY
S10a	0.206	0.106	2.5	2.7	0.0	0.2	2.0	2.1	2.75	LOF
	0.172	0.071	11.8	12.0	-0.1	0.0	2.0	2.1	2.75	LOF
	0.378	0.160	18.5	18.9	0.0	0.3	2.1	2.2	2.75	LOF
S10b	0.654	0.142	8.2	8.8	-0.2	0.0	1.9	2.1	2.75	LOF
	0.206	0.195	4.9	5.1	-0.2	-0.1	1.3	1.5	2.75	LOF
	0.378	0.177	2.0	2.4	-0.1	0.1	2.0	2.2	2.75	LOF
	0.585	0.230	0.2	0.8	0.0	0.2	1.7	2.0	2.75	LOF
S11b	0.459	0.142	16.0	16.4	0.0	0.2	2.2	2.4	2.75	LOF
S12b	0.321	0.160	2.2	2.4	-0.1	0.1	2.0	2.2	2.75	LOF
S13b	0.138	0.142	8.4	8.7	0.5	0.6	1.6	1.8	2.75	ROOT
H1	0.265	0.550	2.8	3.1	-0.1	0.1	0.9	1.5	2.75	SLAG
V5b	0.596	0.213	36.5	37.2	0.0	0.2	2.1	2.3	2.75	LOP
	0.413	0.177	36.8	37.2	-0.2	-0.1	0.9	1.1	2.75	LOP

Table 4.2: Valve #5 downstream weld discontinuity dimensions.

Valve 5 DS Welds	Length S(m-r)	Height U(m-r)	X1 (in)	X2 (in)	Y1 (in)	Y2 (in)	Z1 (in)	Z2 (in)	Thickness (in)	Discontinuity
H1	0.459	0.142	32.4	32.8	0.2	0.4	2.5	2.7	2.75	LOP
	3.807	0.355	35.2	39.0	0.0	0.4	2.4	2.7	2.75	LOF/LOP
H2	5.963	0.301	24.2	30.4	-0.6	-0.2	1.3	1.7	2.75	LOF
	0.321	0.147	10.6	11.1	0.0	0.1	2.0	2.2	2.75	LOP
V2	0.229	0.142	22.8	23.1	-0.10	0.0	2.5	2.7	2.75	ROOT
V3	1.789	0.229	41.1	42.9	-0.4	-0.1	2.4	2.7	2.75	LOF
	1.376	0.213	32.2	33.6	-0.3	0.0	2.5	2.7	2.75	LOF
	0.929	0.142	26.8	27.8	-0.3	-0.2	2.2	2.3	2.75	LOF
	0.447	0.213	15.5	15.9	-0.5	-0.3	1.7	1.9	2.75	LOF
	0.551	0.319	9.5	10.1	-0.3	-0.1	1.2	1.6	2.75	LOF
	0.619	0.142	7.8	8.5	-0.2	0.0	2.4	2.5	2.75	LOF
O1a	1.008	0.461	6.4	7.6	-0.7	-0.4	1.5	2.0	2.75	LOF
O1b	0.169	0.213	27.2	27.3	-0.8	-0.6	1.6	1.9	2.75	LOF
O3a	0.244	0.195	35.1	35.4	-0.5	-0.3	1.9	2.1	2.75	LOF
	0.207	0.195	32.4	32.6	-0.1	0.1	1.5	1.7	2.75	LOF
	0.432	0.195	27.9	28.3	0.1	0.3	1.5	1.7	2.75	LOF
O3b	0.200	0.213	19.3	19.5	-0.2	-0.1	1.5	1.7	2.75	LOF
	0.275	0.195	34.0	34.3	-0.7	-0.6	1.3	1.5	2.75	LOF
O4a	1.616	0.230	18.3	20.0	-0.7	-0.5	1.5	1.7	2.75	LOF
	0.333	0.213	11.2	11.5	-0.7	-0.5	1.4	1.7	2.75	LOP
X2b	0.472	0.213	3.7	4.2	-1.0	-0.8	2.1	2.3	2.75	LOF
C1	0.344	0.301	32.4	32.8	0.2	0.4	2.5	2.7	2.75	Planar
C2	3.762	0.34	35.2	39.0	0.0	0.4	2.4	2.7	2.75	Planar

The downstream side contained 6 weld discontinuities longer than 1" as shown in Table 4.2. The downstream side contained 1 weld discontinuities with a height greater than 0.375". The most severe discontinuity was found in H2 with a length of 5.963" and a height of 0.301". The PAUT inspection details for all welds inspected is presented in Section 5. The data for Weld H2 shows that the discontinuity was found mid-wall and was classified as lack of penetration. (LOF).

4.2 PAUT Inspection Summary

The upstream and downstream valves were inspected with PAUT per the statement of work. Most areas that were scanned had tightly adhered coating that permitted adequate transfer of ultrasound into the valve shell. The data acquired supports this observation as root and toe reflections were observed in many of the welds. However, data was lost over a small percentage of the scanned areas and many welds required rescanning of rough surface areas. In many cases, it was impossible to transfer ultrasound into the valve shell. This lack of data is depicted in the Section 5 PAUT data as black gaps in the C-scan. For Butterfly valve #5, all discontinuities detected were characterized as fabrication related flaws which included lack of penetration, lack of fusion, and inclusions.

Only a total of 177" of the circumferential weld were scanned with PAUT. Discontinuities over approximately 21" of this area that were not attributable to an inherent feature from the valve drawing. The discontinuities were approximately 1.25" deep from the skin surface. The estimated location is shown in Figure 4.2. The indications were representative of a lamination or other planar defect parallel skin surface. The remainder of the circumferential weld was not inspected due to advanced corrosion and surface roughness.

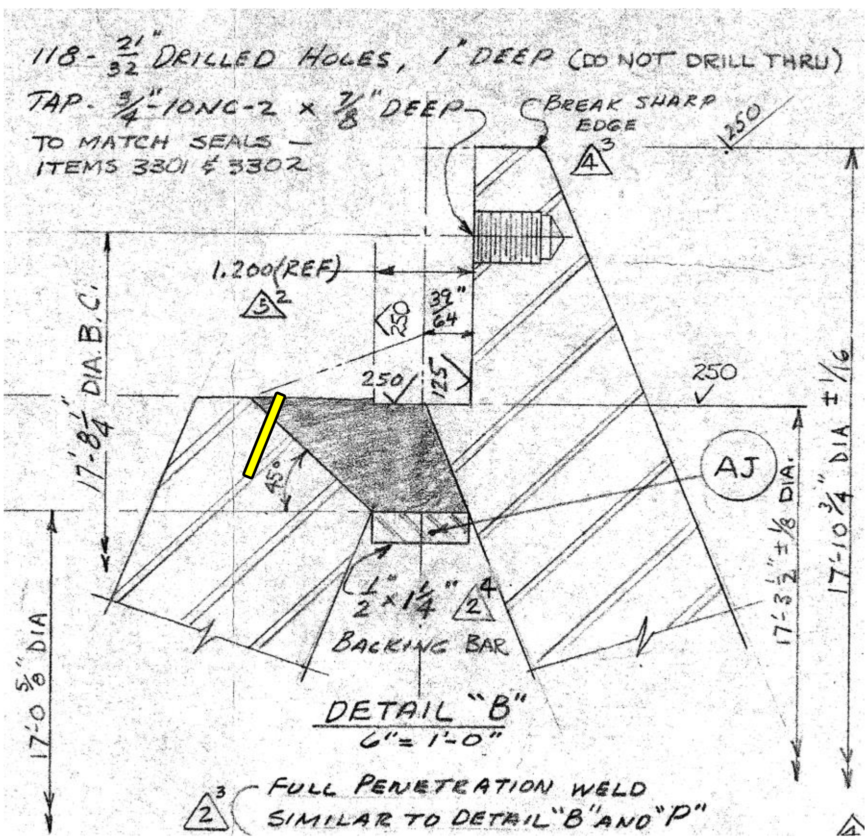


Figure 4.5: Estimated location of discontinuities detected with PAUT at C1 and C2 locations.

C1 and C2 were located 30-45" and 60-66", respectively, from Weld V2 in the clockwise direction looking at the downstream face.

The following recommendations are presented for the next major valve maintenance event:

1. For all color-coded red welds in Tables 4.1 and 4.2. remove lead paint with industry standard practices, blast to bare metal, and clean the weld surfaces 6" back from the toe. Perform encoded PAUT to more accurately locate and size the weld discontinuities. Apply new coating system to these areas after inspection. Re-assess possible repair action after new sizing data is made available.

2. Particular attention should be dedicated to the two areas, C1 and C2, in which discontinuities were detected with PAUT. If the USACE elects to blast and clean the circumferential welds, the surface should be inspected for geometric features at 1.25" from the skin surface. C1 and C2 were located 30-45" and 60-66", respectively, from Weld V2 in the clockwise direction looking at the downstream face.

3. Upstream Side Weld S3b: A possible in-service fatigue crack was detected in Weld S3b at the weld root. It is recommended to remove lead paint with industry standard practices, blast to bare metal, and clean the weld area for follow-up inspection at the next maintenance event.

4. For all welds with intermittent weld discontinuities, remove lead paint with industry standard practices, blast to bare metal, and clean the weld surfaces 6" back from the toe. Perform encoded PAUT to determine if intermittent weld discontinuities detected are indeed intermittent or instead a longer continuous weld discontinuity.

5. Remove lead paint with industry standard practices, blast to bare metal, and clean the circumferential weld and shell to at least 6 inches radially from the valve OD. Perform PAUT inspection. Apply new coating system to these areas after inspection.

The objective of scanning on abated, cleaned and blasted surface is threefold. Firstly, it will eliminate and false positives that may occur due to surface conditions. Rough and uneven surfaces may cause false indications that appear in the weld tested.

Secondly, the size and location of the weld discontinuities will be more accurate for potential repair action.

Thirdly, it will determine it if many of the smaller intermittent weld discontinuities detected are indeed intermittent or indicative of longer continuous weld discontinuities that were not detected due to surface roughness.

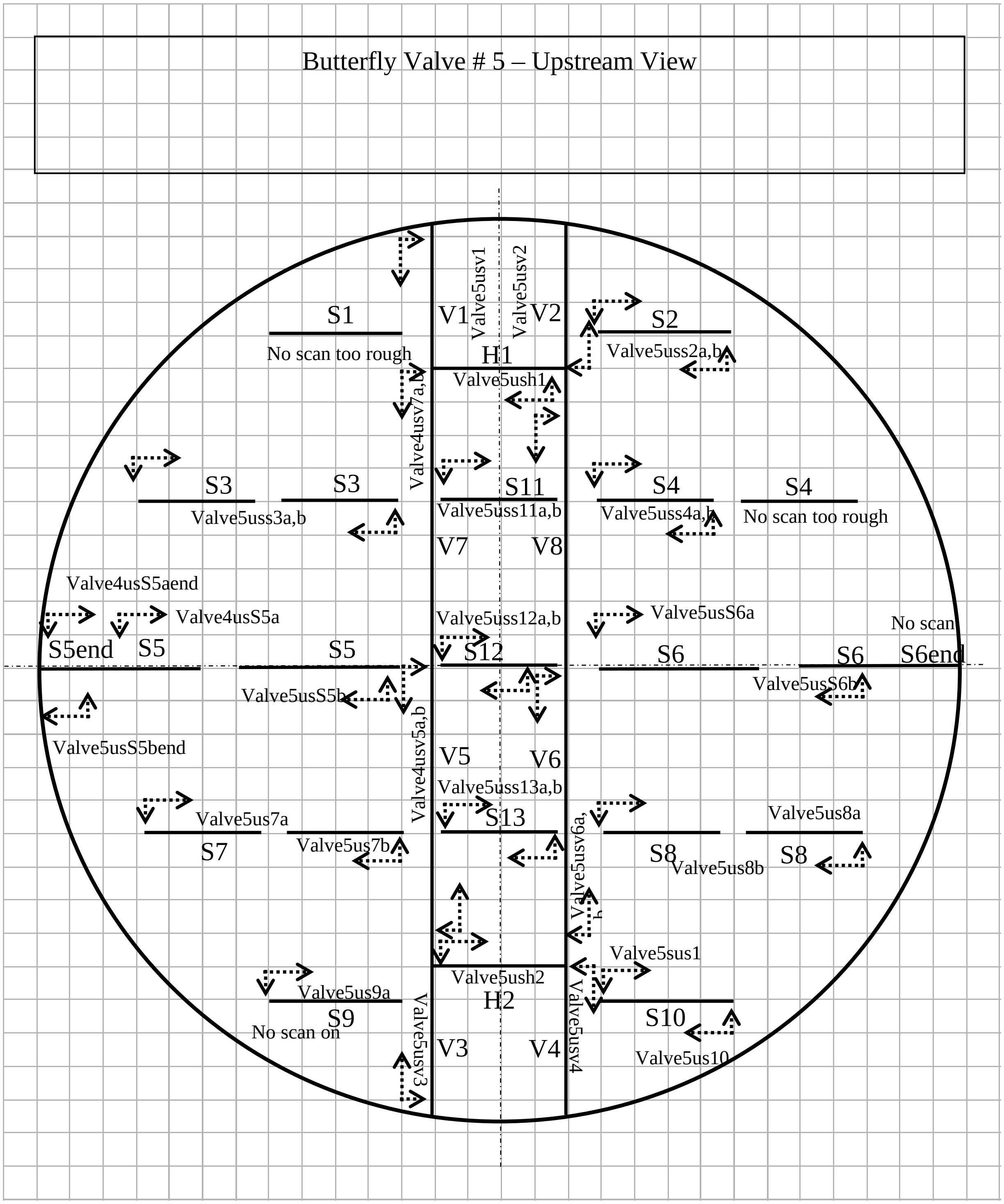


Figure 4.6: PAUT scan directions and data file names for Valve #5 upstream welds.

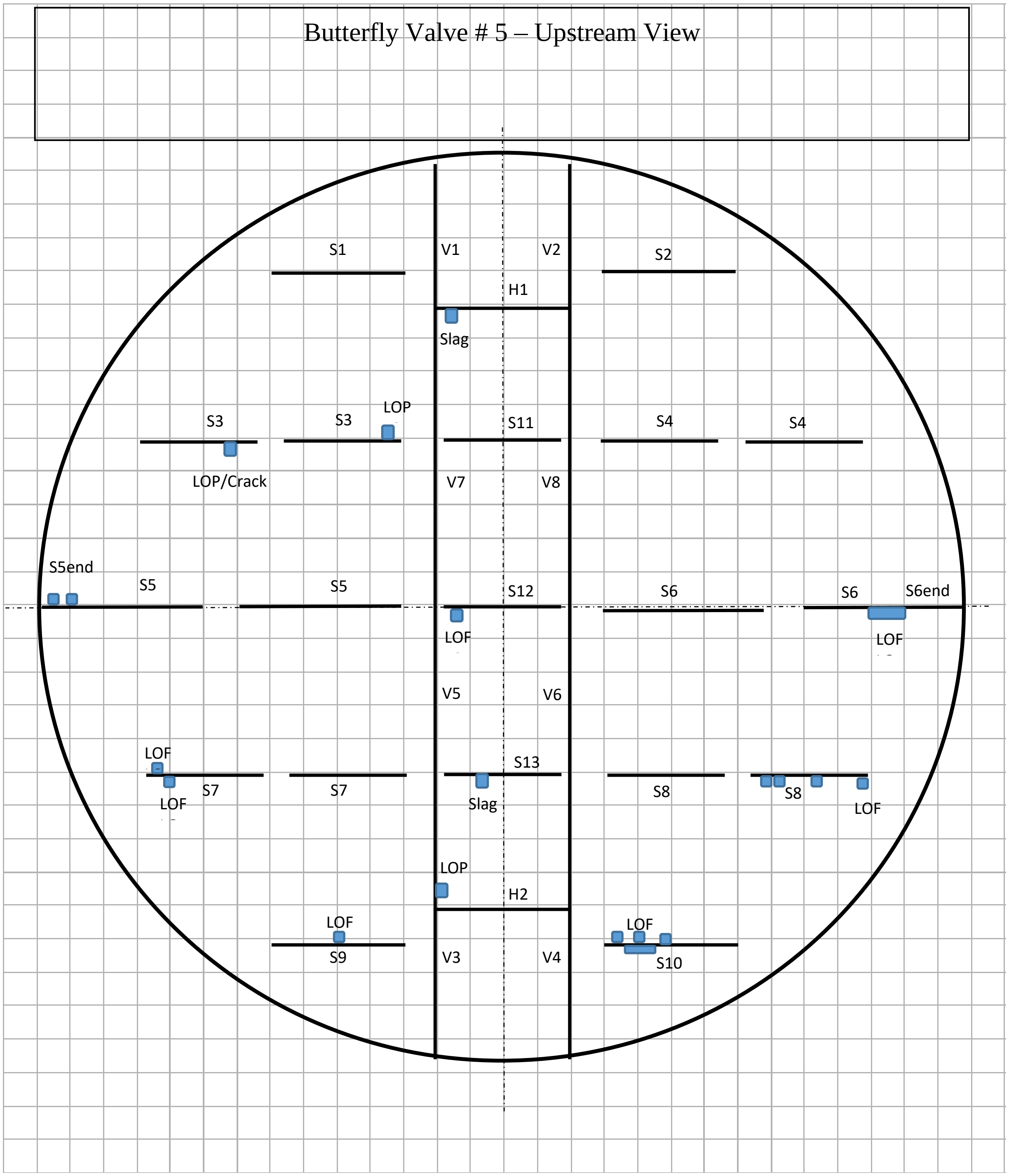


Figure 4.7: Valve #5 upstream PAUT weld discontinuities longer than 0.20”.

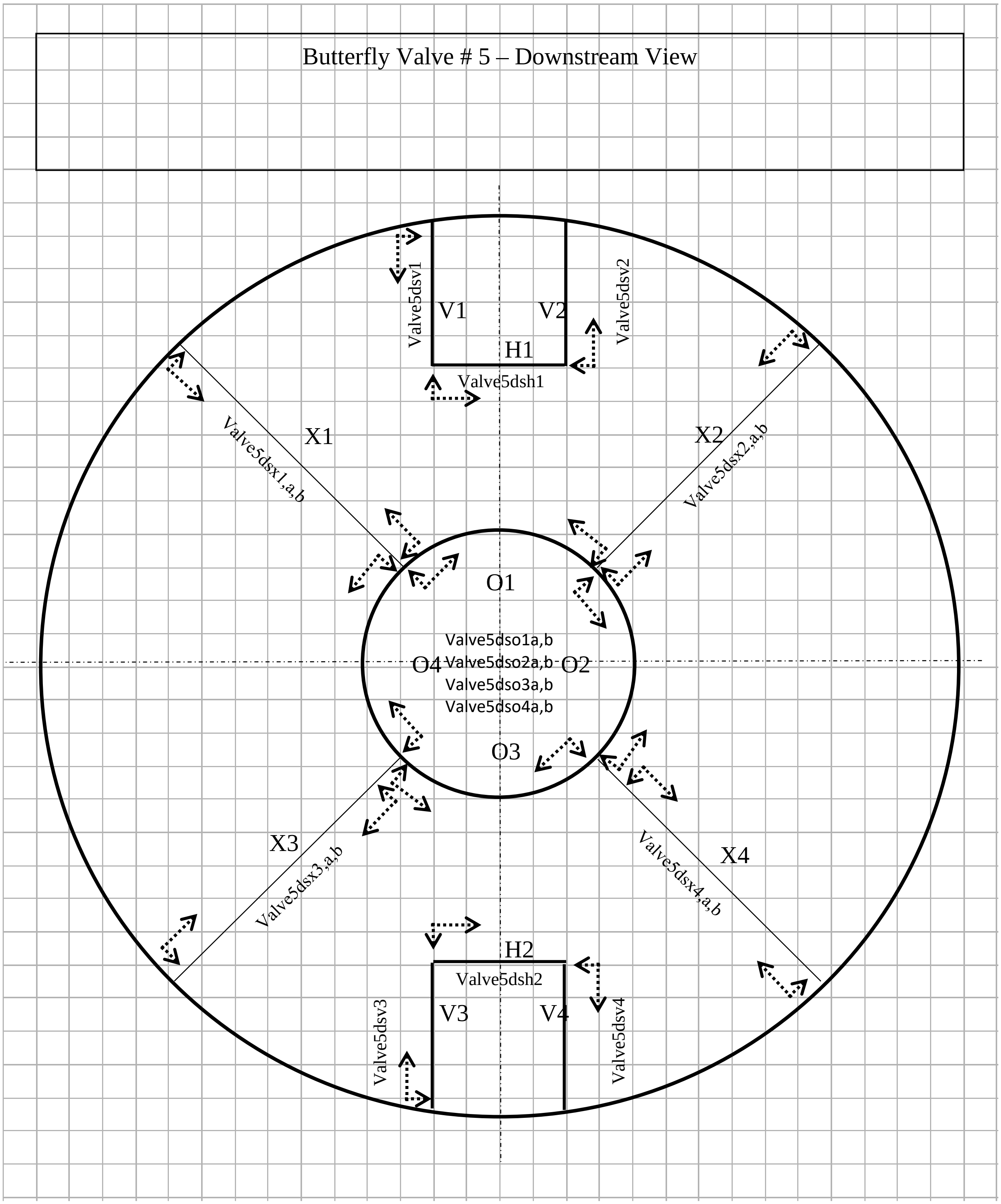


Figure 4.8: PAUT scan directions and data file names for Valve #5 downstream welds.

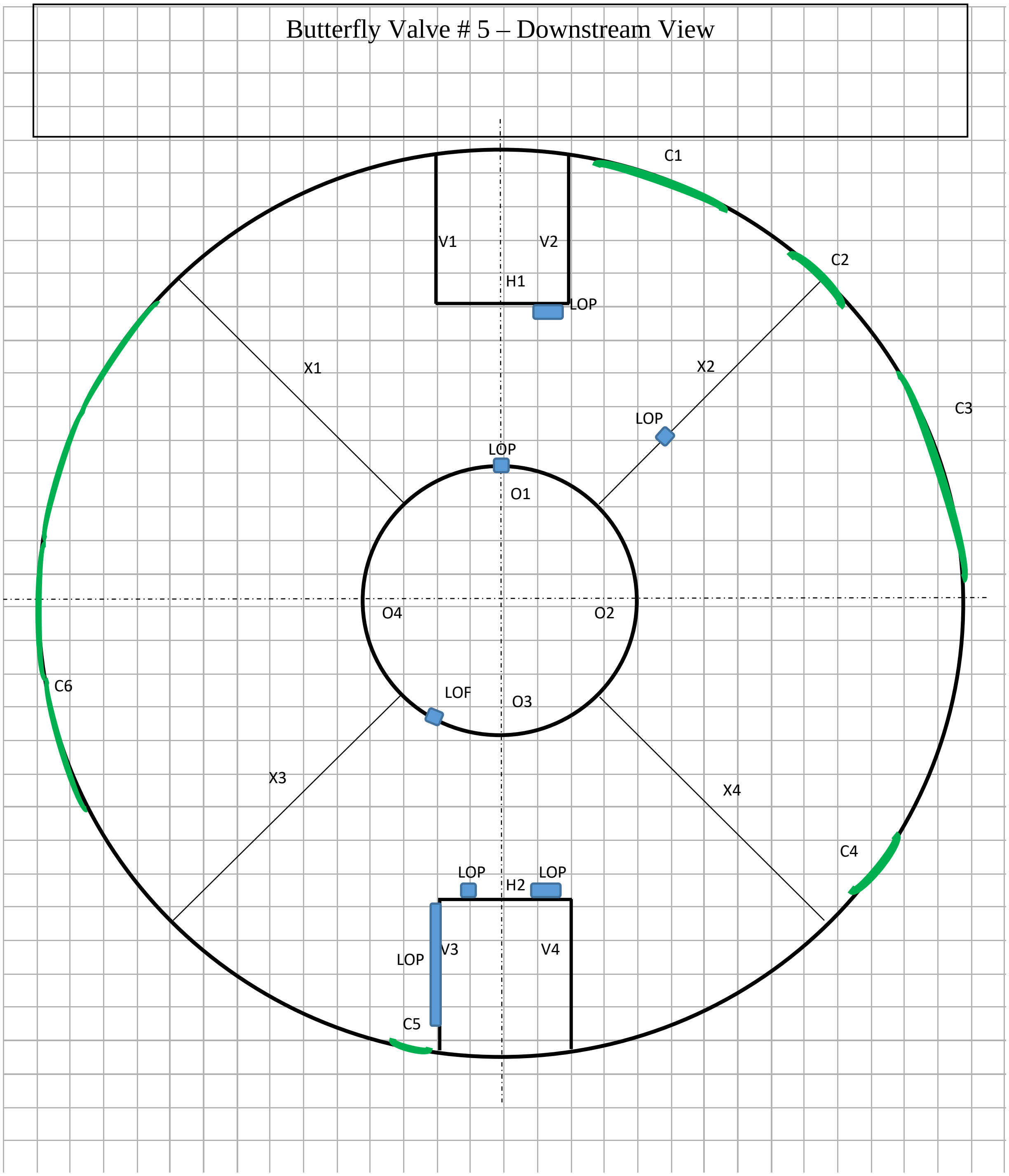
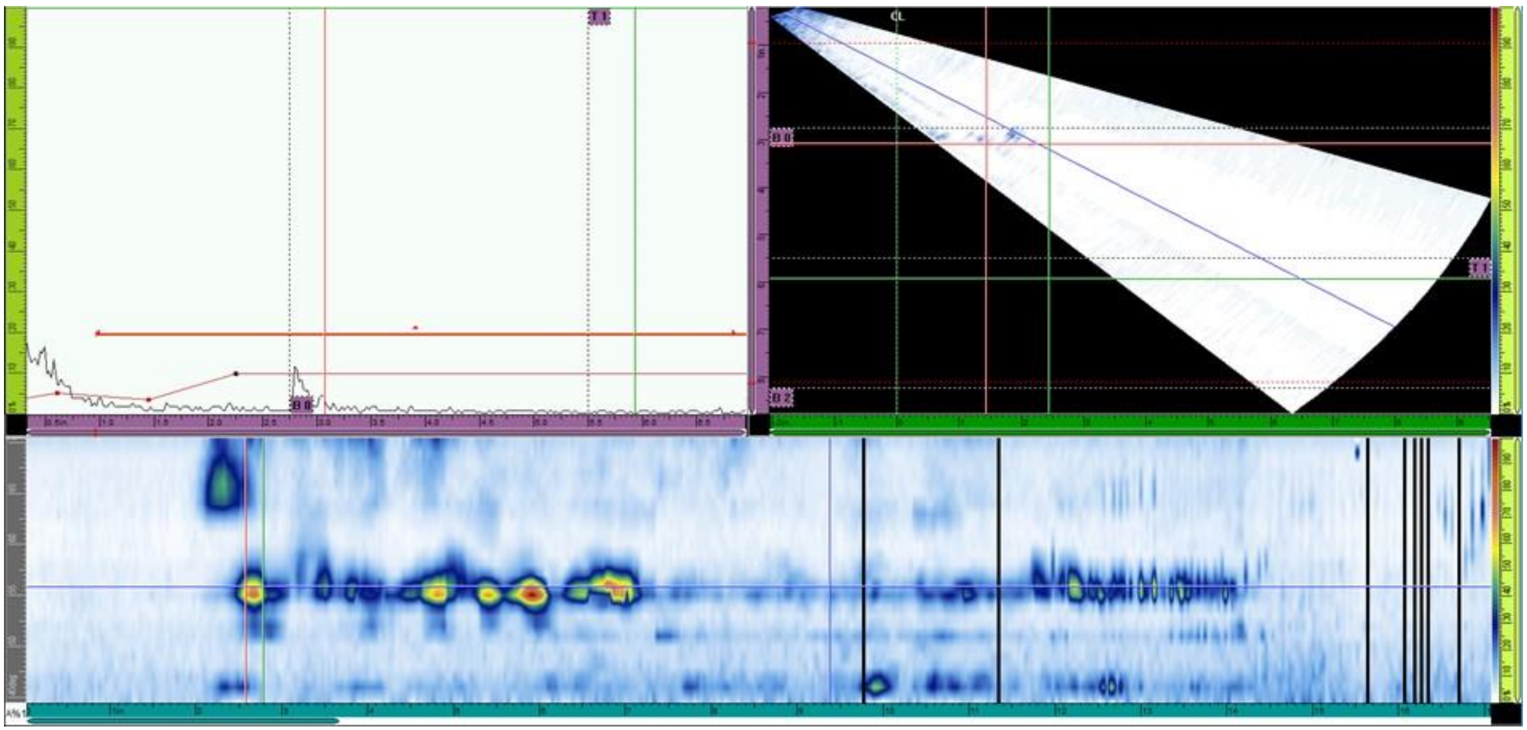


Figure 4.9: Valve #5 downstream PAUT weld discontinuities longer than 0.20" and areas over which the circumferential weld was manually scanned with PAUT (green). C1 is located at 30 to 45" in the clock-wise direction from V2. C2 is located at 60 to 66" in the clock-wise direction from V2.

5 PAUT Inspection Results

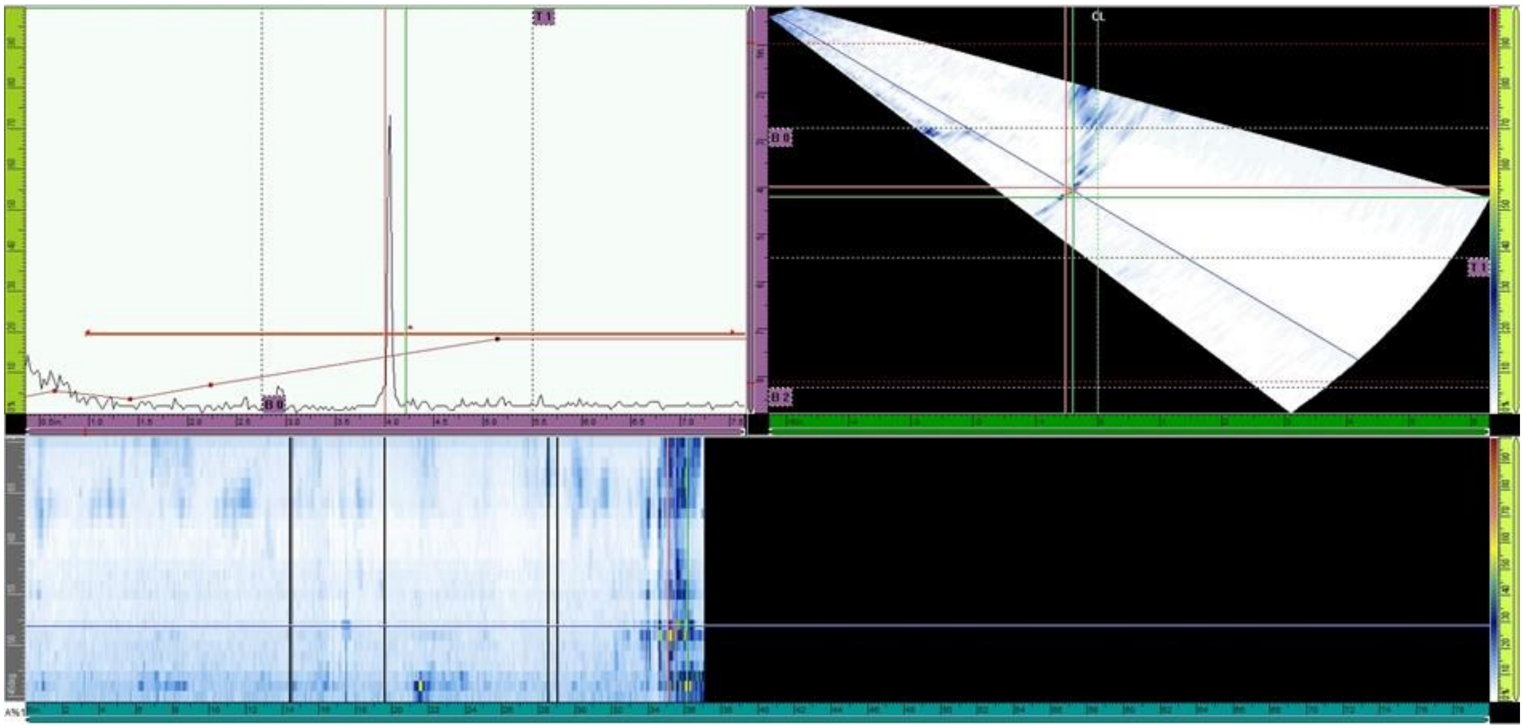
5.1 Valve 5 Upstream

Valve 5 Upstream Side	
Weld	Comments
S1a,b	No scanning possible due to rough surface
S2a	14” scanned from top weld – no indications observed other than from root. 

Valve 5 Upstream Side

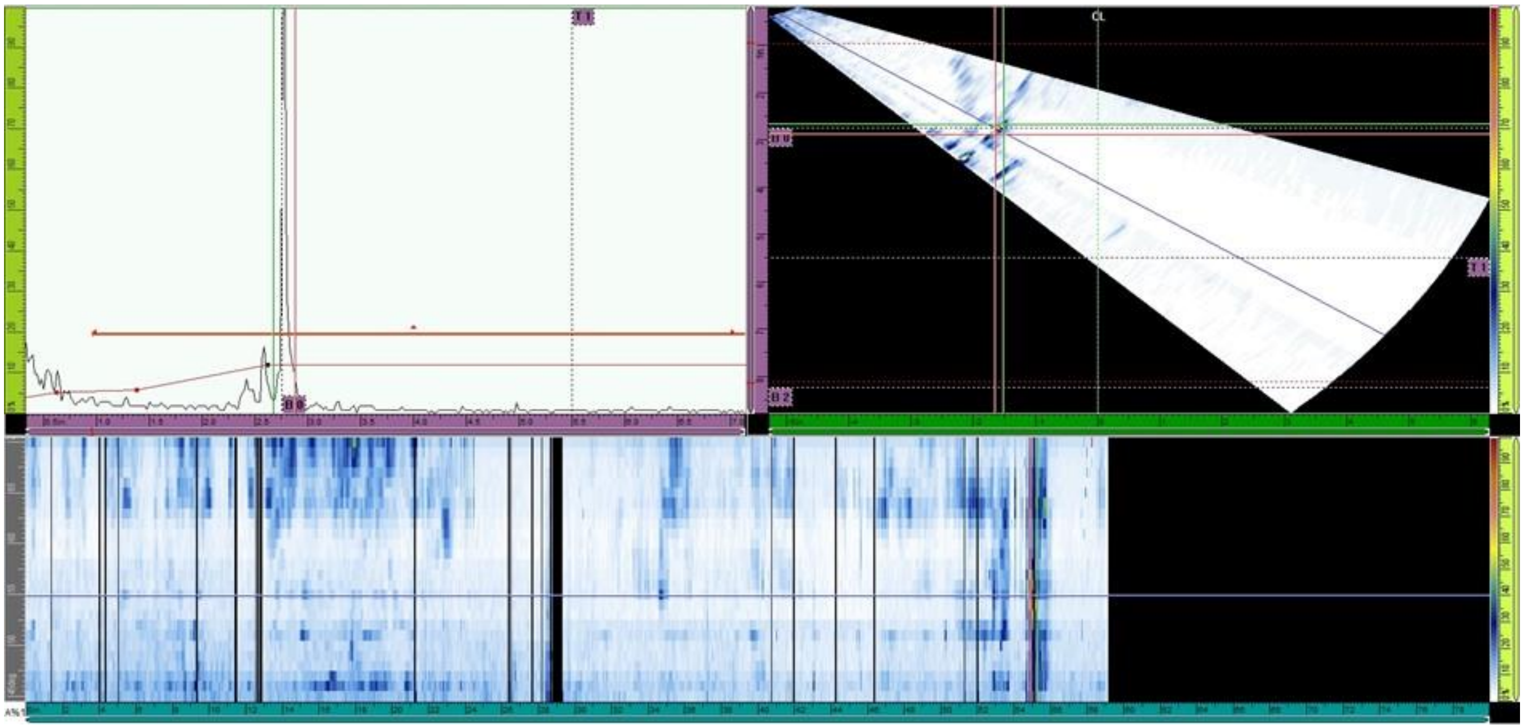
Weld	Comments
S2b	14” scanned from top weld only – remainder of surface too rough.

Gain (dB)	Indication #	Scan (in)	Index (in)	Group	Channel	A%1 (%)	DA/1 (in)	PA/1 (in)	SA/1 (in)	U(m-r) (in)	I(m-r) (in)	I•U(m-r) (in)	S(m-r) (in)	Type
46.66	1	35.512	-6.500	PA 1	51.00º	75.3	1.370	4.474	6.562	0.195	0.148	0.245	0.917	LOF



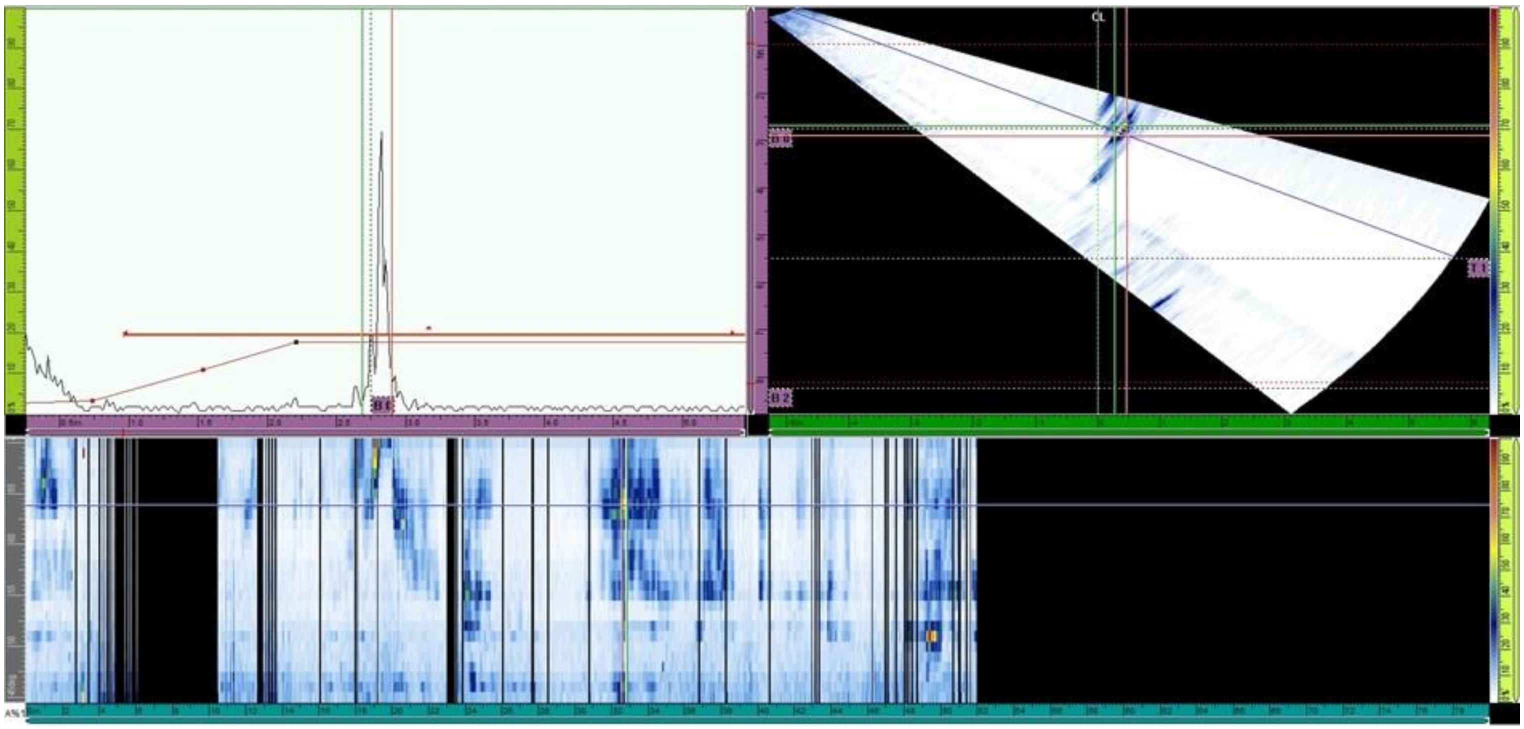
Valve 5 Upstream Side	
Weld	Comments
S3a	Lack of penetration at root.

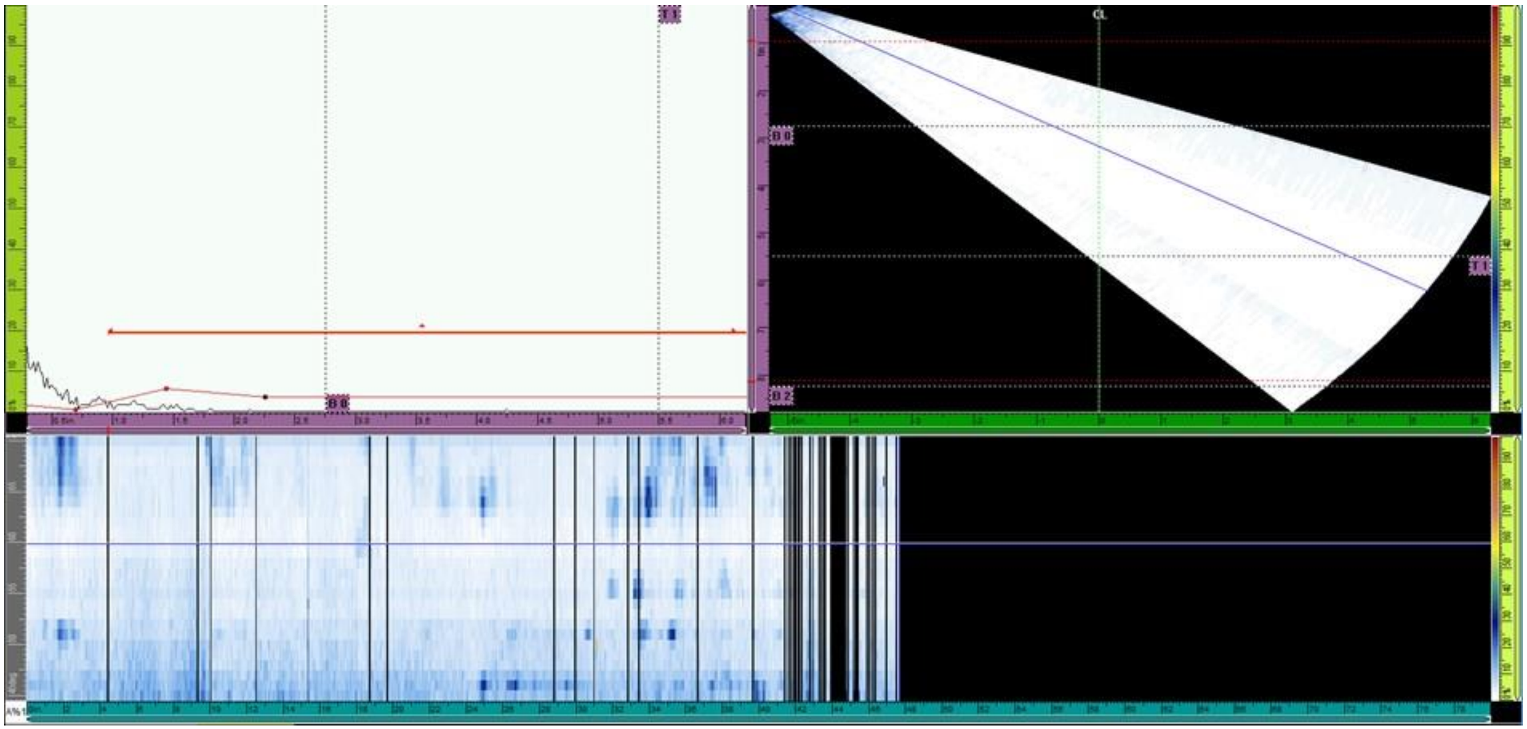
Gain (dB)	Indication #	Scan (in)	Index (in)	Group	Channel	A%1 (%)	DA/1 (in)	PA/1 (in)	SA/1 (in)	U(m-r) (in)	I(m-r) (in)	I•U(m-r) (in)	S(m-r) (in)	Type
46.66	1	54.921	-6.500	PA 1	55.00º	120.3	2.731	3.380	4.828	0.248	0.202	0.320	0.439	LOP



Valve 5 Upstream Side	
Weld	Comments
S3b	Lack of penetration / possible crack observed at bottom surface.

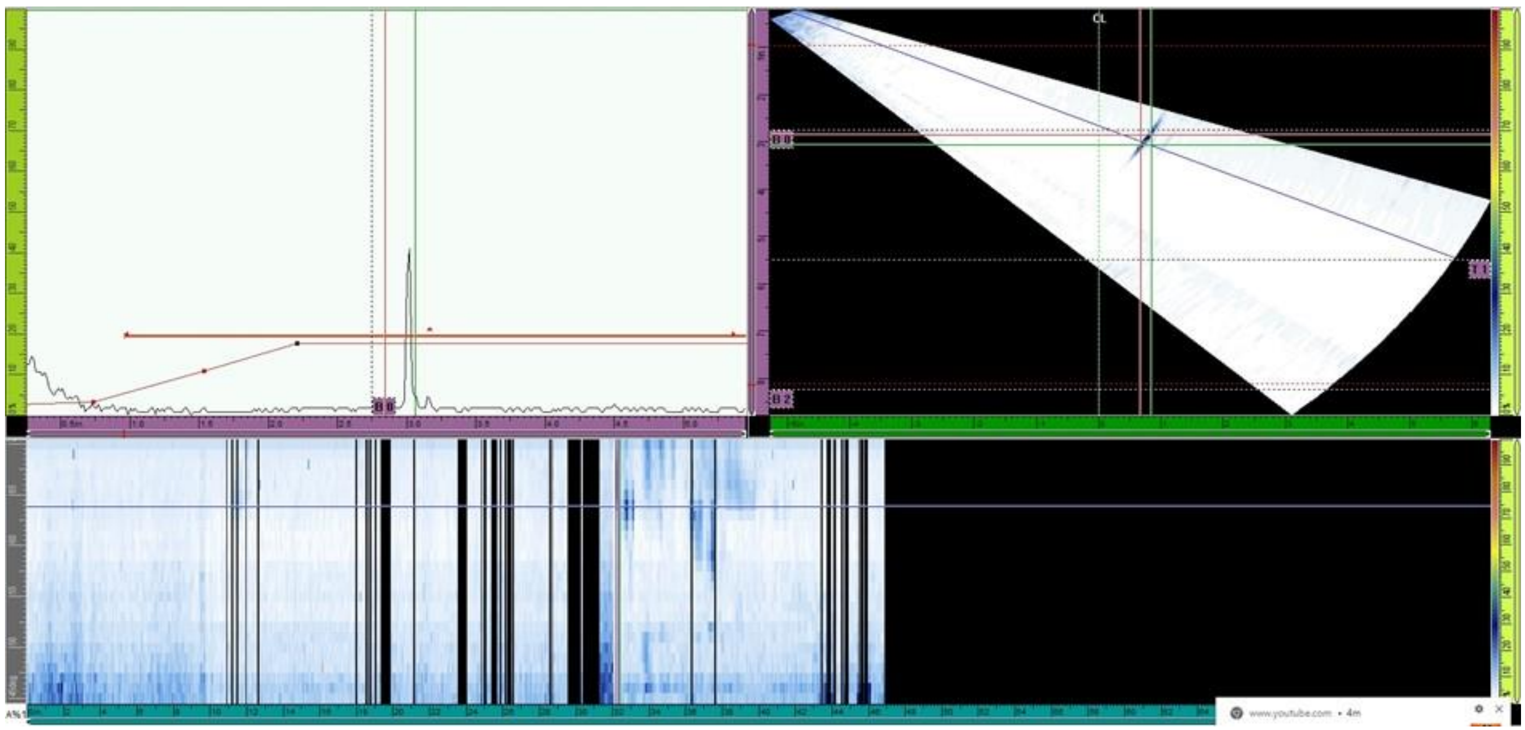
Gain (dB)	Indication #	Scan (in)	Index (in)	Group	Channel	A%1 (%)	DA/1 (in)	PA/1 (in)	SA/1 (in)	U(m-r) (in)	I(m-r) (in)	I•U(m-r) (in)	S(m-r) (in)	Type
46.66	1	32.795	-6.500	PA 1	64.00º	19.6	2.745	5.186	6.286	0.284	0.148	0.320	0.917	LOP/ Crack



Valve 5 Upstream Side	
Weld	Comments
S4a	Standard root reflection(s) 

Valve 5 Upstream Side	
Weld	Comments
S4b	Standard root reflection(s)

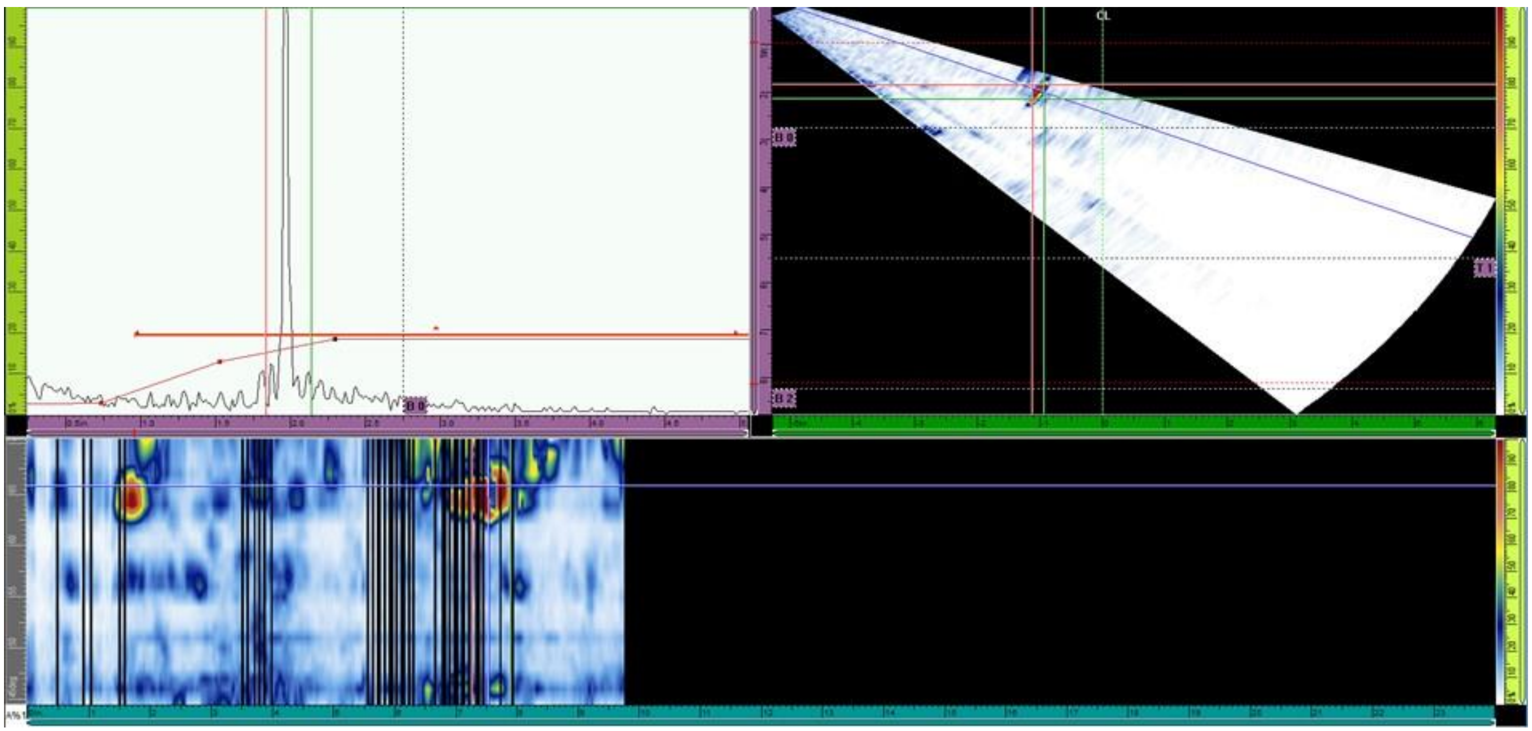
Gain (dB)	Indication #	Scan (in)	Index (in)	Group	Channel	A%1 (%)	DA/1 (in)	PA/1 (in)	SA/1 (in)	U(m-r) (in)	I(m-r) (in)	I•U(m-r) (in)	S(m-r) (in)	Type
46.66	1	32.795	-6.500	PA 1	64.00º	27.4	2.651	5.378	6.500	0.142	0.148	0.205	0.229	Root

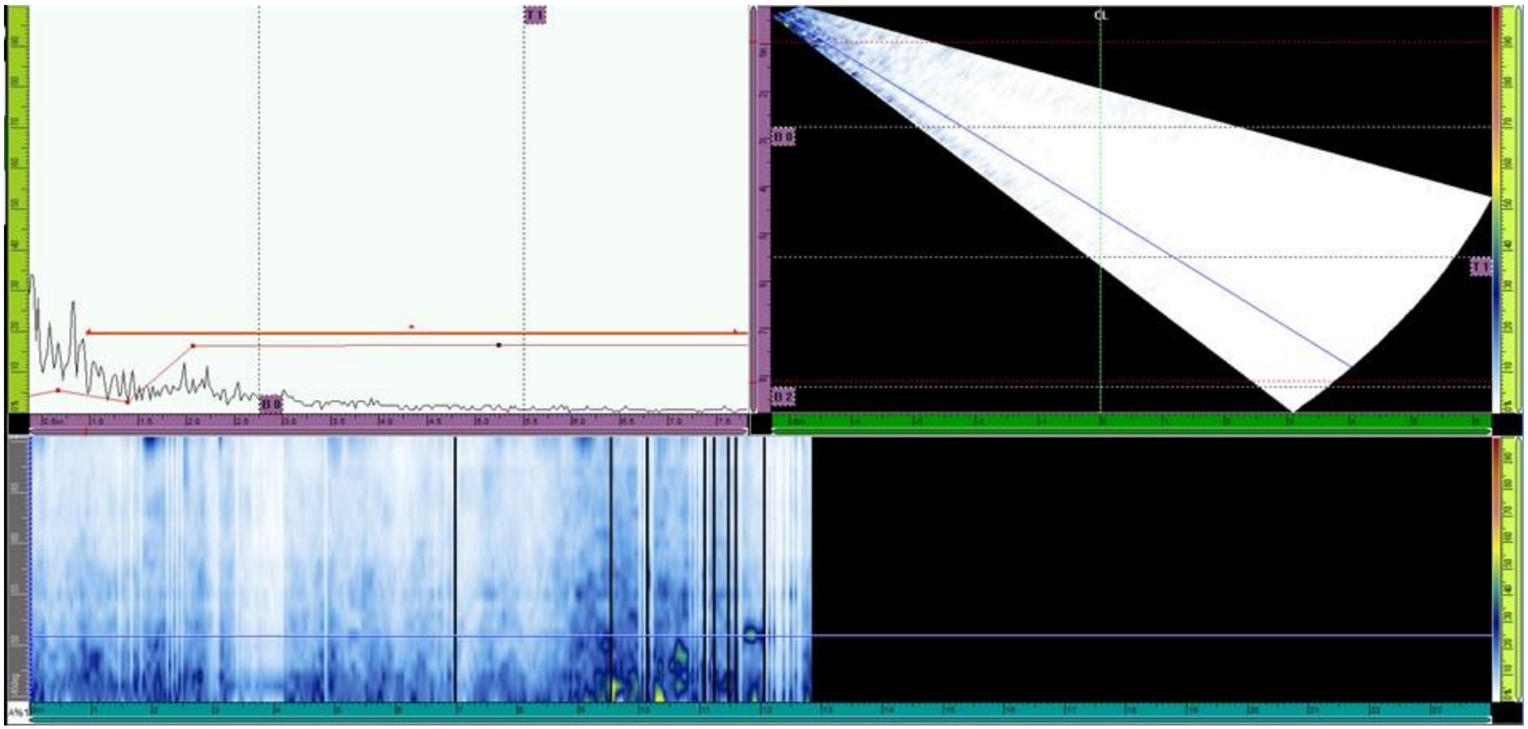


Valve 5 Upstream Side

Weld	Comments
S5a-End	2 LOF detected 0.5” in length each.

Gain (dB)	Indication #	Scan (in)	Index (in)	Group	Channel	A%1 (%)	DA/1 (in)	PA/1 (in)	SA/1 (in)	U(m-r) (in)	I(m-r) (in)	I•U(m-r) (in)	S(m-r) (in)	Type
40.66	1	7.685	-6.500	PA 1	64.00º	104.7	2.100	3.843	4.792	0.390	0.283	0.482	0.358	LOF
40.66	2	1.655	-6.500	PA 1	65.00º	98.8	1.985	3.805	4.697	0.248	0.216	0.329	0.400	LOF

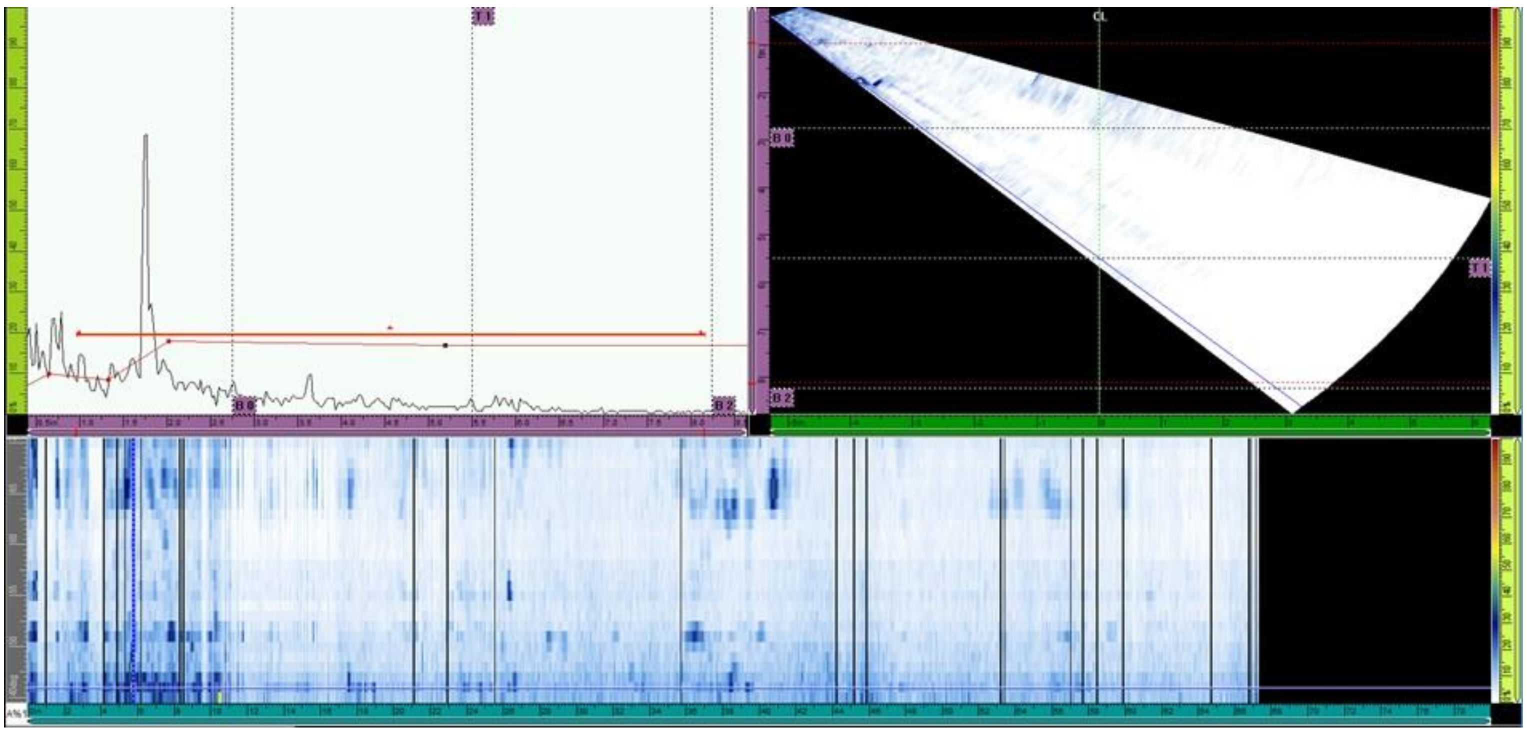


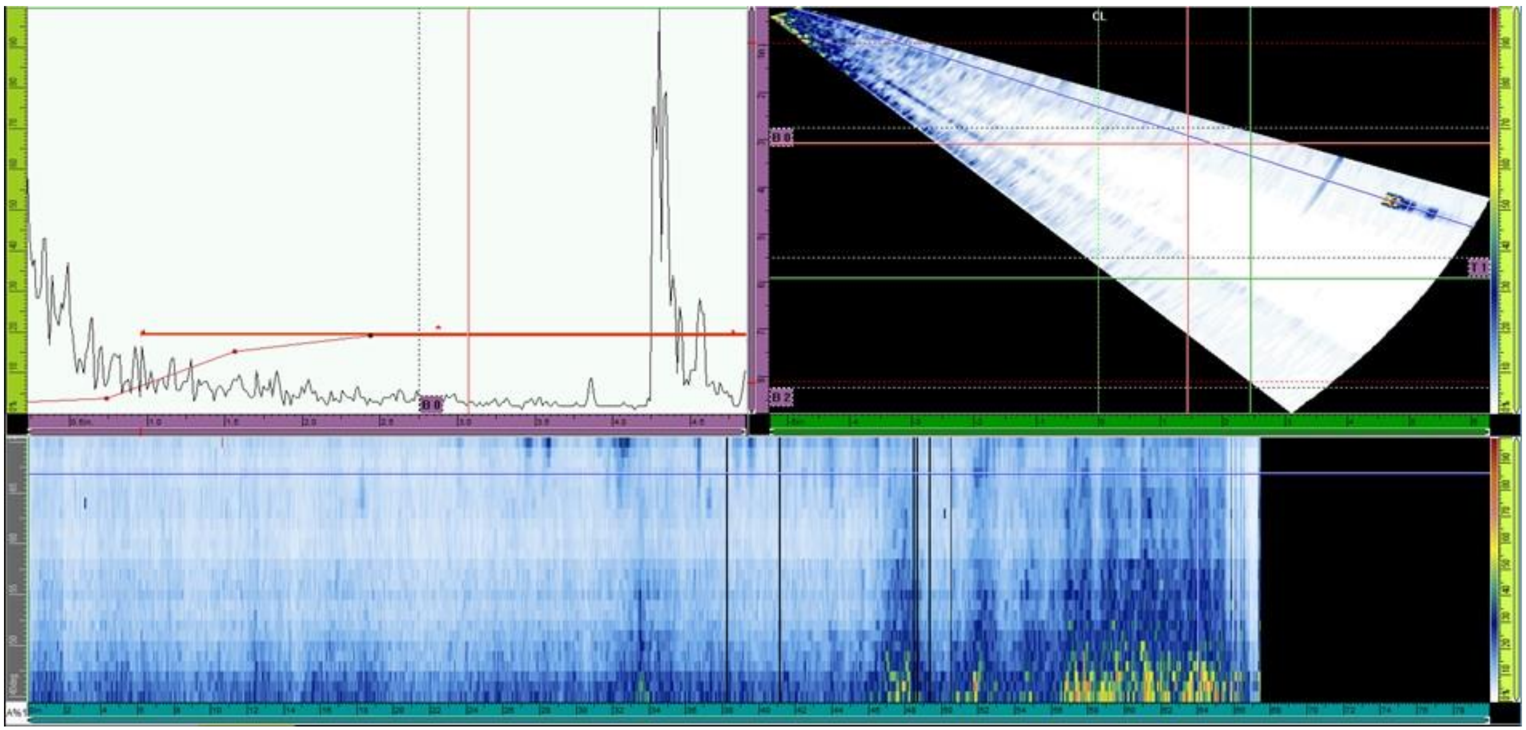
Valve 5 Upstream Side	
Weld	Comments
S5b-End	No reportable indications 

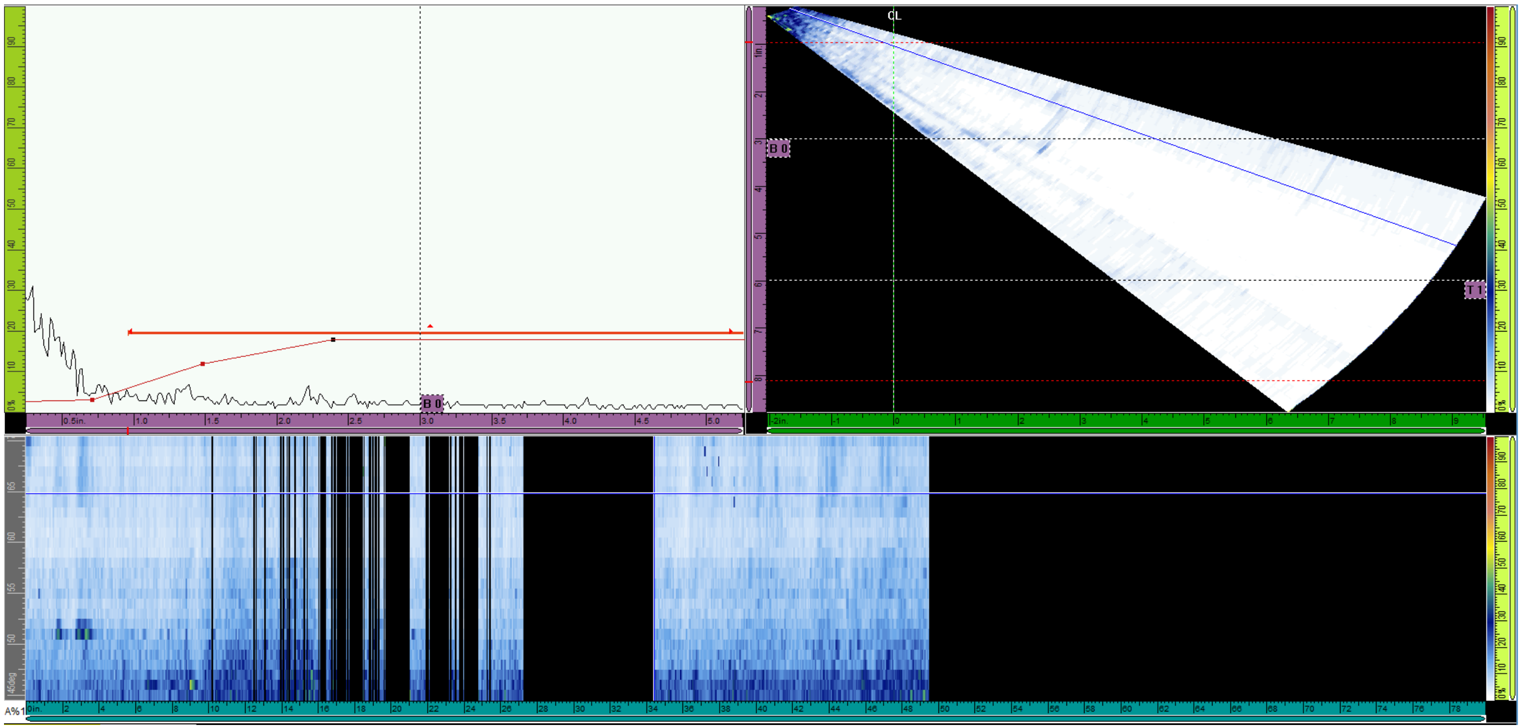
Valve 5 Upstream Side

Weld	Comments
S5a	Standard root reflection(s)

Gain (dB)	Indication #	Scan (in)	Index (in)	Group	Channel	A%1 (%)	DA/1 (in)	PA/1 (in)	SA/1 (in)	U(m-r) (in)	I(m-r) (in)	I•U(m-r) (in)	S(m-r) (in)	Type
40.66	1	40.788	-6.500	PA 1	65.00º	36.2	2.519	4.950	5.960	0.337	0.121	0.358	0.459	Root

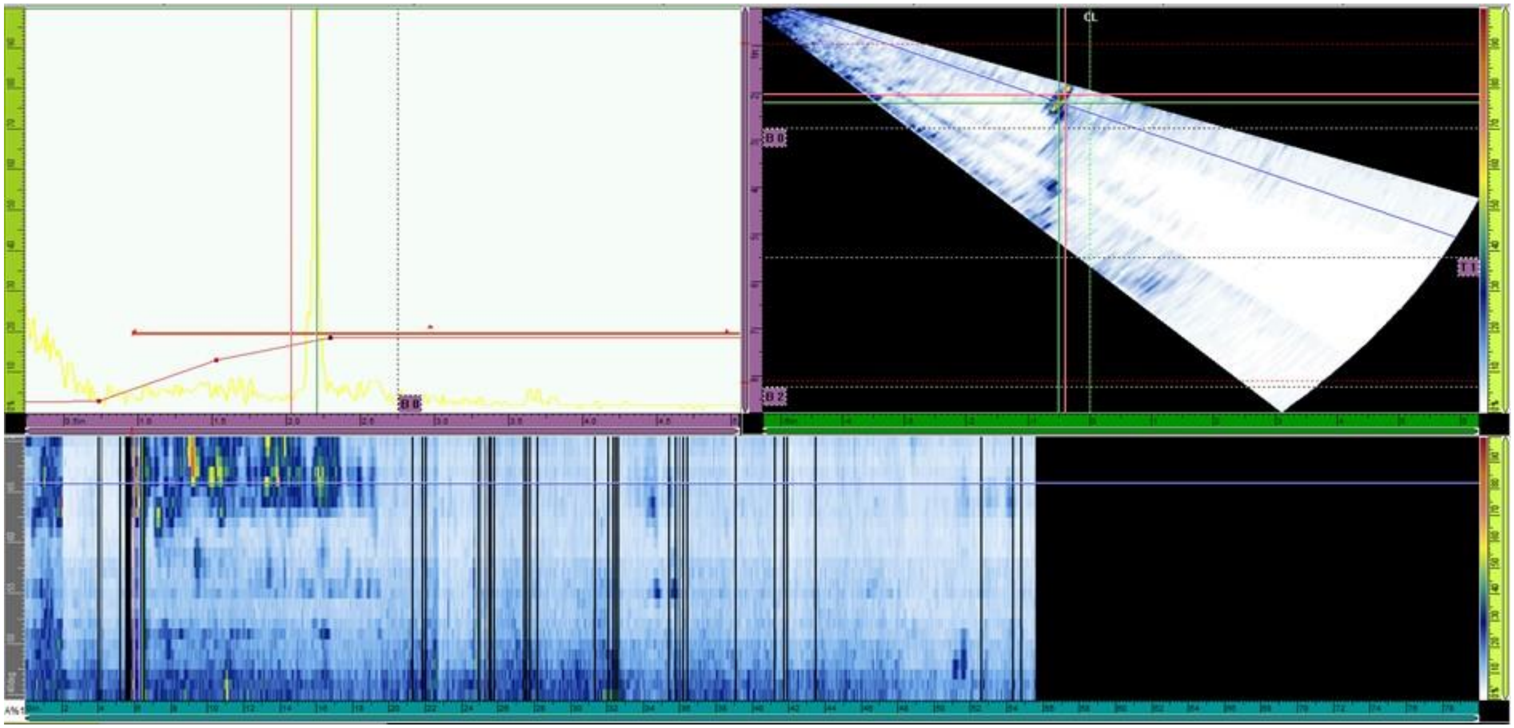


Valve 5 Upstream Side	
Weld	Comments
S5b	No indications, yellow area due to surface roughness. 

Valve 5 Upstream Side	
Weld	Comments
S6a	No reportable indications. 

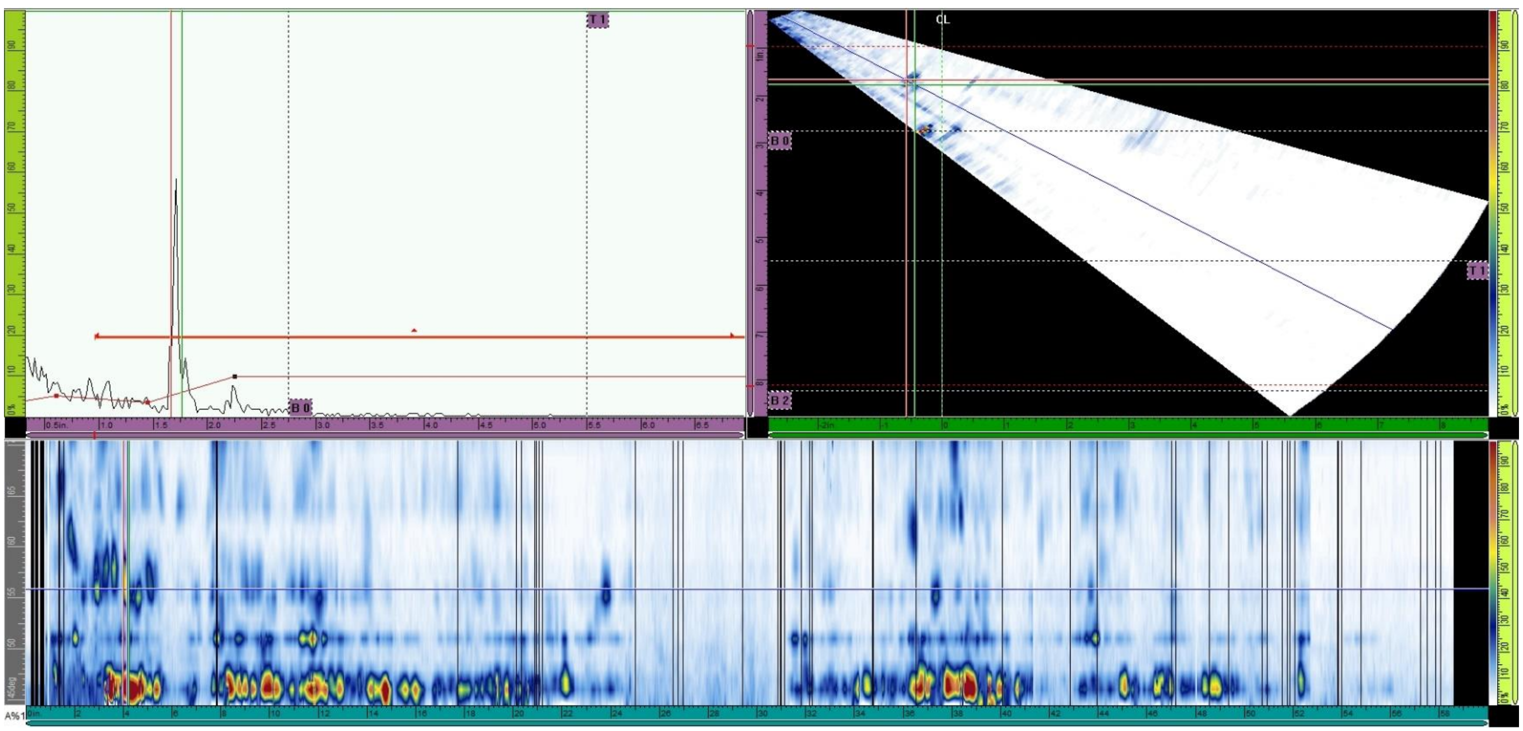
Valve 5 Upstream Side	
Weld	Comments
S6b	Lack of fusion 11" long

Gain (dB)	Indication #	Scan (in)	Index (in)	Group	Channel	A%1 (%)	DA/1 (in)	PA/1 (in)	SA/1 (in)	U(m-r) (in)	I(m-r) (in)	I•U(m-r) (in)	S(m-r) (in)	Type
46.66	1	6.345	-6.500	PA 1	67.00º	22.5	2.062	4.427	5.276	0.603	0.337	0.691	11.100	LOF



Valve 5 Upstream Side	
Weld	Comments
S6a-End	No scan surface too rough.
S6b-End	No scan surface too rough.
S7a	Slag.

Gain (dB)	Indication #	Scan (in)	Index (in)	Group	Channel	A%1 (%)	DA/1 (in)	PA/1 (in)	SA/1 (in)	U(m-r) (in)	I(m-r) (in)	I•U(m-r) (in)	S(m-r) (in)	Type
40.66	1	4.100	-2.500	PA 1	56.00º	58.7	1.704	1.965	3.048	0.106	0.135	0.172	0.241	Slag

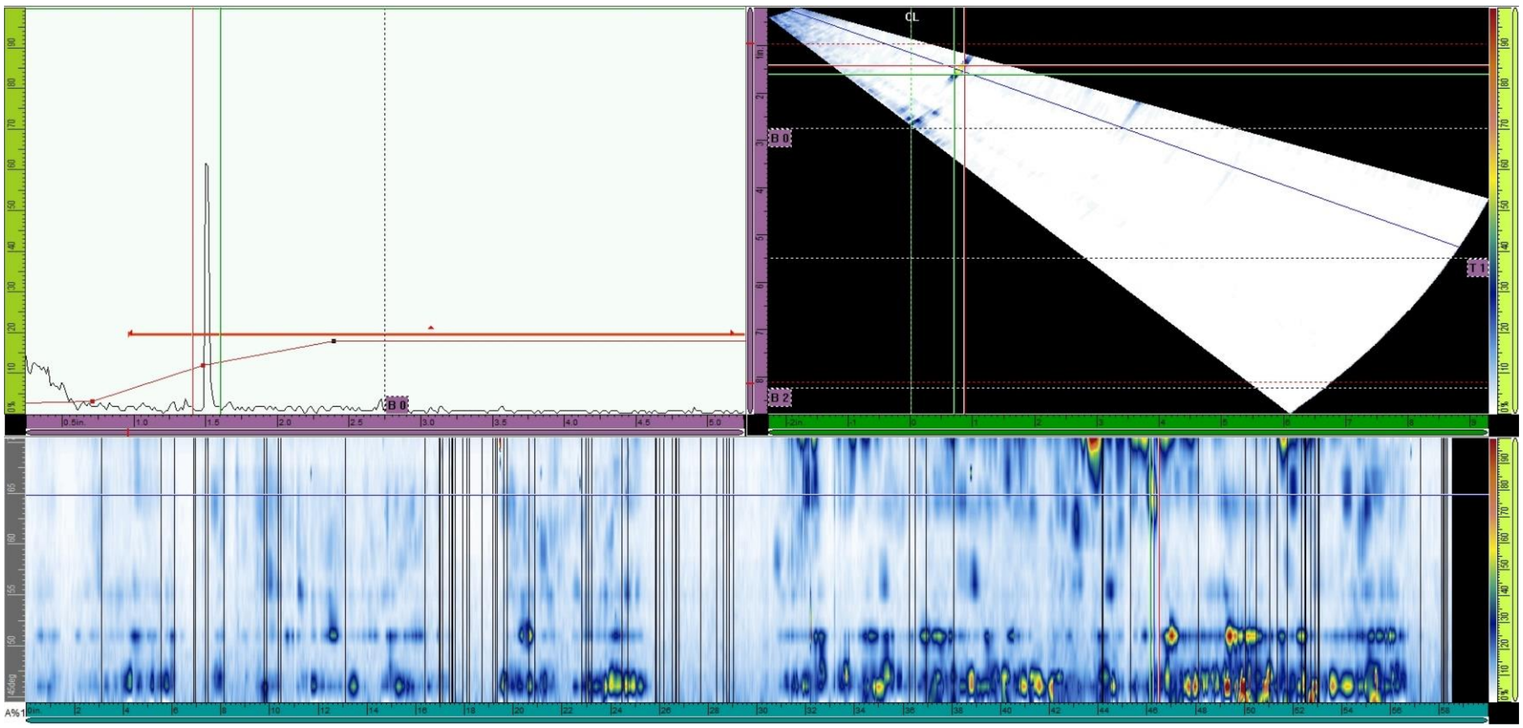


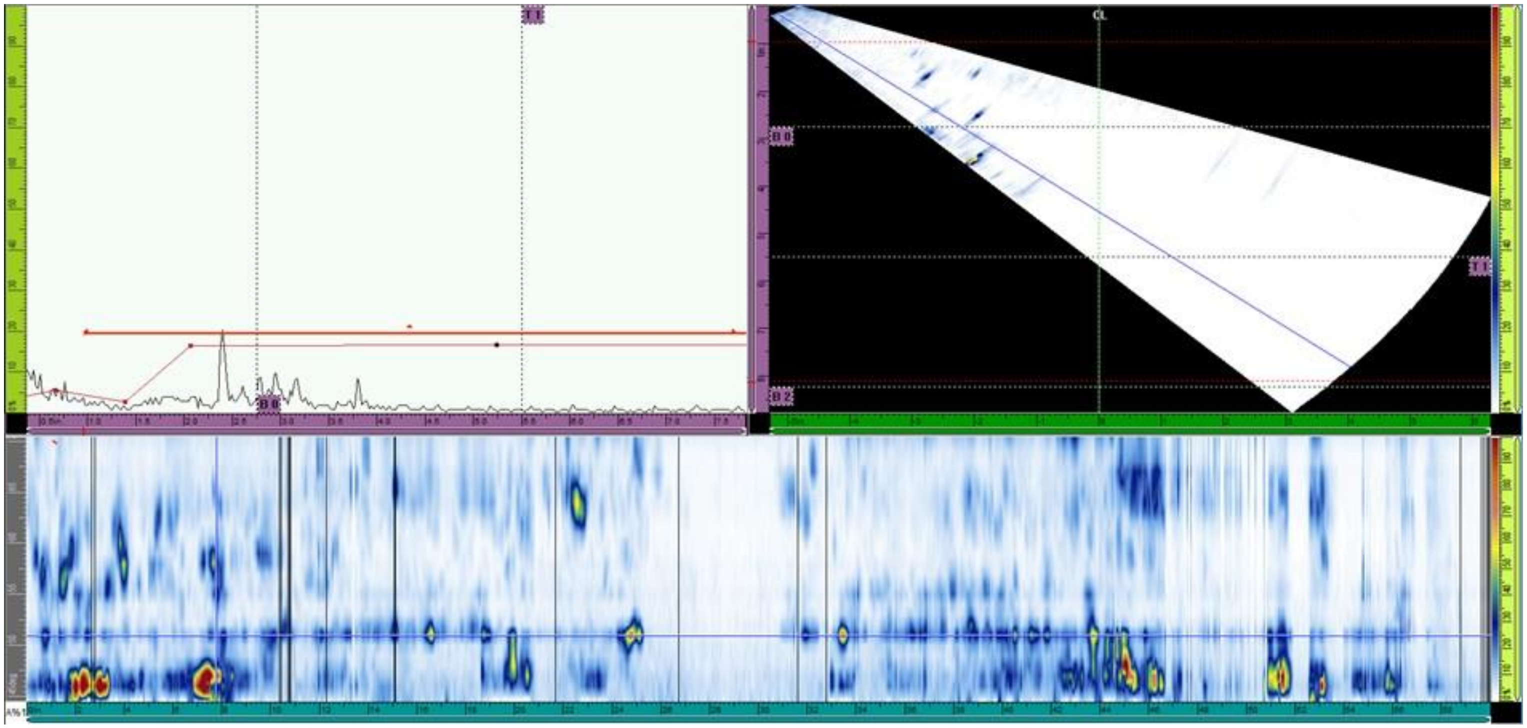
TechKnowServ™
TECHNOLOGY, KNOWLEDGE, SERVICE

Valve 5 Upstream Side

Weld	Comments
S7b	Lack of fusion – 0.344" long.

Gain (dB)	Indication #	Scan (in)	Index (in)	Group	Channel	A%1 (%)	DA/1 (in)	PA/1 (in)	SA/1 (in)	U(m-r) (in)	I(m-r) (in)	I•U(m-r) (in)	S(m-r) (in)	Type
40.66	1	46.242	-2.000	PA 1	65.00º	61.6	1.504	2.774	3.560	0.195	0.162	0.253	0.344	LOF

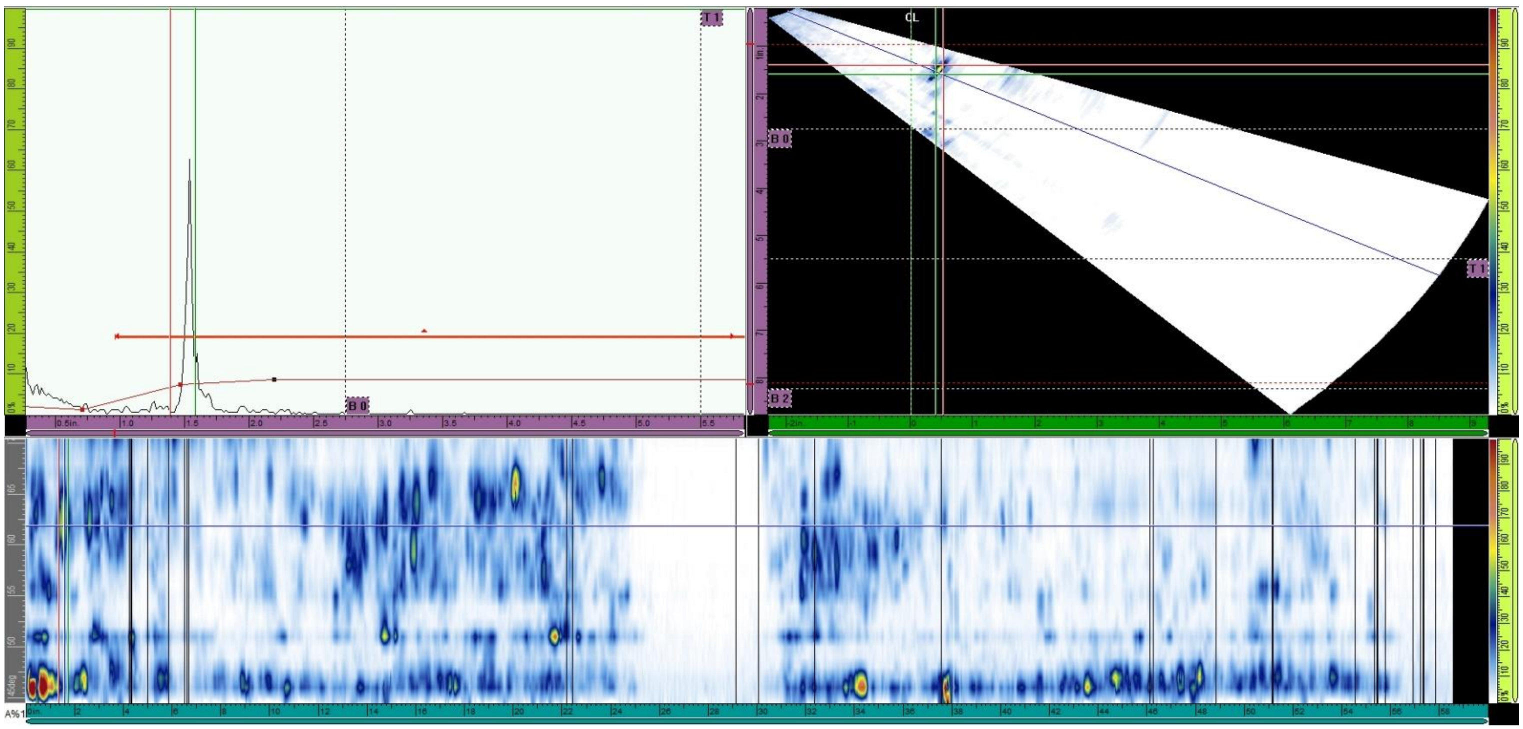


Valve 5 Upstream Side	
Weld	Comments
S8a	No reportable indications, yellow areas due to surface roughness and relating to root. 

Valve 5 Upstream Side

Weld	Comments
S8b	Numerous LOF between 0.241 to 0.378” long.

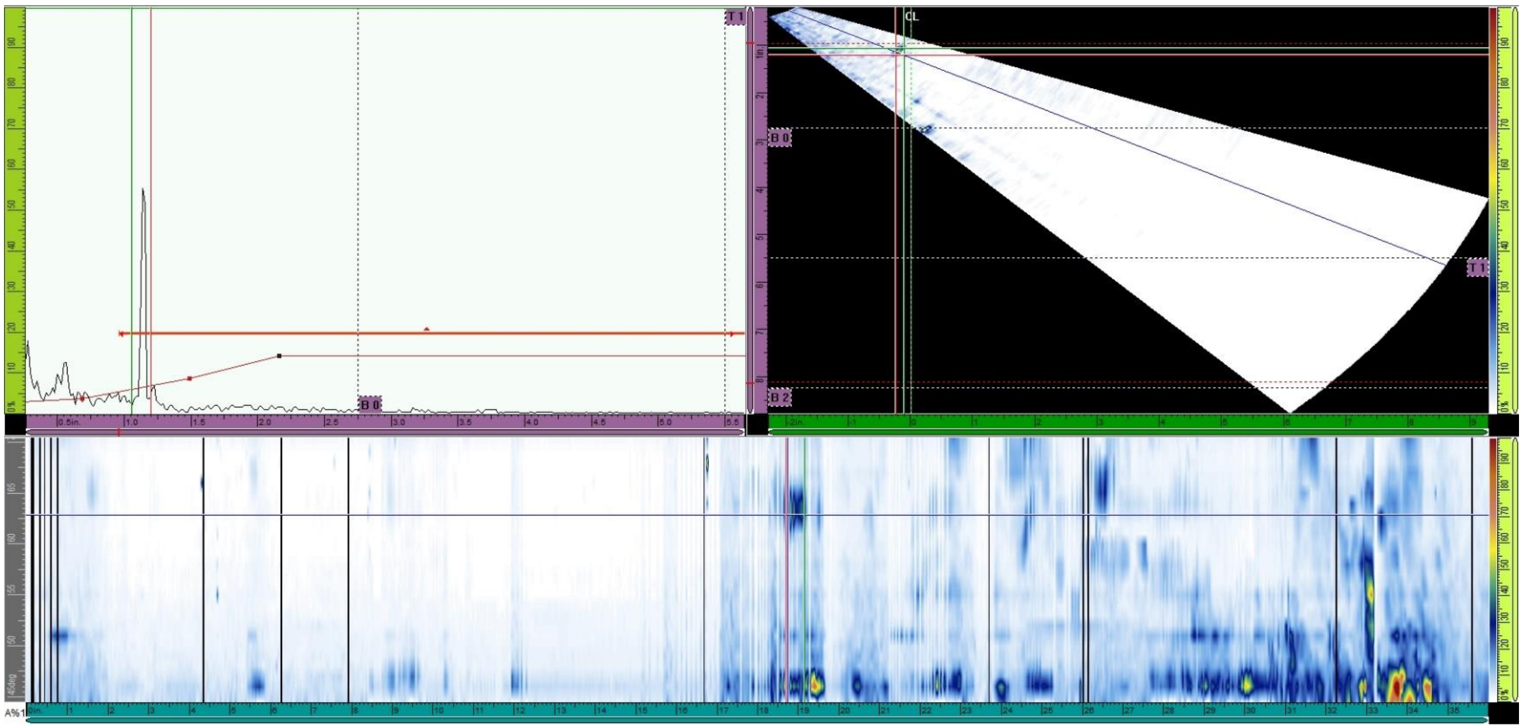
Gain (dB)	Indication #	Scan (in)	Index (in)	Group	Channel	A%1 (%)	DA/1 (in)	PA/1 (in)	SA/1 (in)	U(m-r) (in)	I(m-r) (in)	I•U(m-r) (in)	S(m-r) (in)	Type
40.66	1	1.537	-6.500	PA 1	62.00º	62.2	1.507	2.347	3.211	0.195	0.121	0.230	0.378	LOF
40.66	2	20.066	-6.500	PA 1	66.00º	73.9	1.396	2.696	3.433	0.195	0.148	0.245	0.310	LOF
40.66	3	14.704	-6.500	PA 1	51.00º	60.1	1.974	1.812	3.137	0.071	0.081	0.108	0.241	LOF
40.66	4	21.721	-6.500	PA 1	51.00º	81.5	2.440	2.388	3.878	0.124	0.135	0.183	0.378	LOF



Valve 5 Upstream Side

Weld	Comments
S9a	Porosity 0.455” long

Gain (dB)	Indication #	Scan (in)	Index (in)	Group	Channel	A%1 (%)	DA/1 (in)	PA/1 (in)	SA/1 (in)	U(m-r) (in)	I(m-r) (in)	I•U(m-r) (in)	S(m-r) (in)	Type
40.66	1	18.729	-6.500	PA 1	63.00º	55.0	1.121	1.725	2.470	0.142	0.135	0.196	0.454	PORO

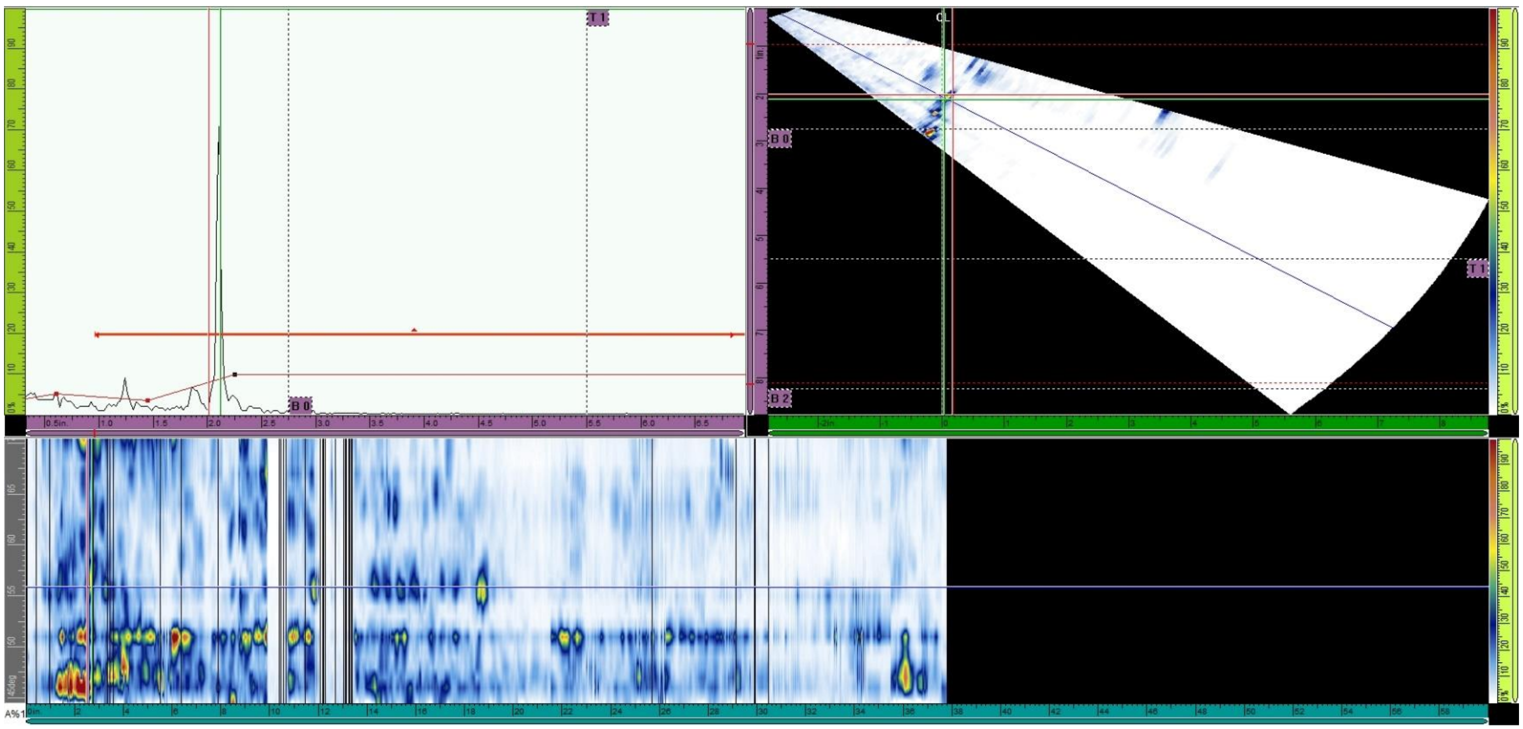


Weld	Comments
S9b	No scanning possible due to rough surface.

Valve 5 Upstream Side

Weld	Comments
S10a	

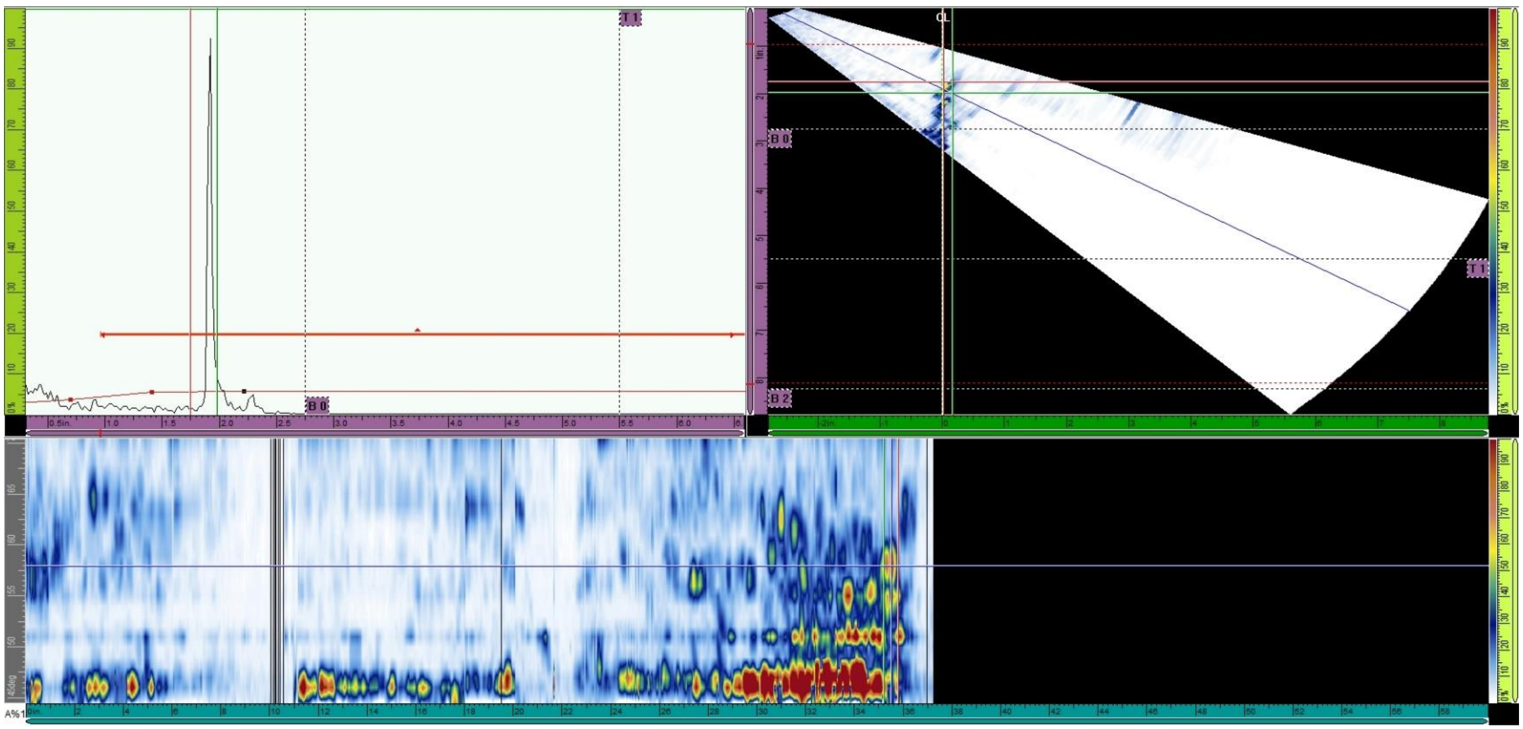
Gain (dB)	Indication #	Scan (in)	Index (in)	Group	Channel	A%1 (%)	DA/1 (in)	PA/1 (in)	SA/1 (in)	U(m-r) (in)	I(m-r) (in)	I•U(m-r) (in)	S(m-r) (in)	Type
40.66	1	2.523	-6.500	PA 1	56.00º	70.4	2.086	2.530	3.730	0.106	0.135	0.172	0.206	LOF
40.66	2	11.827	-6.500	PA 1	56.00º	72.6	2.044	2.469	3.656	0.071	0.094	0.118	0.172	LOF
40.66	3	18.686	-6.500	PA 1	56.00º	52.2	2.127	2.592	3.804	0.160	0.243	0.290	0.378	LOF

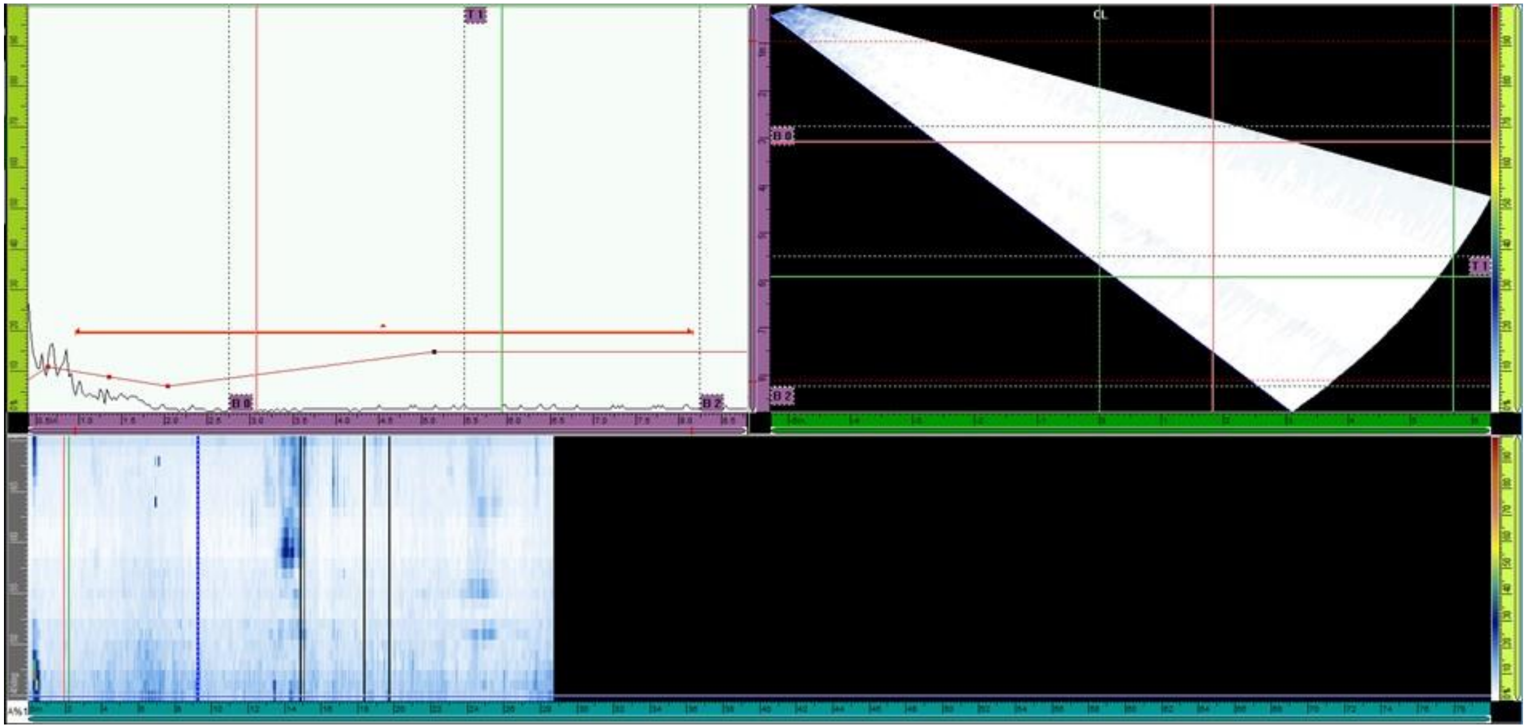


Valve 5 Upstream Side

Weld	Comments
S10b	Intermittent LOF over 8”.

Gain (dB)	Indication #	Scan (in)	Index (in)	Group	Channel	A%1 (%)	DA/1 (in)	PA/1 (in)	SA/1 (in)	U(m-r) (in)	I(m-r) (in)	I•U(m-r) (in)	S(m-r) (in)	Type
40.66	1	27.359	-6.500	PA 1	56.00º	59.9	1.941	2.315	3.470	0.142	0.108	0.178	0.654	LOF
40.66	2	30.986	-6.500	PA 1	63.00º	64.3	1.424	2.319	3.137	0.195	0.135	0.237	0.206	LOF
40.66	3	33.745	-6.500	PA 1	55.00º	99.0	2.118	2.450	3.693	0.177	0.162	0.240	0.378	LOF
40.66	4	35.480	-6.500	PA 1	58.00º	91.8	1.898	2.501	3.581	0.230	0.148	0.274	0.585	LOF

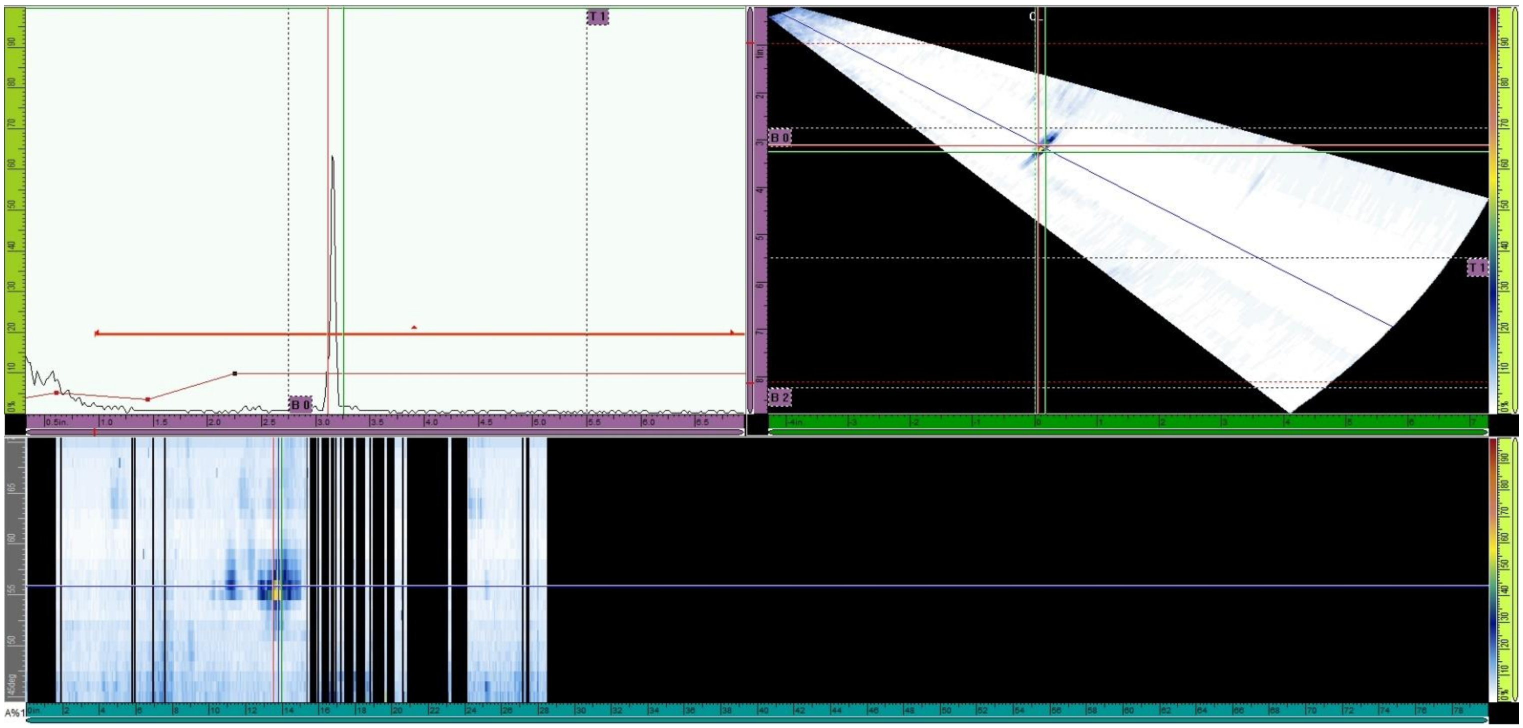


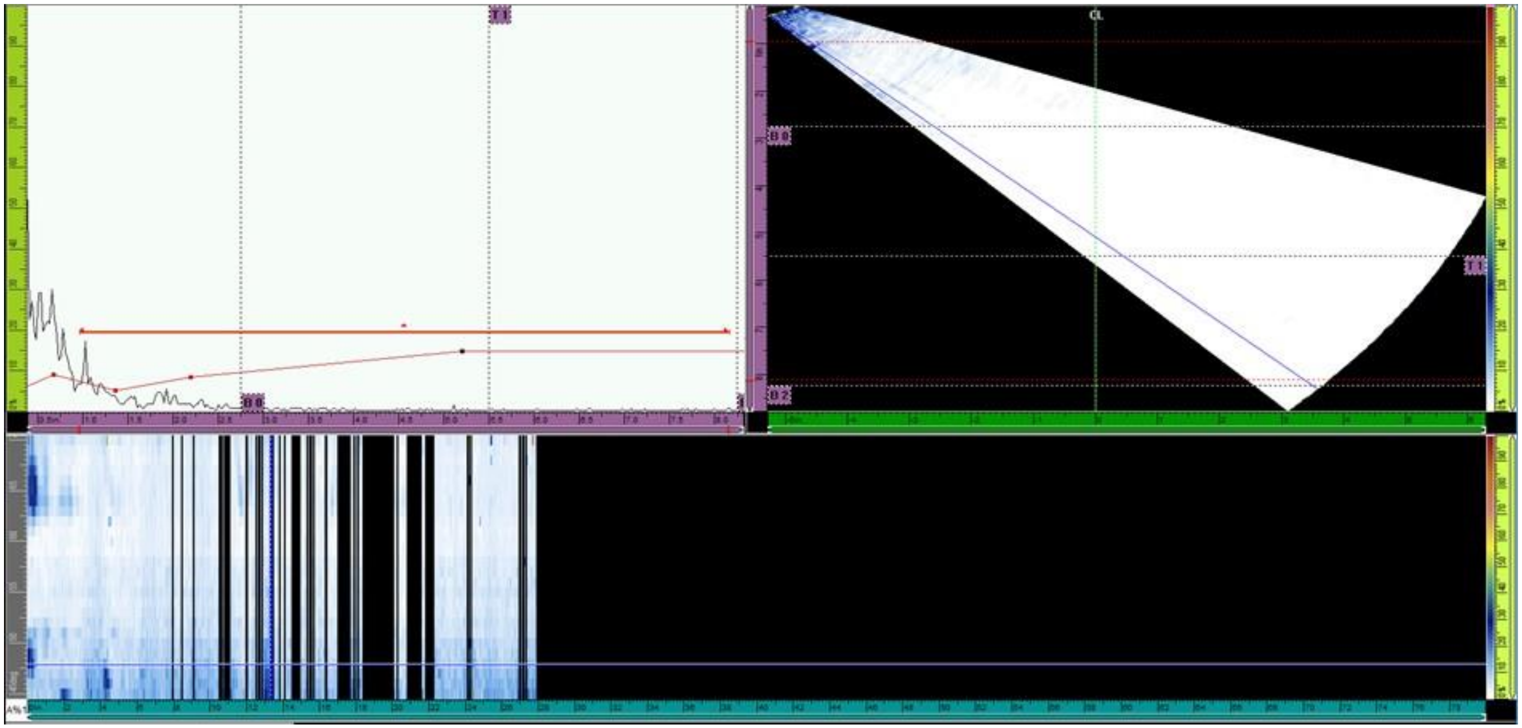
Valve 5 Upstream Side	
Weld	Comments
S11a	No indications to report. 

Valve 5 Upstream Side

Weld	Comments
S11b	

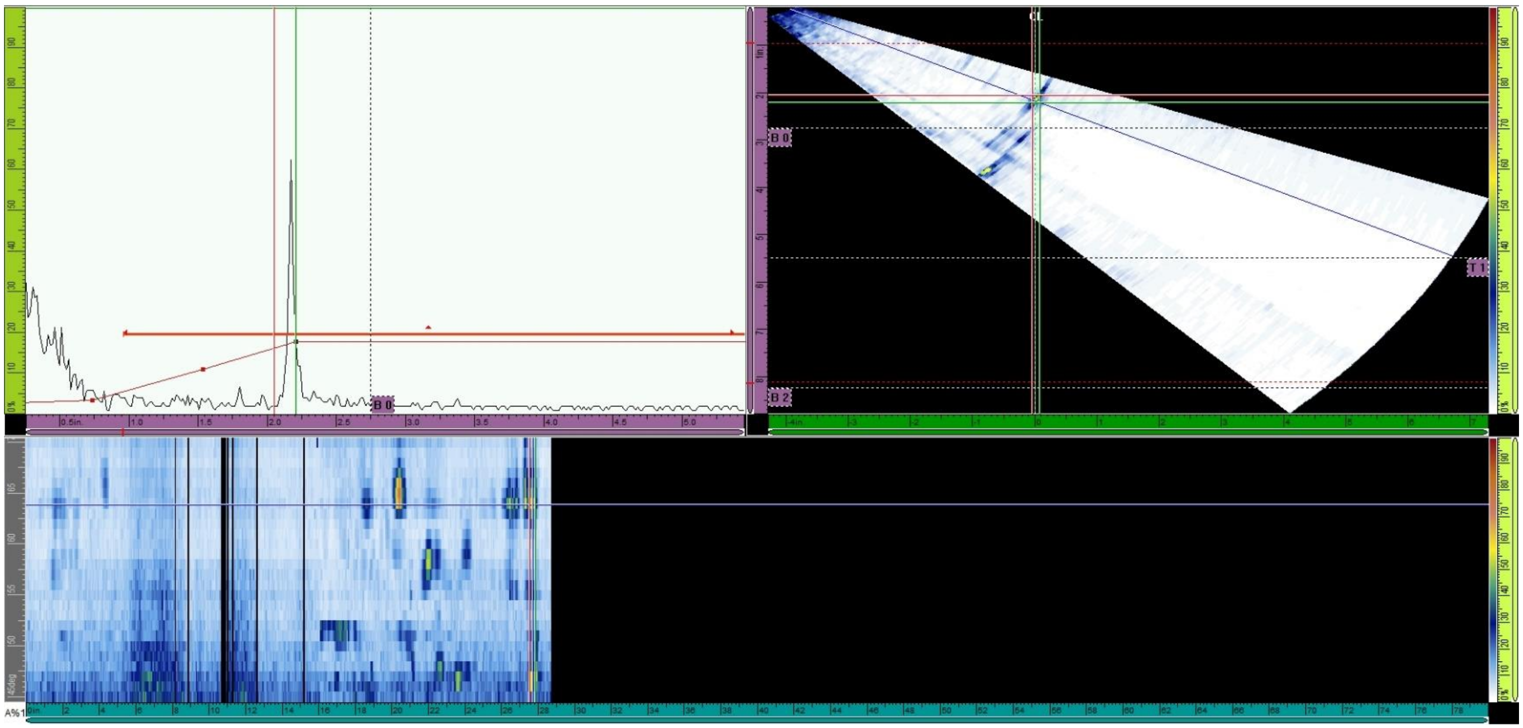
Gain (dB)	Indication #	Scan (in)	Index (in)	Group	Channel	A%1 (%)	DA/1 (in)	PA/1 (in)	SA/1 (in)	U(m-r) (in)	I(m-r) (in)	I•U(m-r) (in)	S(m-r) (in)	Type
46.66	1	13.740	-6.500	PA 1	56.00º	63.6	2.349	4.109	5.634	0.142	0.121	0.187	0.459	LOF

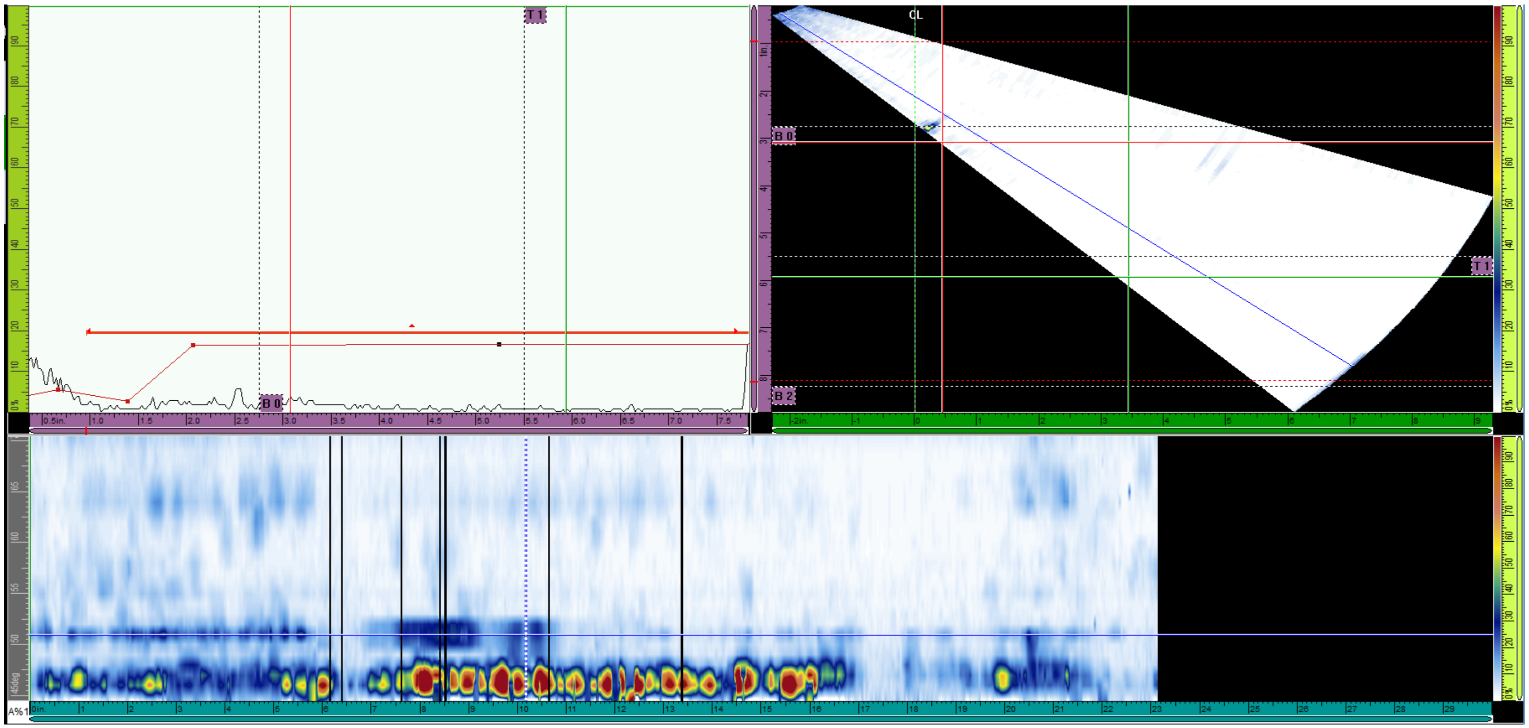


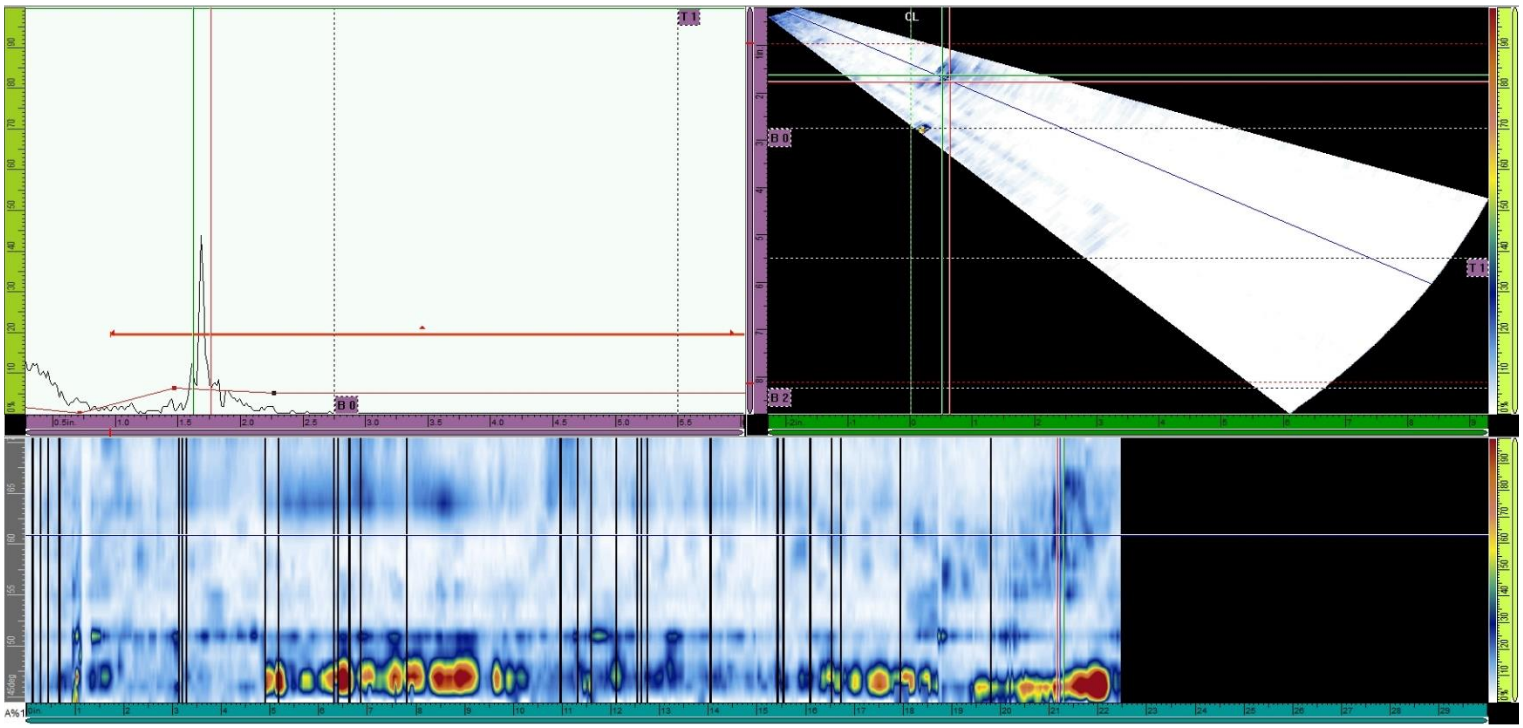
Valve 5 Upstream Side	
Weld	Comments
S12a	No reportable indications. 

Valve 5 Upstream Side	
Weld	Comments
S12b	

Gain (dB)	Indication #	Scan (in)	Index (in)	Group	Channel	A%1 (%)	DA/1 (in)	PA/1 (in)	SA/1 (in)	U(m-r) (in)	I(m-r) (in)	I•U(m-r) (in)	S(m-r) (in)	Type
46.66	1	27.665	-6.500	PA 1	64.00º	62.6	2.162	3.969	4.932	0.160	0.121	0.200	0.321	LOF

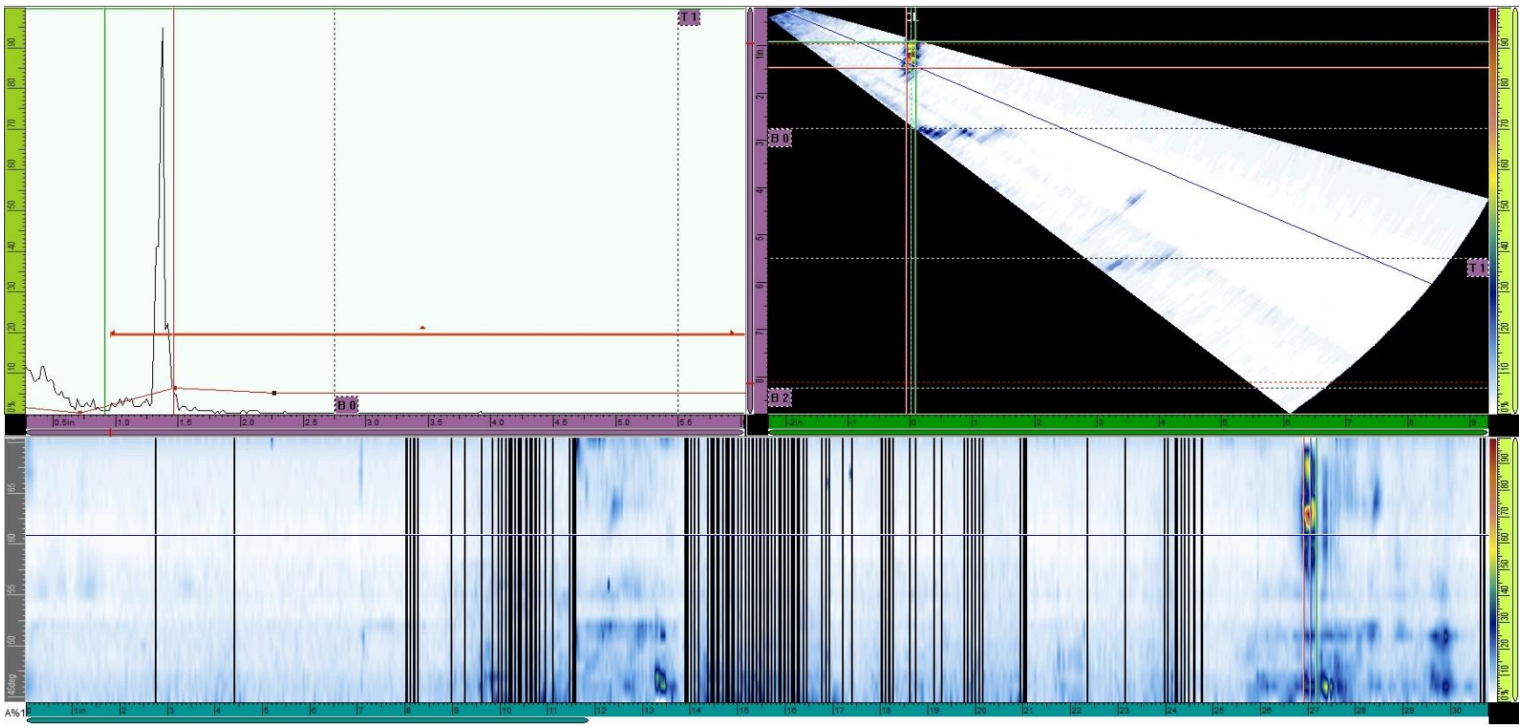


Valve 5 Upstream Side	
Weld	Comments
S13a	Standard root reflection(s) 

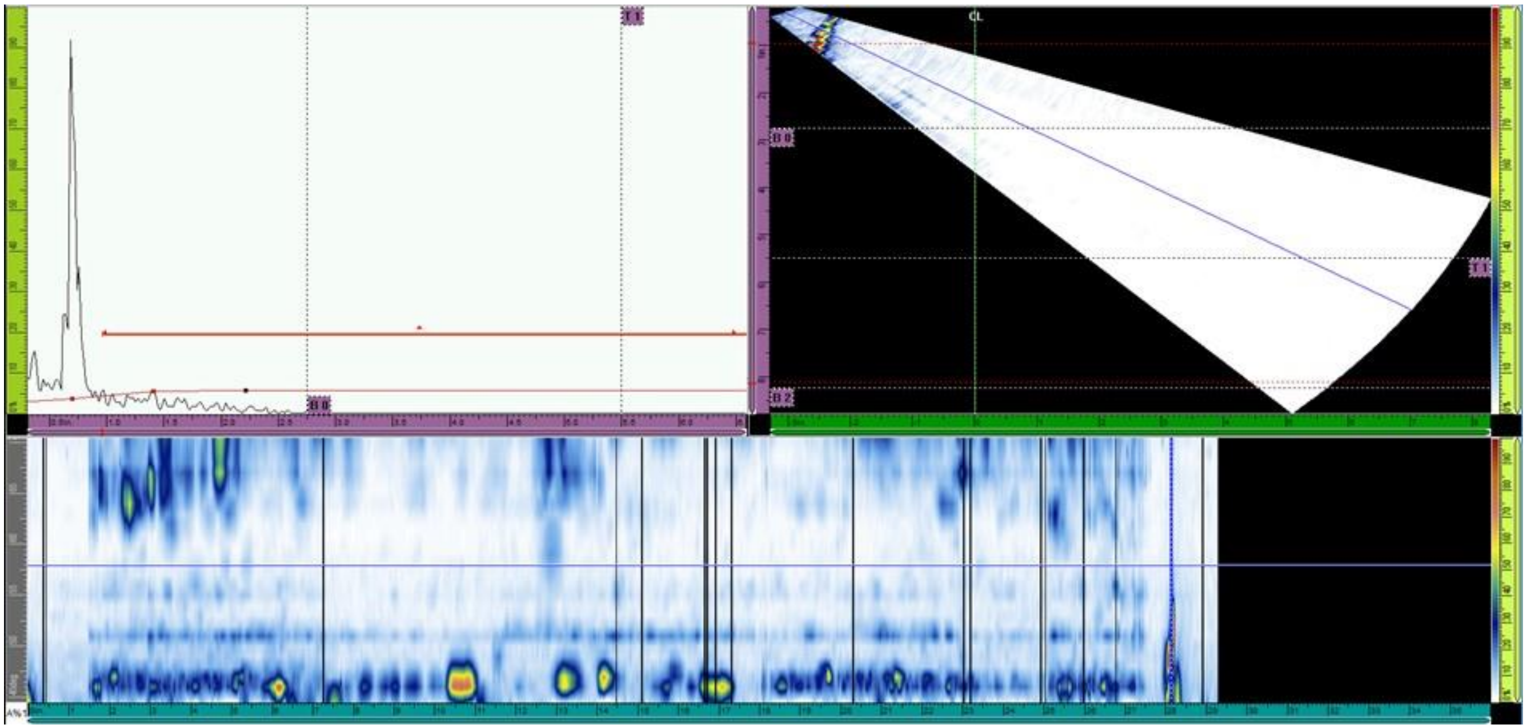
Valve 5 Upstream Side	
Weld	Comments
S13b	Standard root reflection(s) 

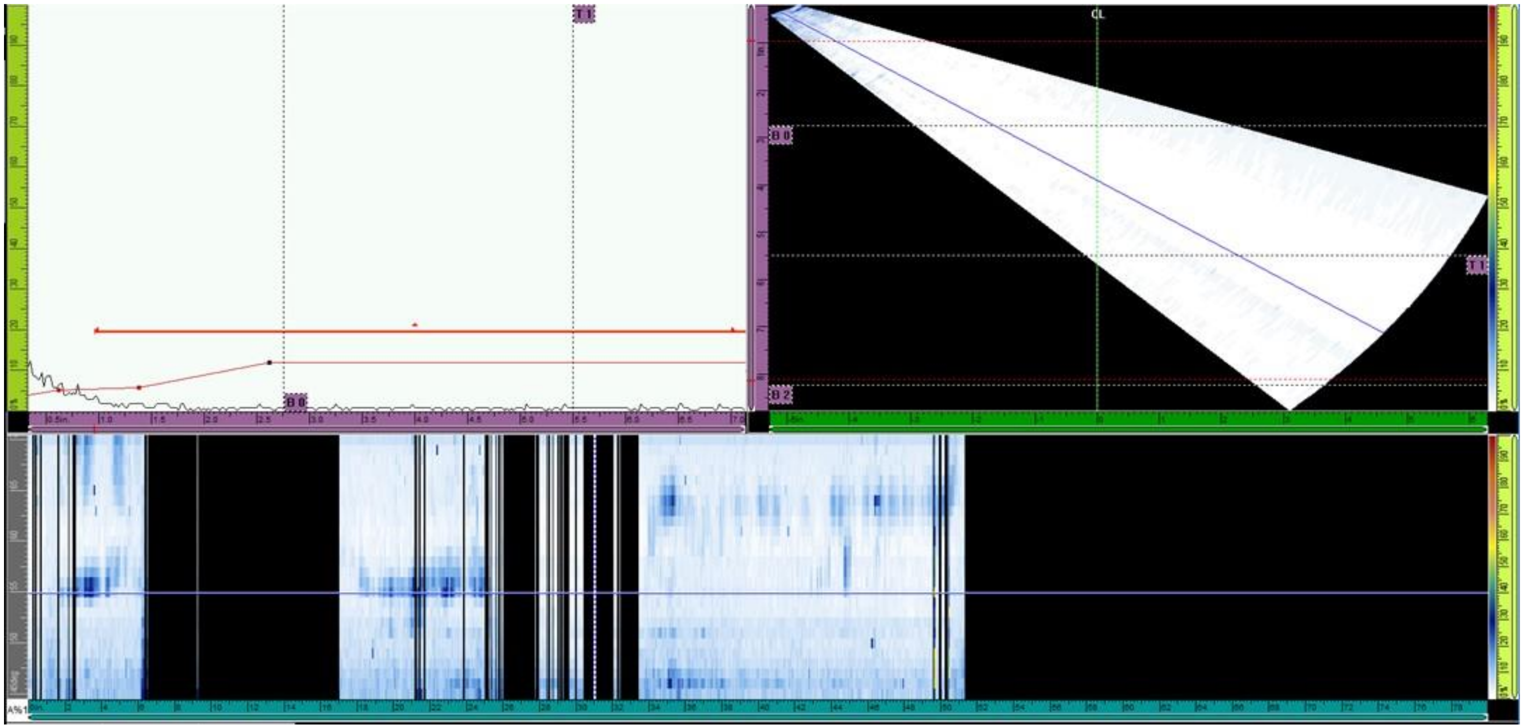
Valve 5 Upstream Side	
Weld	Comments
H1	Inclusion / volumetric defect 0.550” height in vertical direction.

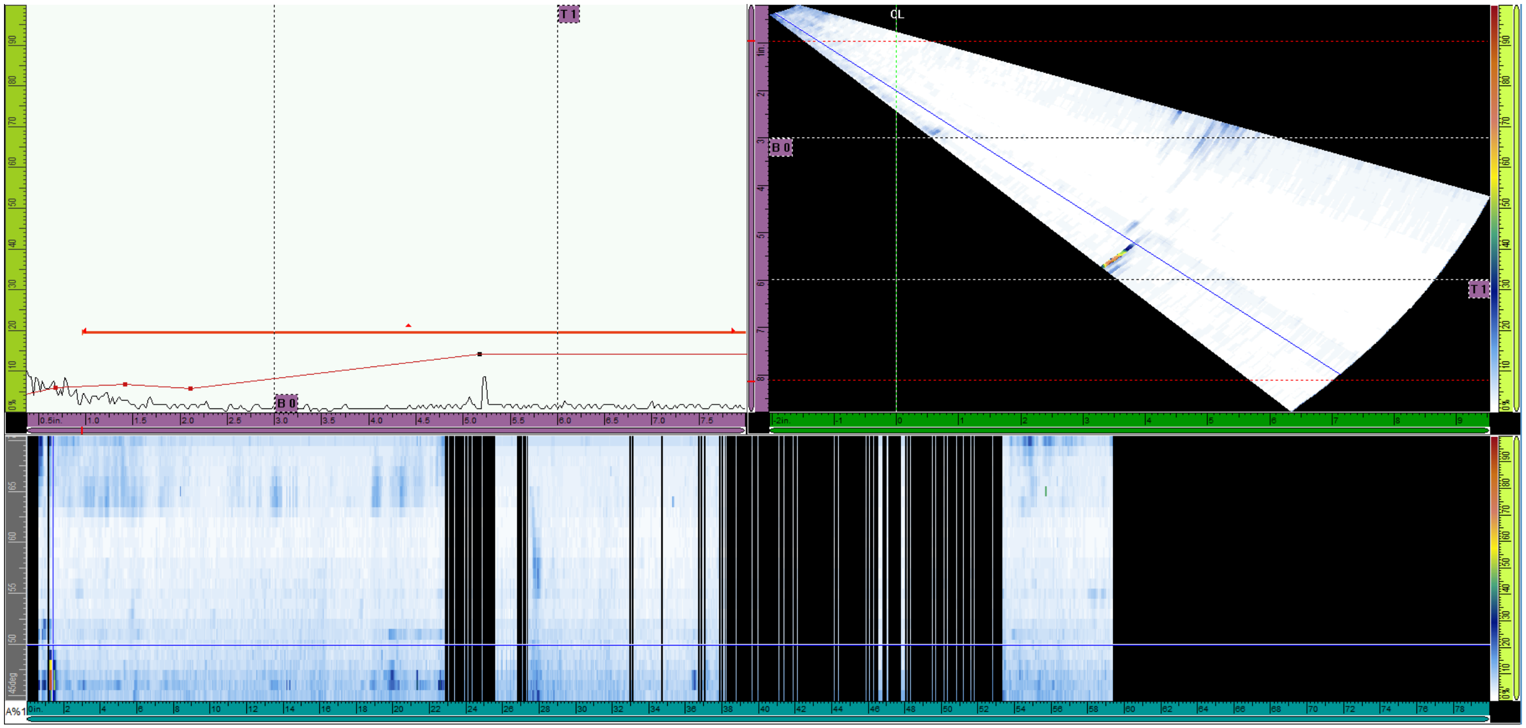
Gain (dB)	Indication #	Scan (in)	Index (in)	Group	Channel	A%1 (%)	DA/1 (in)	PA/1 (in)	SA/1 (in)	U(m-r) (in)	I(m-r) (in)	I•U(m-r) (in)	S(m-r) (in)	Type
46.66	1	27.047	-6.500	PA 1	61.00º	41.1	1.313	1.869	2.708	0.550	0.148	0.569	0.265	Slag

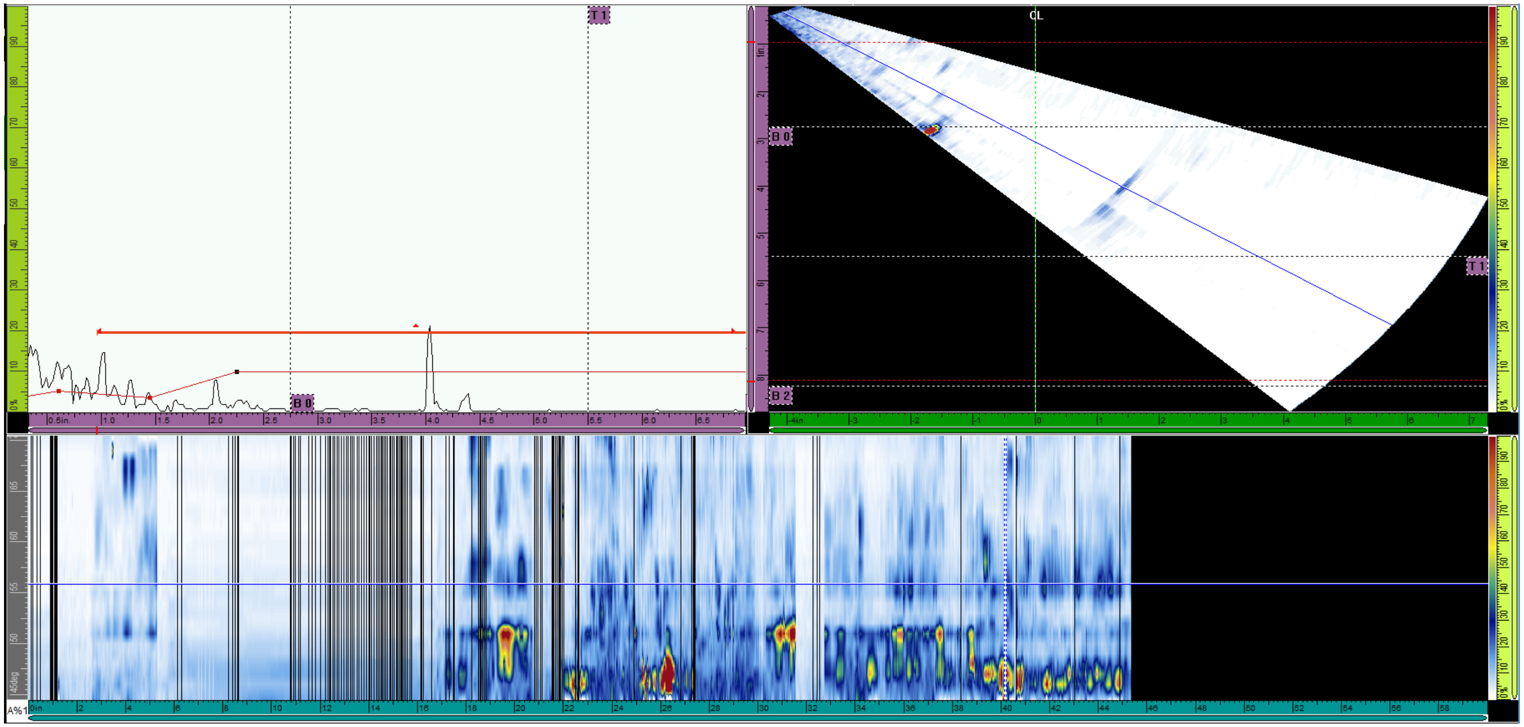


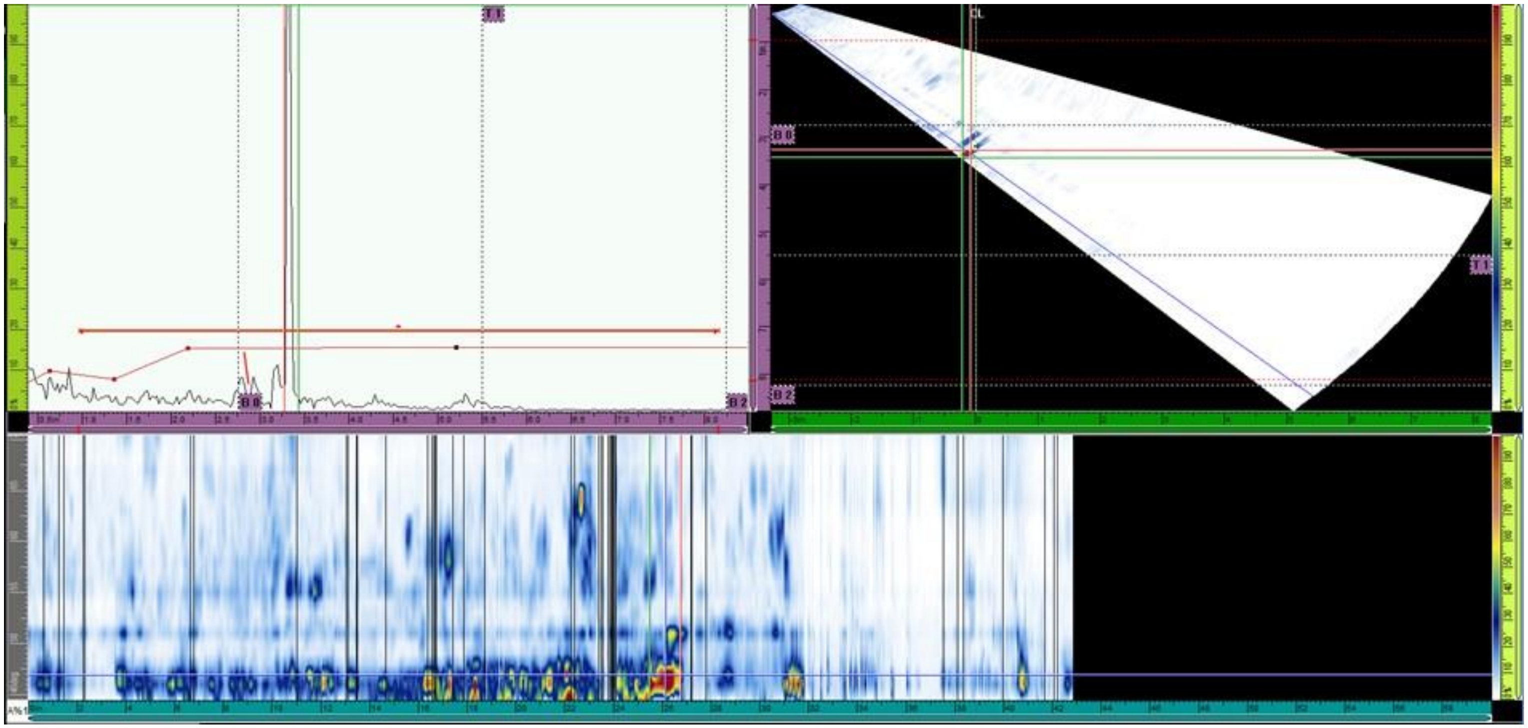
TechKnowServ
TECHNOLOGY, KNOWLEDGE, SERVICE

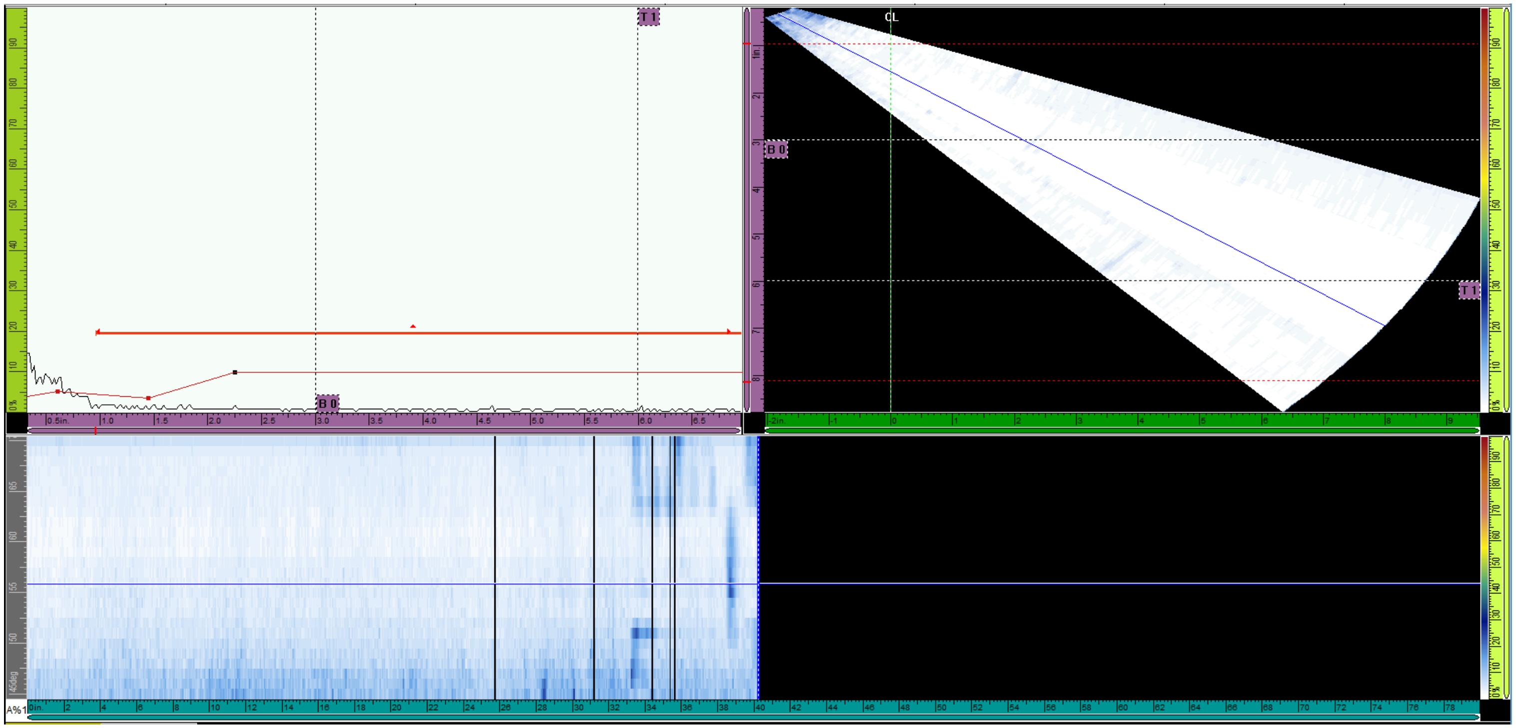
Valve 5 Upstream Side	
Weld	Comments
H2	Standard root reflection(s) and surface roughness related reflections 

Valve 5 Upstream Side	
Weld	Comments
V1	No reportable indications. 

<table>
<tr><th colspan="2">Valve 5 Upstream Side</th></tr>
<tr><th>Weld</th><th>Comments</th></tr>
<tr><td>V2</td><td>No reportable indications.
</td></tr>
</table>

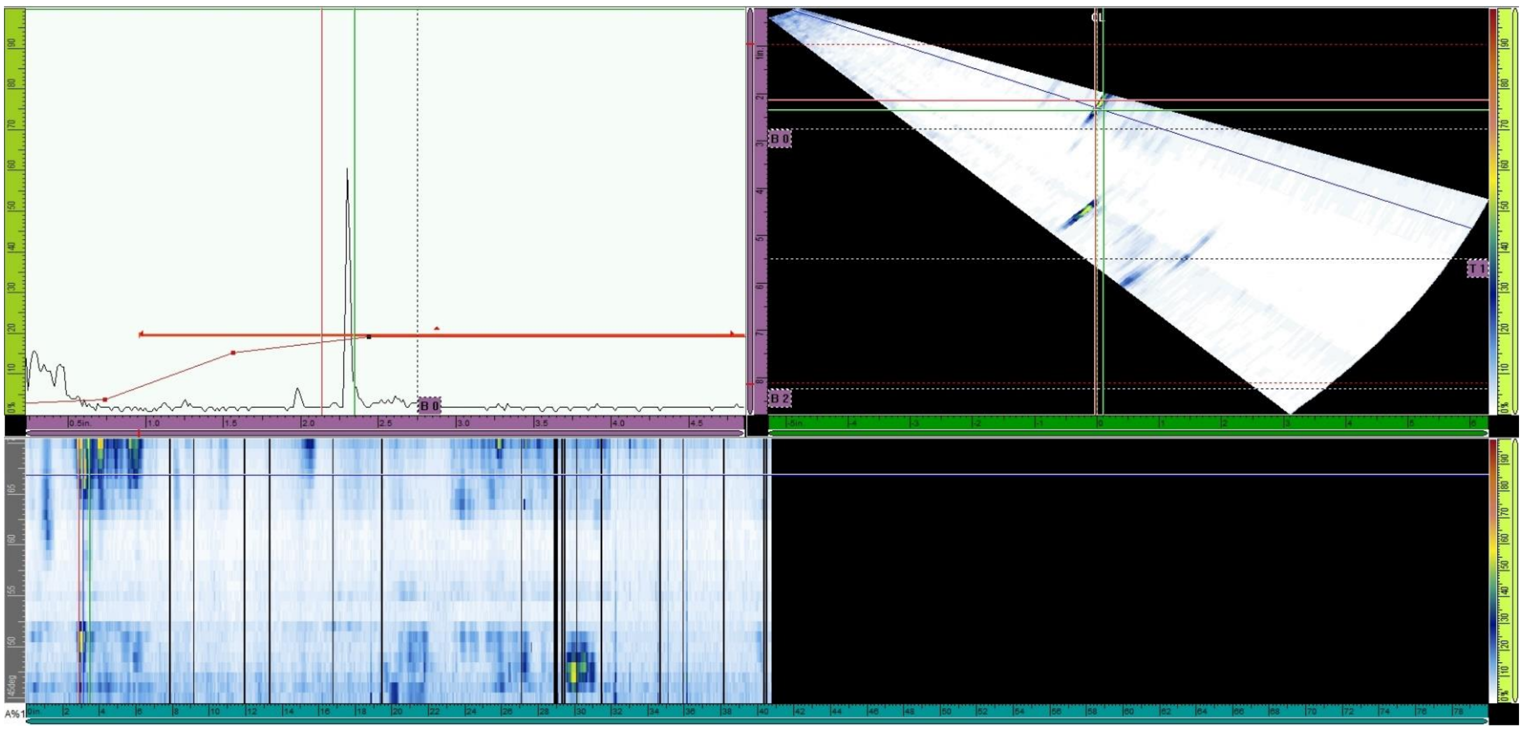
Valve 5 Upstream Side	
Weld	Comments
V3	Standard root reflection(s) 

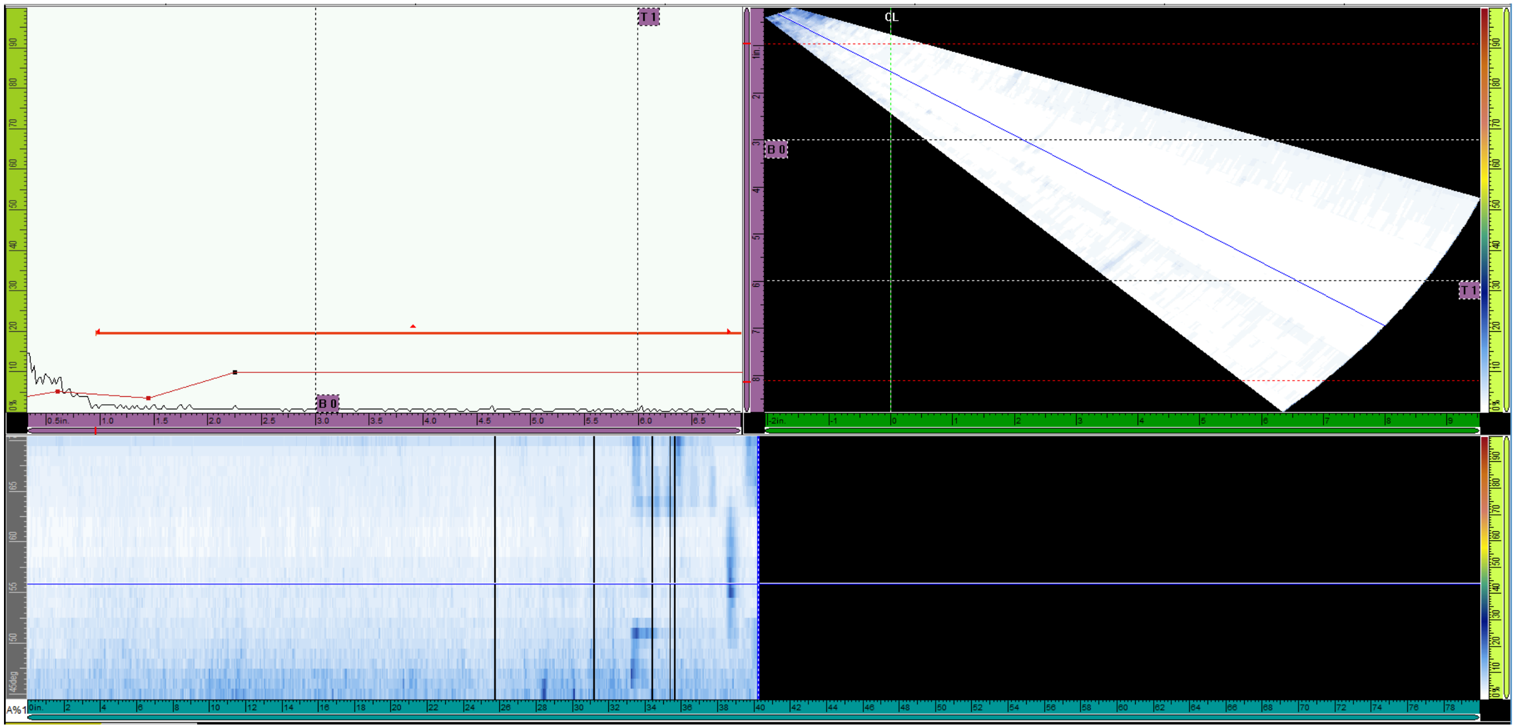
Valve 5 Upstream Side	
Weld	Comments
V4	Standard root reflection(s) 

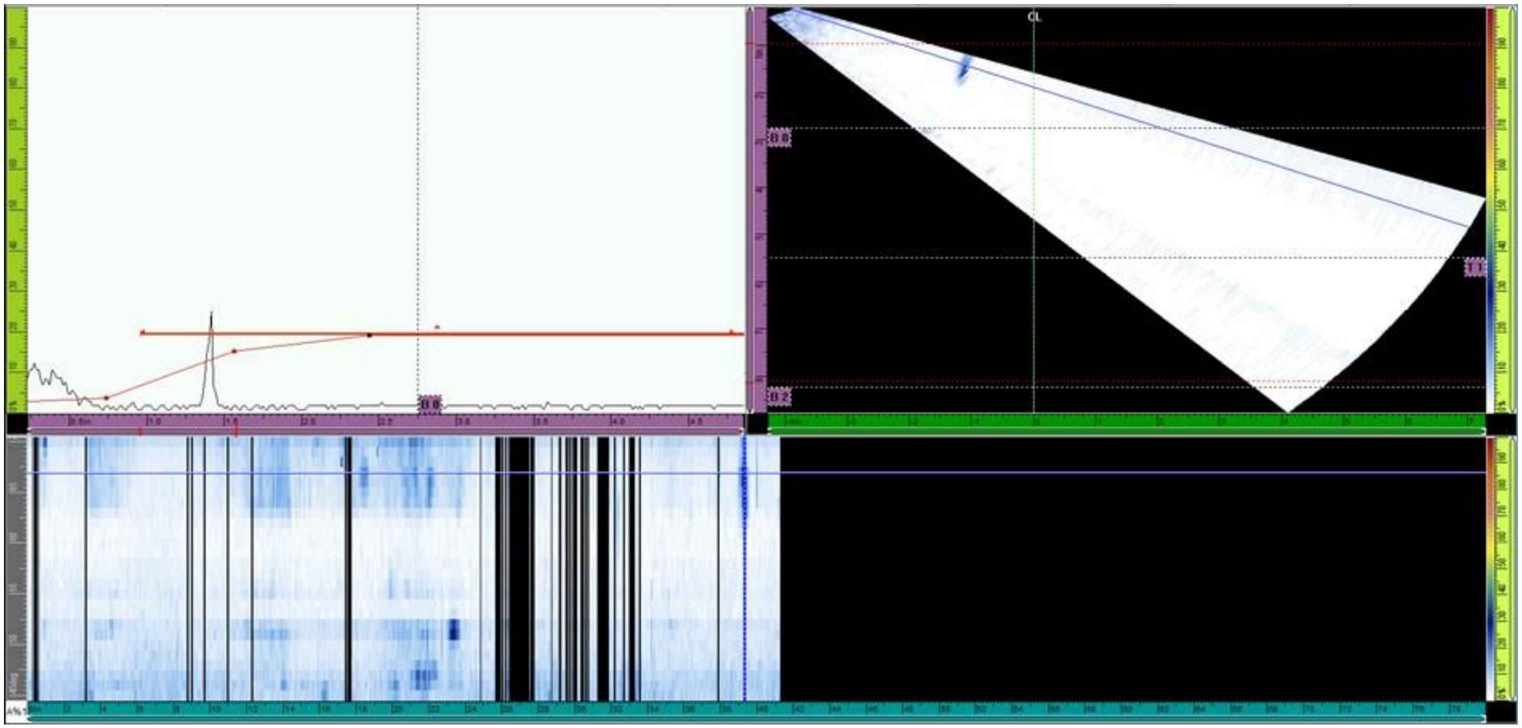
Valve 5 Upstream Side	
Weld	Comments
V5a	No reportable indications. 

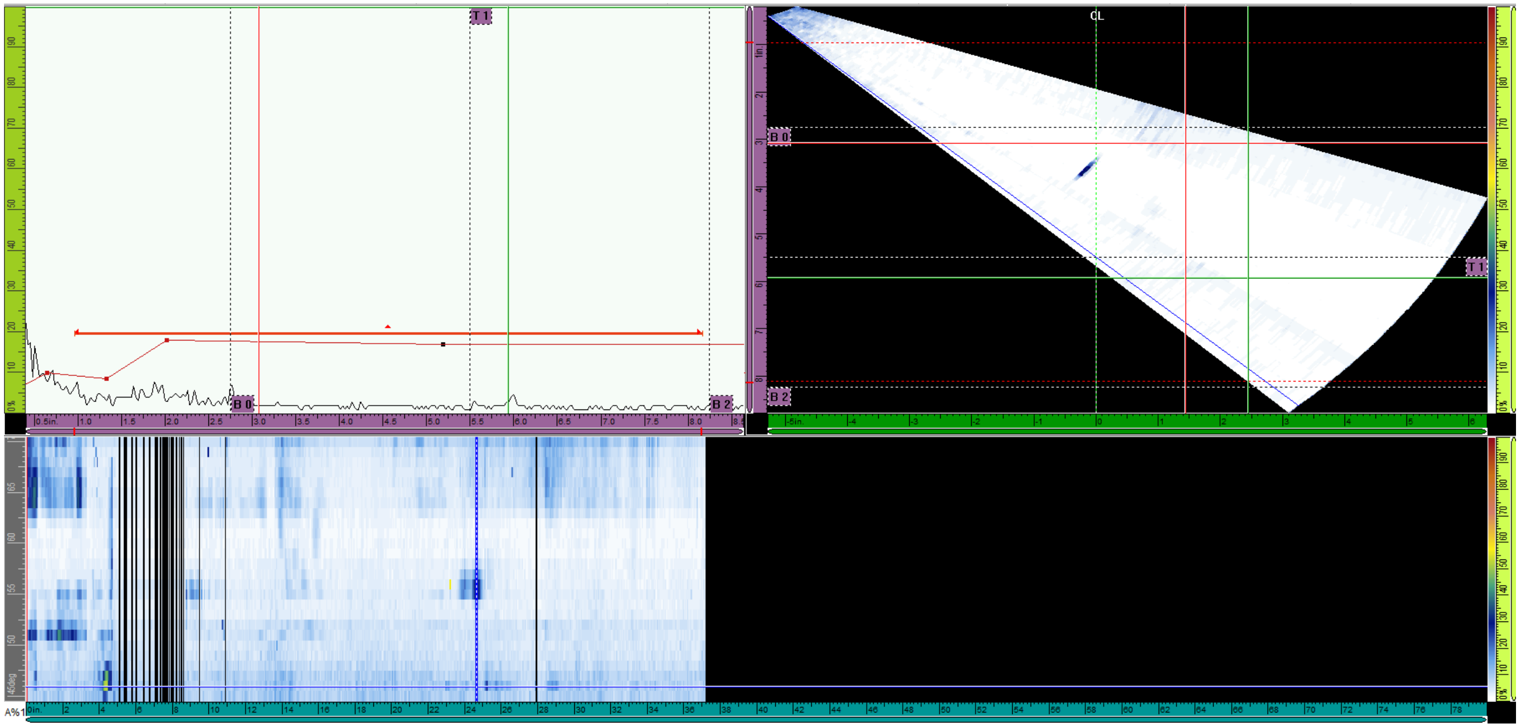
Valve 5 Upstream Side	
Weld	Comments
V5b	

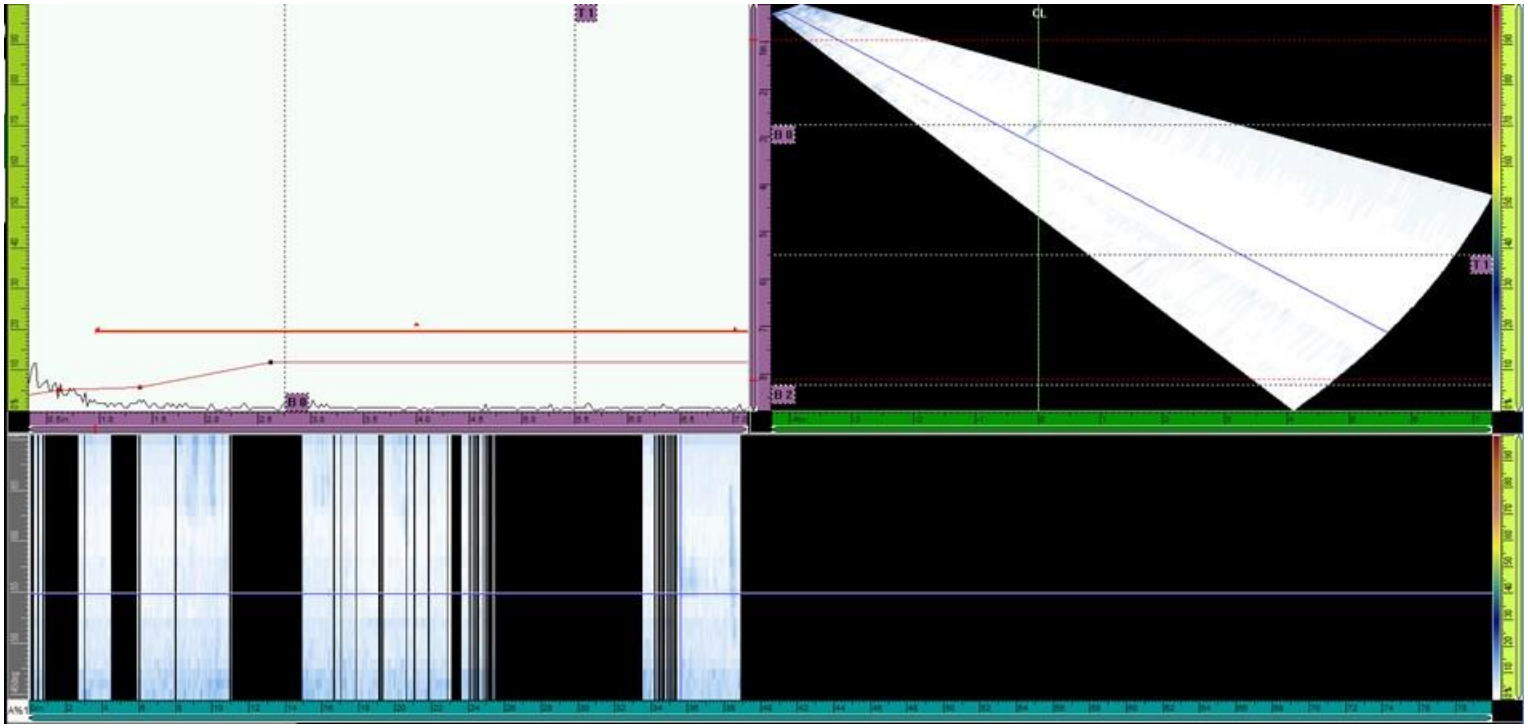
Gain (dB)	Indication #	Scan (in)	Index (in)	Group	Channel	A%1 (%)	DA/1 (in)	PA/1 (in)	SA/1 (in)	U(m-r) (in)	I(m-r) (in)	I•U(m-r) (in)	S(m-r) (in)	Type
46.66	1	3.071	-6.500	PA 1	67.00º	60.7	2.290	4.966	5.862	0.213	0.135	0.252	0.596	LOP
46.66	2	3.071	-6.500	PA 1	51.00º	59.7	1.082	4.830	7.020	0.177	0.108	0.208	0.413	LOP

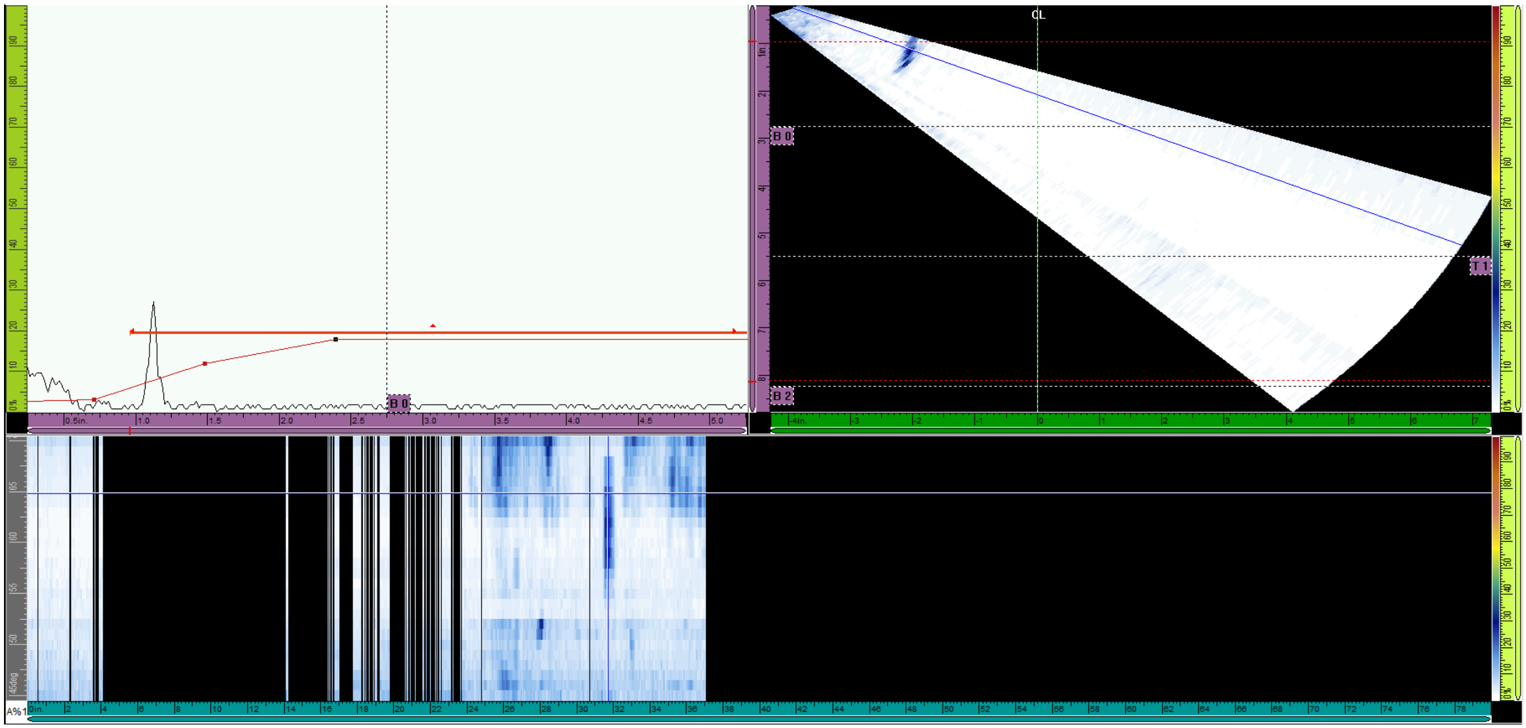


Valve 5 Upstream Side	
Weld	Comments
V6a	No reportable indications. 

Valve 5 Upstream Side	
Weld	Comments
V6b	No reportable indications. 

Valve 5 Upstream Side	
Weld	Comments
V7a	No reportable indications. 

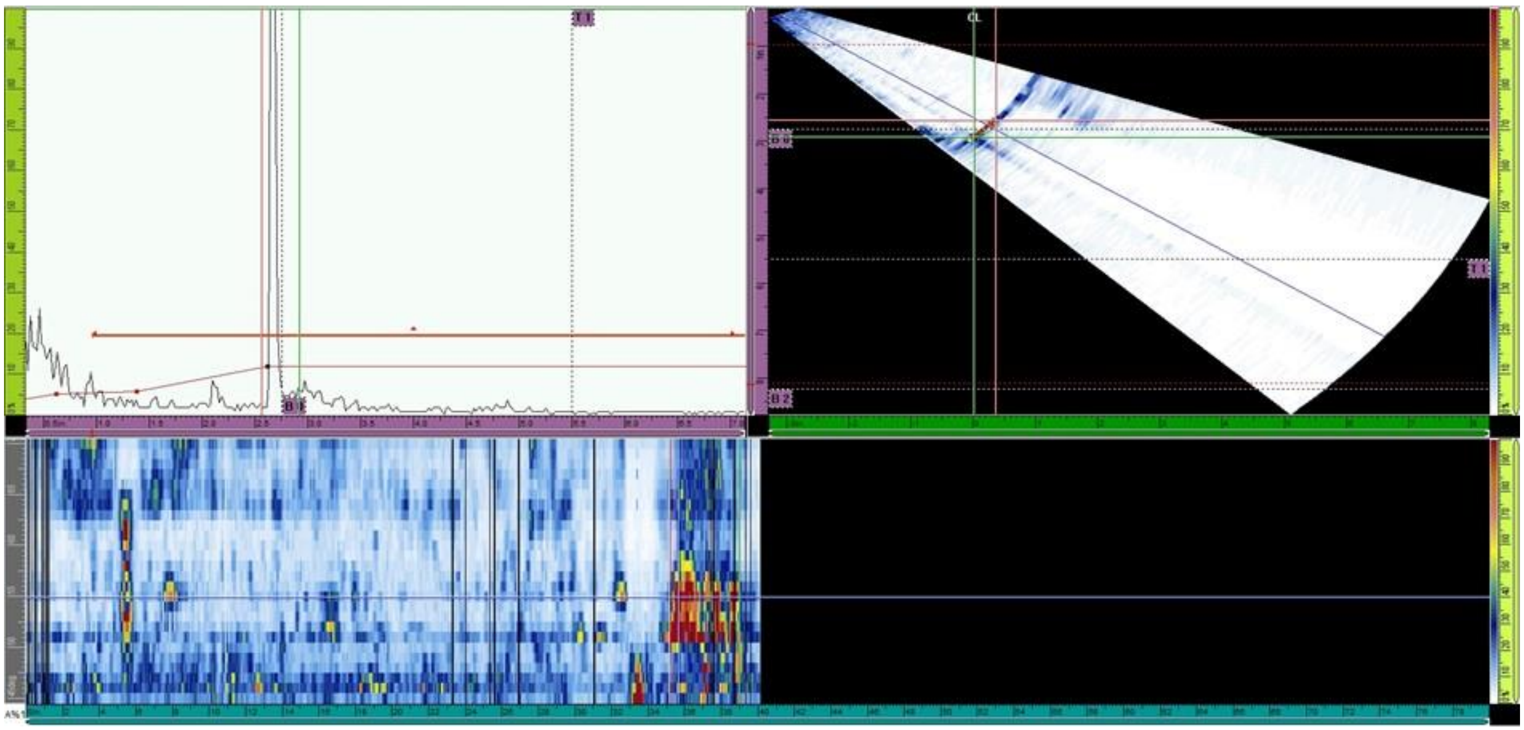
Valve 5 Upstream Side	
Weld	Comments
V7b	No reportable indications. 

Valve 5 Upstream Side	
Weld	Comments
V8a	No reportable indications. 
V8b	No scanning possible due to rough surface

5.2 Valve 5 Downstream

Valve 5 Downstream Side	
Weld	Comments
H1	Lack of fusion and lack of penetration.

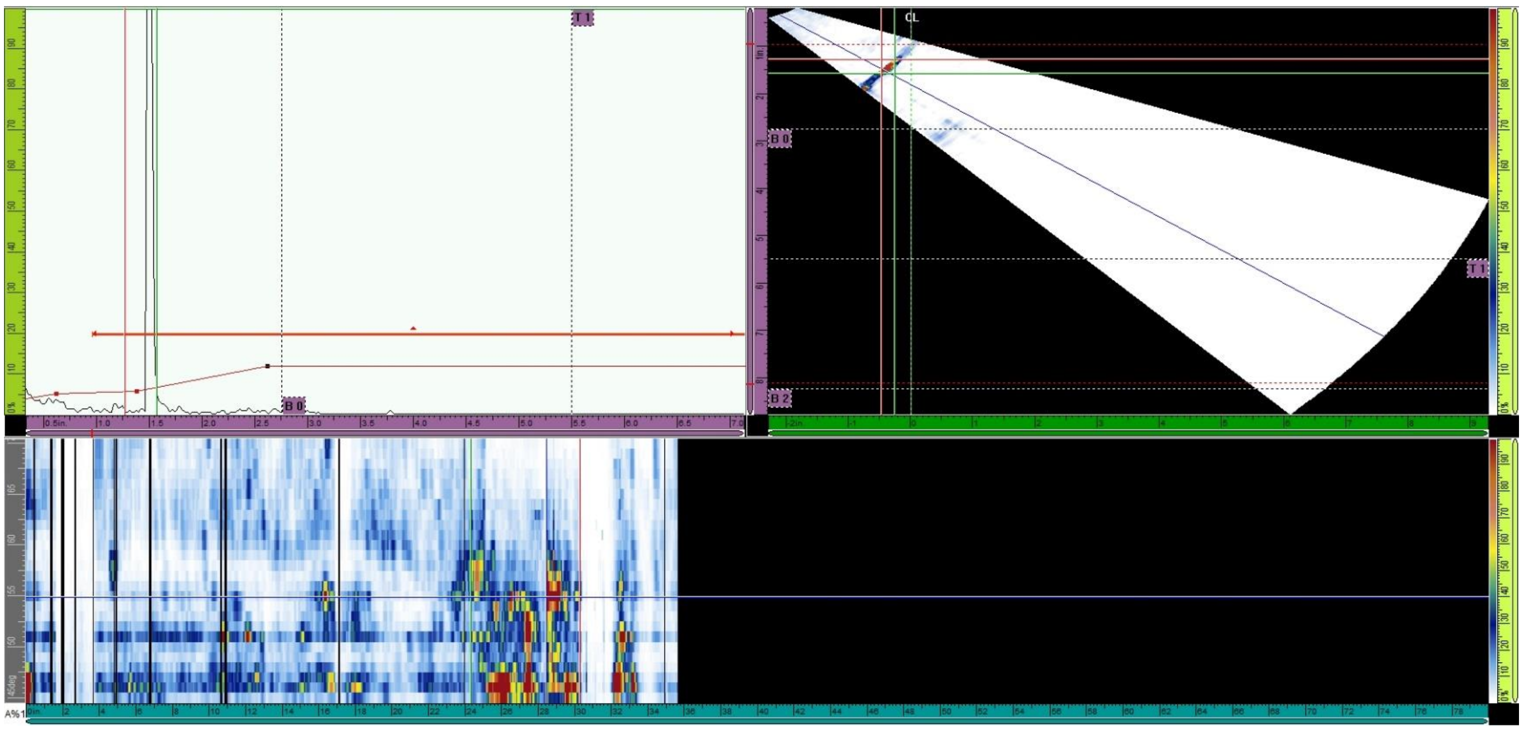
Gain (dB)	Indication #	Scan (in)	Index (in)	Group	Channel	A%1 (%)	DA/1 (in)	PA/1 (in)	SA/1 (in)	U(m-r) (in)	I(m-r) (in)	I•U(m-r) (in)	S(m-r) (in)	Type
46.66	1	32.598	-6.500	PA 1	55.00º	79.3	2.681	3.254	4.673	0.142	0.121	0.187	0.459	LOP
46.66	2	35.669	-6.500	PA 1	55.00º	141.9	2.653	3.214	4.625	0.355	0.351	0.499	3.807	LOF/ LOP

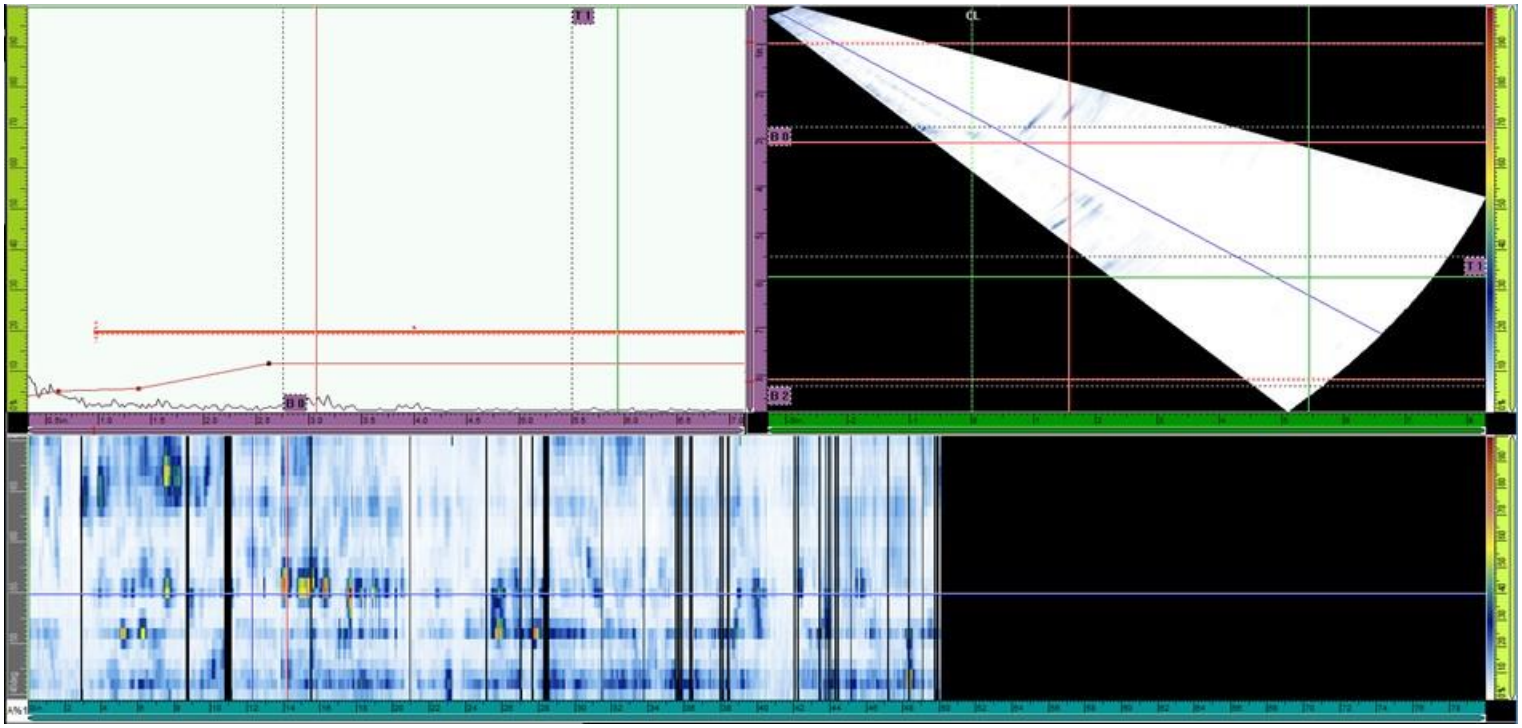


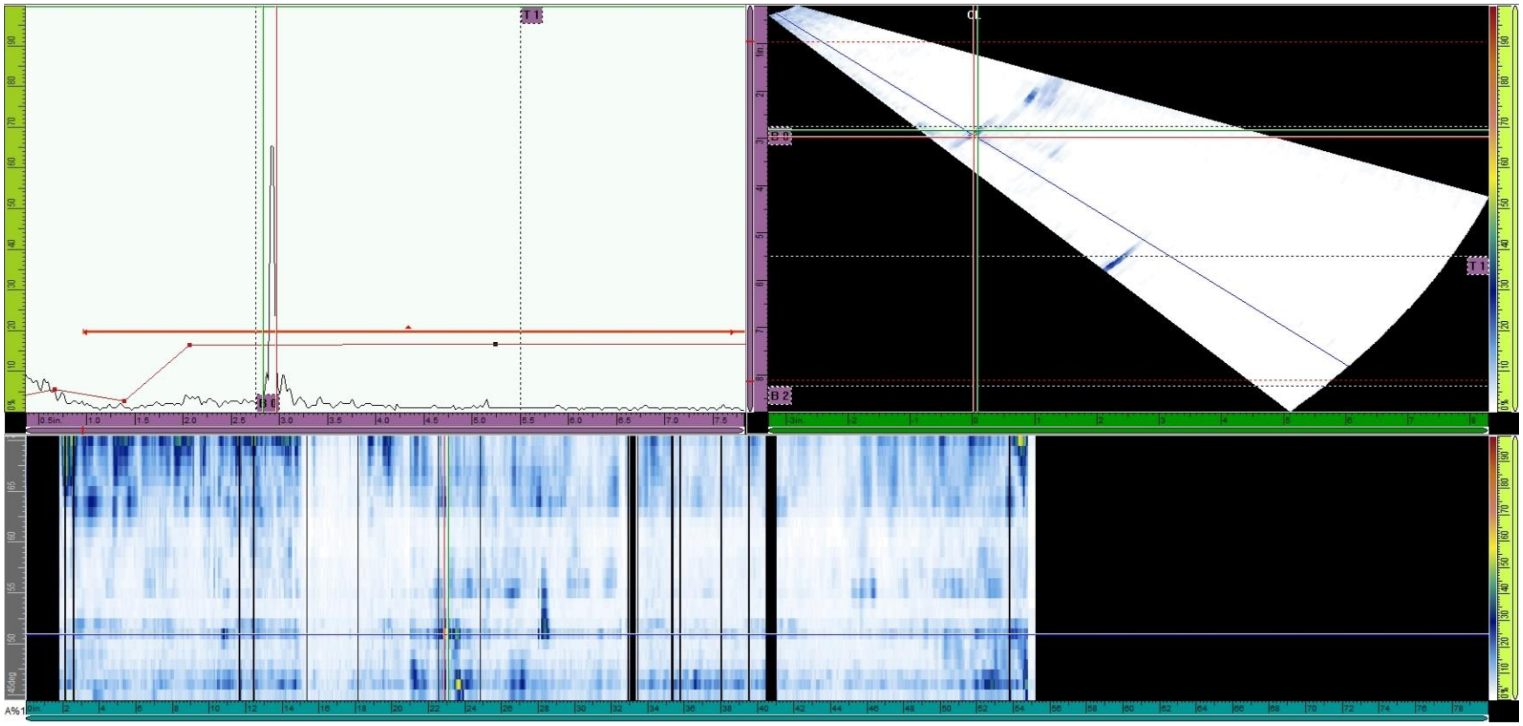
Valve 5 Downstream Side

Weld	Comments
H2	

Gain (dB)	Indication #	Scan (in)	Index (in)	Group	Channel	A%1 (%)	DA/1 (in)	PA/1 (in)	SA/1 (in)	U(m-r) (in)	I(m-r) (in)	I•U(m-r) (in)	S(m-r) (in)	Type
40.66	1	28.428	-6.500	PA 1	55.00º	98.9	1.480	1.540	2.581	0.301	0.216	0.371	5.963	LOF
40.66	2	10.764	-6.500	PA 1	51.00º	98.9	2.067	1.927	3.285	0.147	0.121	0.190	0.321	LOP

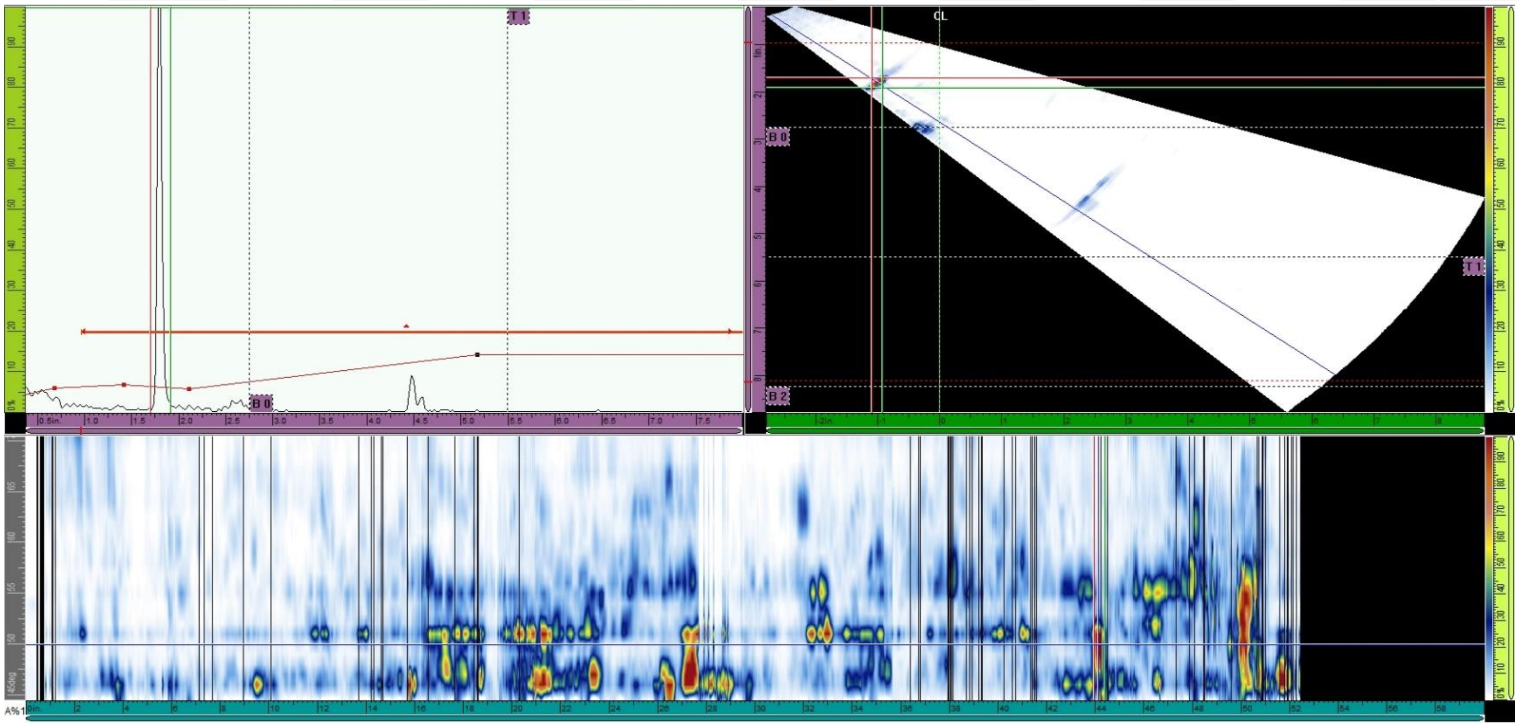


Valve 5 Downstream Side	
Weld	Comments
V1	Standard root reflection(s) no indication to report. 

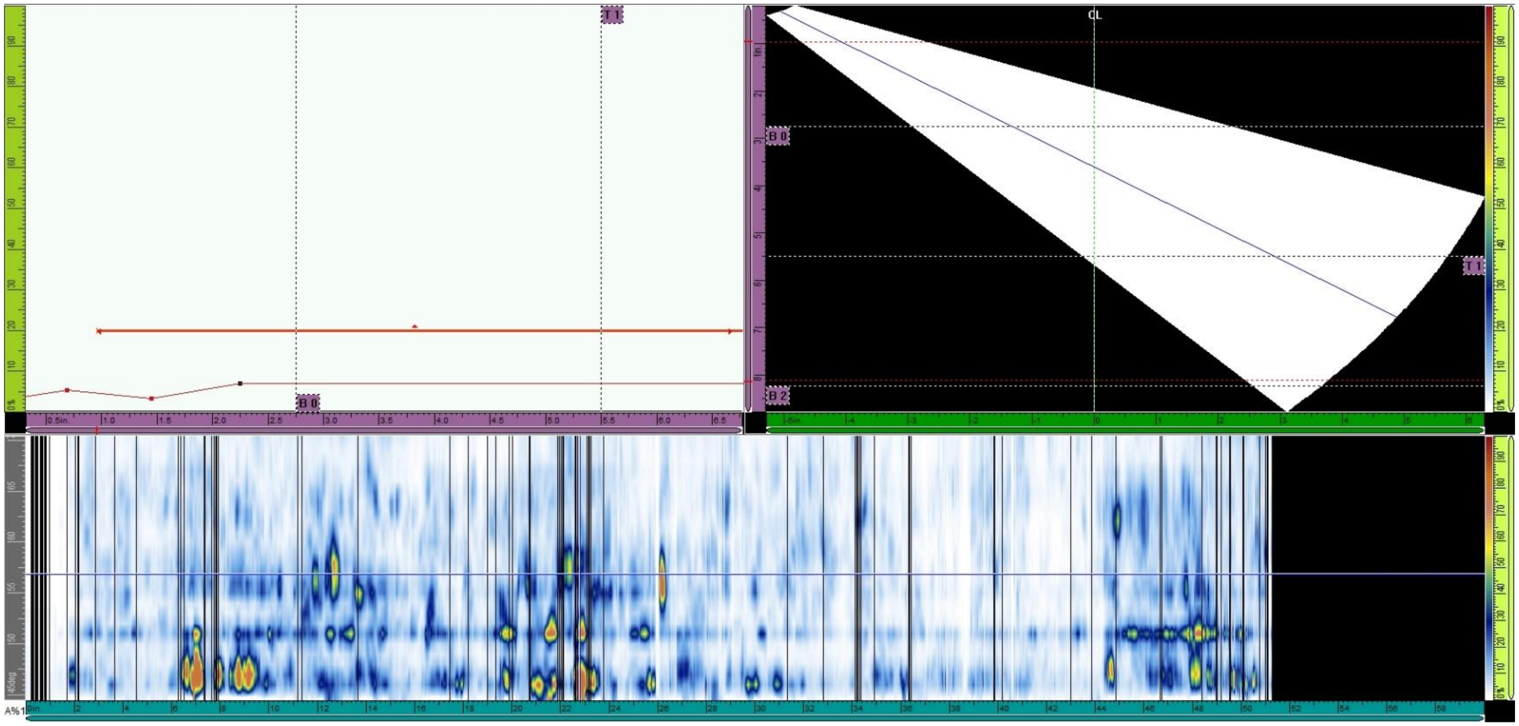
Valve 5 Downstream Side	
Weld	Comments
V2	Standard root reflection(s) no indication to report. 

Valve 5 Downstream Side	
Weld	Comments
V3	Intermittent LOF from over most of weld. Flaw height ranging from 0.142” to 0.319”.

Gain (dB)	Indication #	Scan (in)	Index (in)	Group	Channel	A%1 (%)	DA/1 (in)	PA/1 (in)	SA/1 (in)	U(m-r) (in)	I(m-r) (in)	I•U(m-r) (in)	S(m-r) (in)	Type
40.66	1	17.267	-6.500	PA 1	48.00º	68.9	2.545	2.163	3.804	0.230	0.256	0.345	1.789	LOF
40.66	2	27.398	-6.500	PA 1	48.00º	98.9	2.719	2.356	4.063	0.213	0.283	0.354	1.376	LOF
40.66	3	32.957	-6.500	PA 1	51.00º	98.9	2.277	2.187	3.619	0.142	0.121	0.187	0.929	LOF
40.66	4	44.074	-6.500	PA 1	50.00º	98.9	1.778	1.481	2.766	0.213	0.175	0.276	0.447	LOF
40.66	5	50.105	-6.500	PA 1	54.00º	98.9	1.343	1.261	2.284	0.319	0.216	0.385	0.551	LOF
40.66	6	51.682	-6.500	PA 1	47.00º	98.9	2.476	2.566	4.434	0.142	0.175	0.225	0.619	LOF

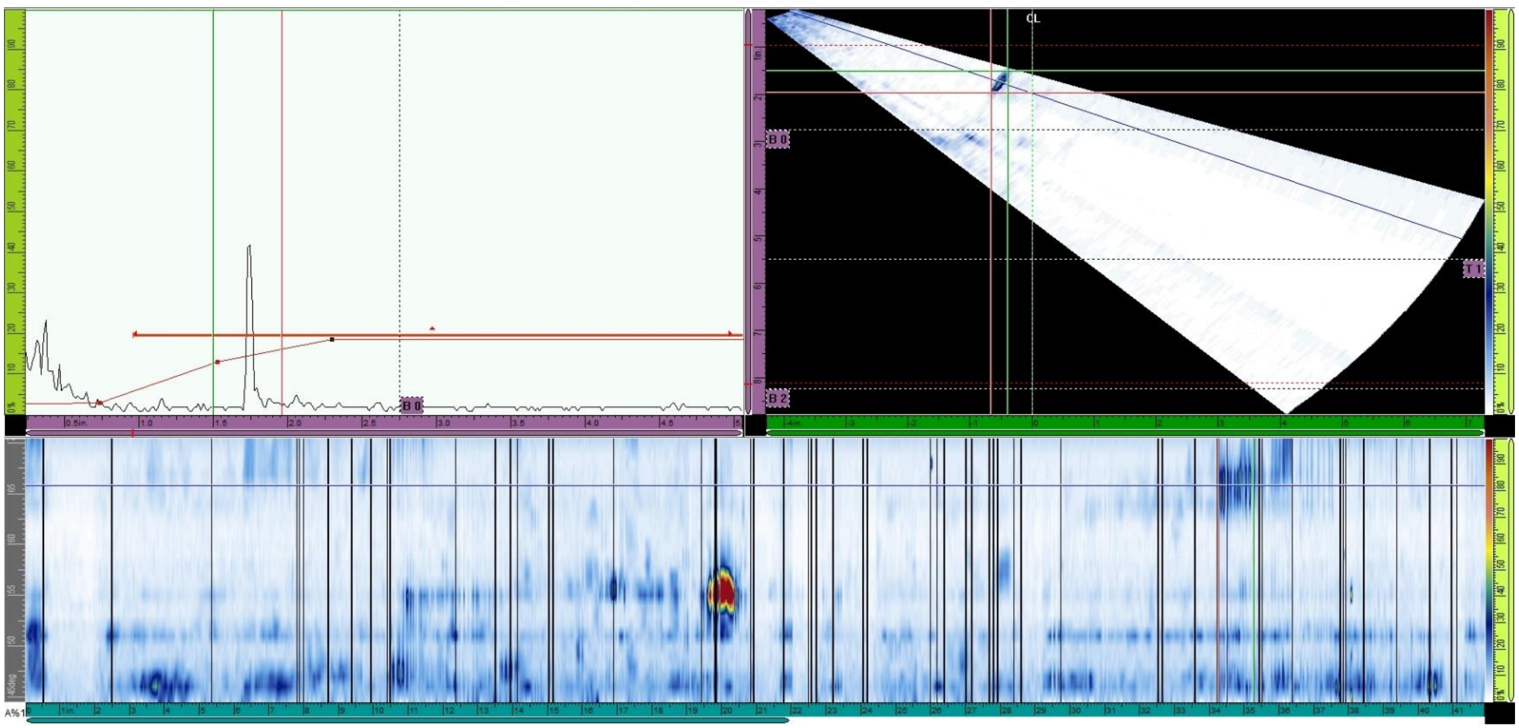


TechKnowServ™
TECHNOLOGY, KNOWLEDGE, SERVICE

Valve 5 Downstream Side	
Weld	Comments
V4	No reportable indications. 

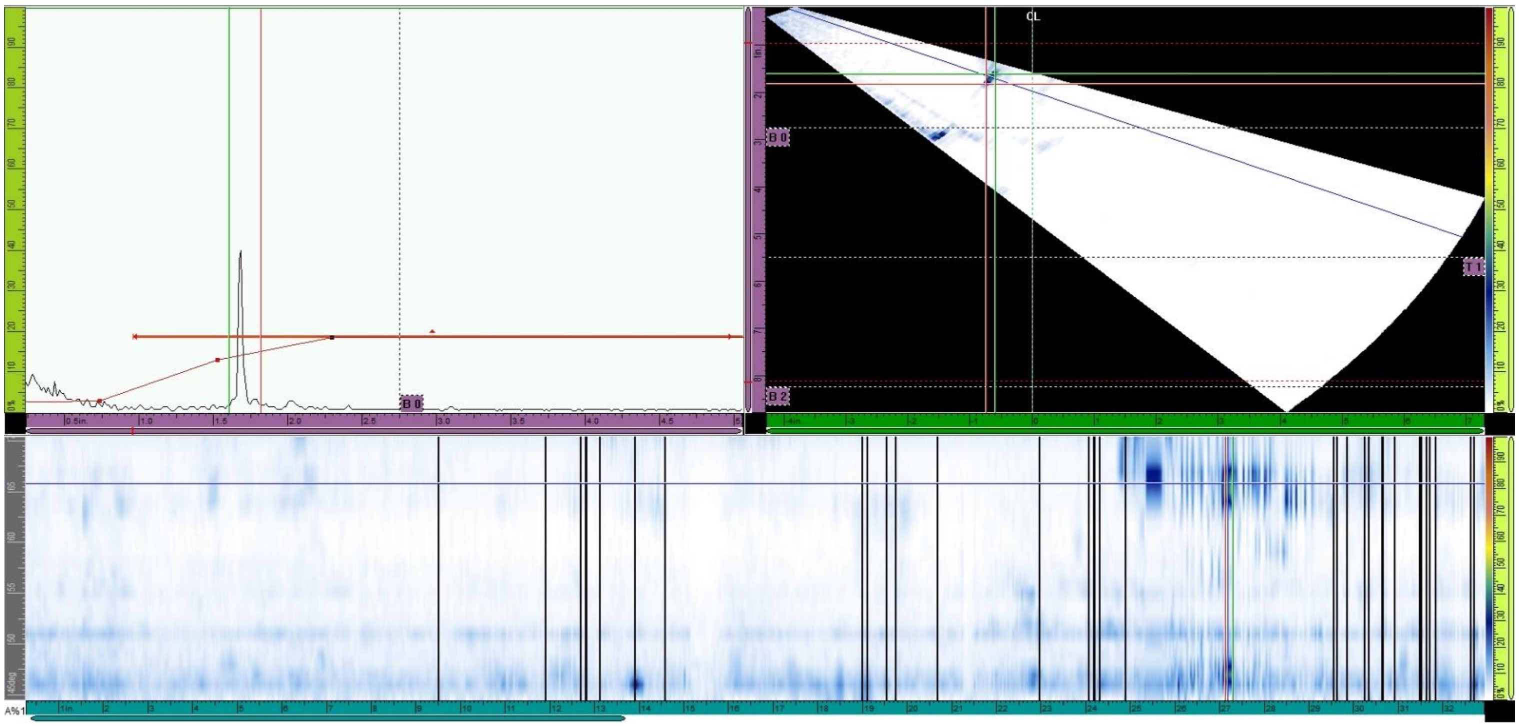
Valve 5 Downstream Side

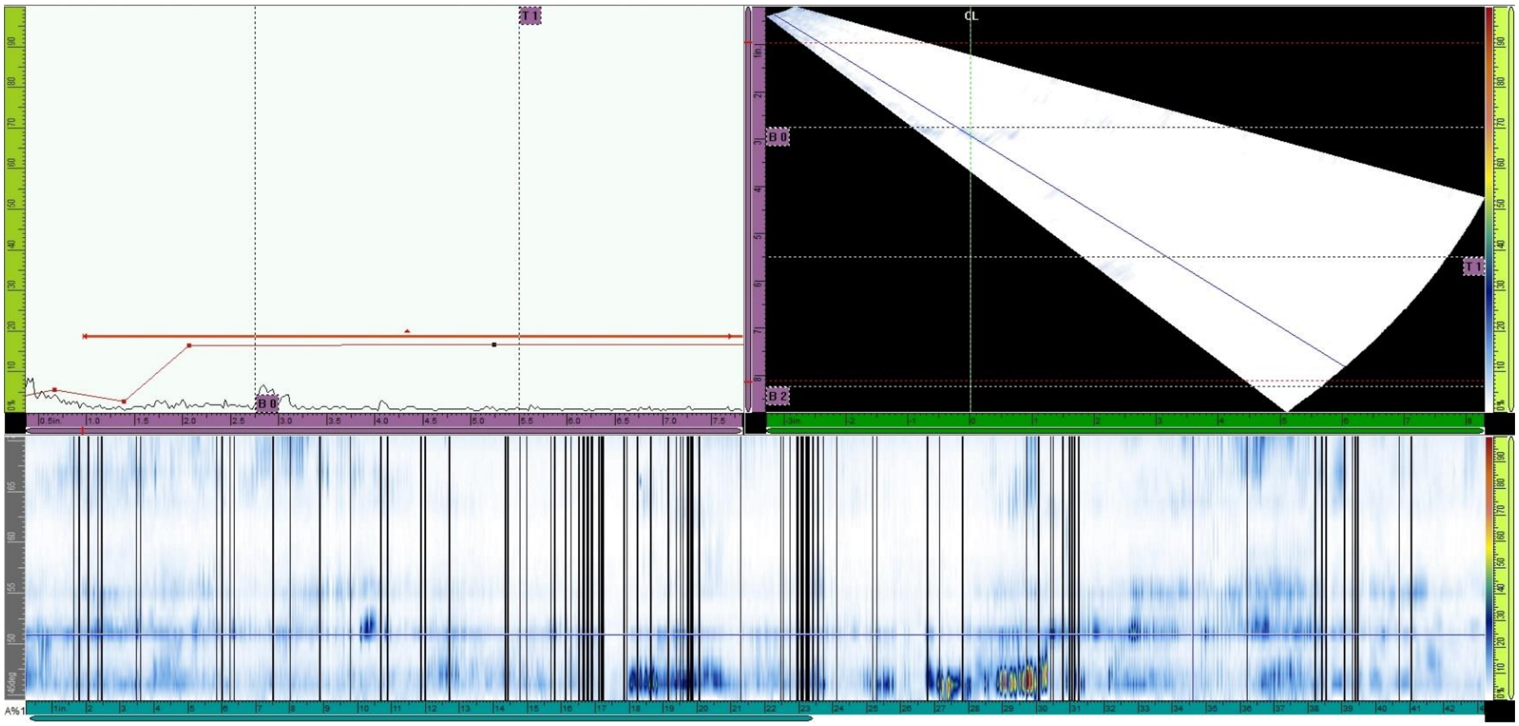
Weld	Comments														
	Gain (dB)	**Indication #**	**Scan (in)**	**Index (in)**	**Group**	**Channel**	**A%1 (%)**	**DA/1 (in)**	**PA/1 (in)**	**SA/1 (in)**	**U(m-r) (in)**	**I(m-r) (in)**	**I•U(m-r) (in)**	**S(m-r) (in)**	**Type**
O1a	46.66	1	34.488	-6.500	PA 1	66.00º	42.1	1.738	3.464	4.273	0.461	0.270	0.534	1.008	LOF

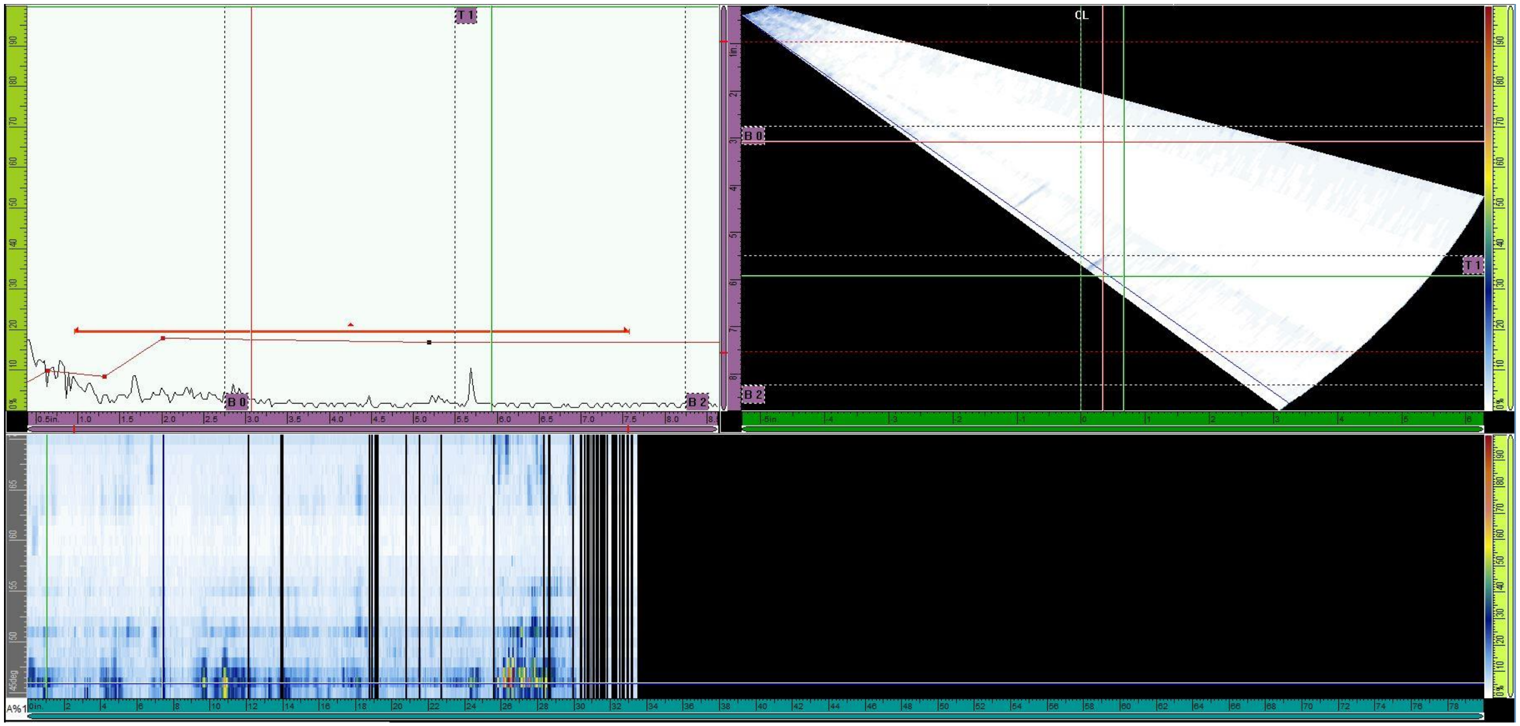


Valve 5 Downstream Side	
Weld	Comments
O1b	

Gain (dB)	Indication #	Scan (in)	Index (in)	Group	Channel	A%1 (%)	DA/1 (in)	PA/1 (in)	SA/1 (in)	U(m-r) (in)	I(m-r) (in)	I•U(m-r) (in)	S(m-r) (in)	Type
46.66	1	27.165	-4.000	PA 1	66.00º	40.1	1.668	3.306	4.100	0.213	0.148	0.259	0.169	LOF



Valve 5 Downstream Side	
Weld	Comments
O2a	No reportable indications. 

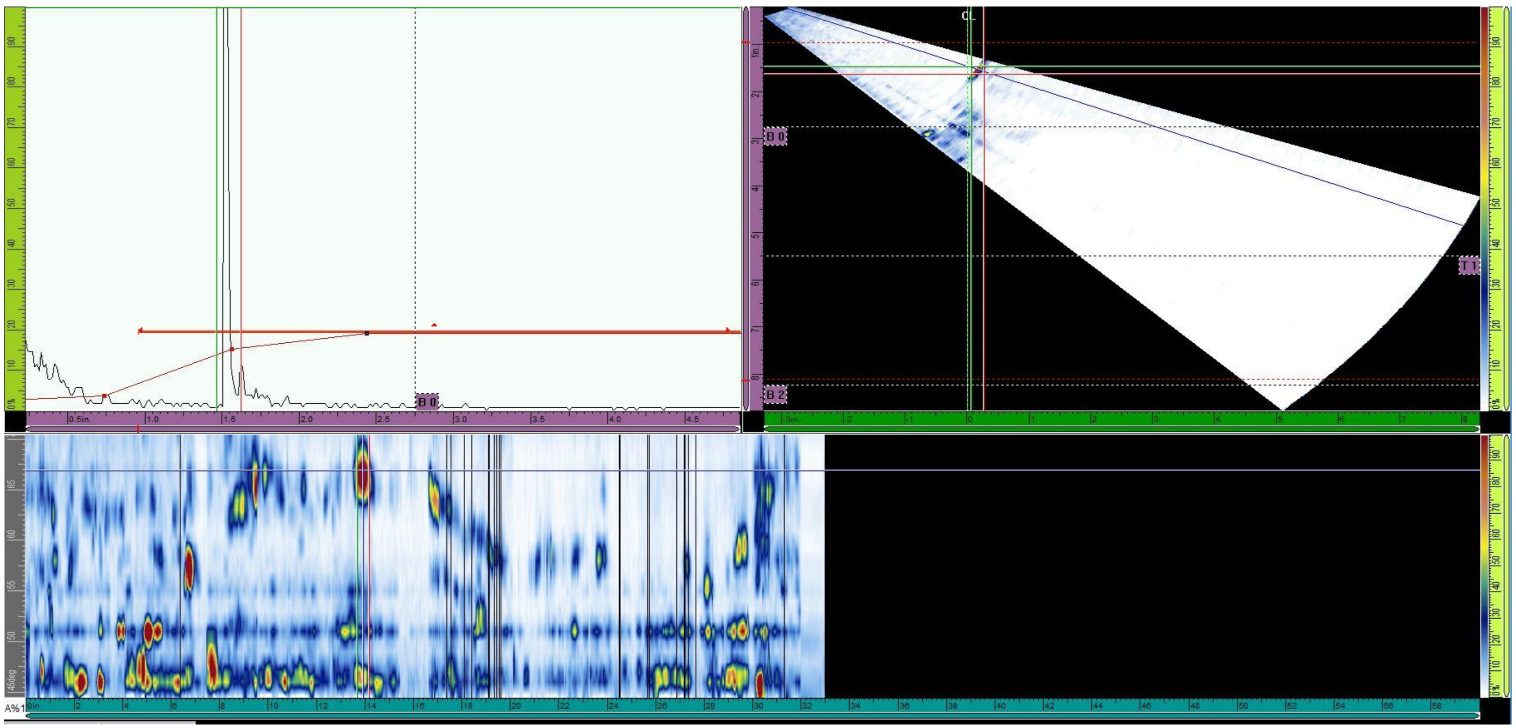
Valve 5 Downstream Side	
Weld	Comments
O2b	No reportable indications. 

TechKnowServ
TECHNOLOGY, KNOWLEDGE, SERVICE

Valve 5 Downstream Side

Weld	Comments
O3a	

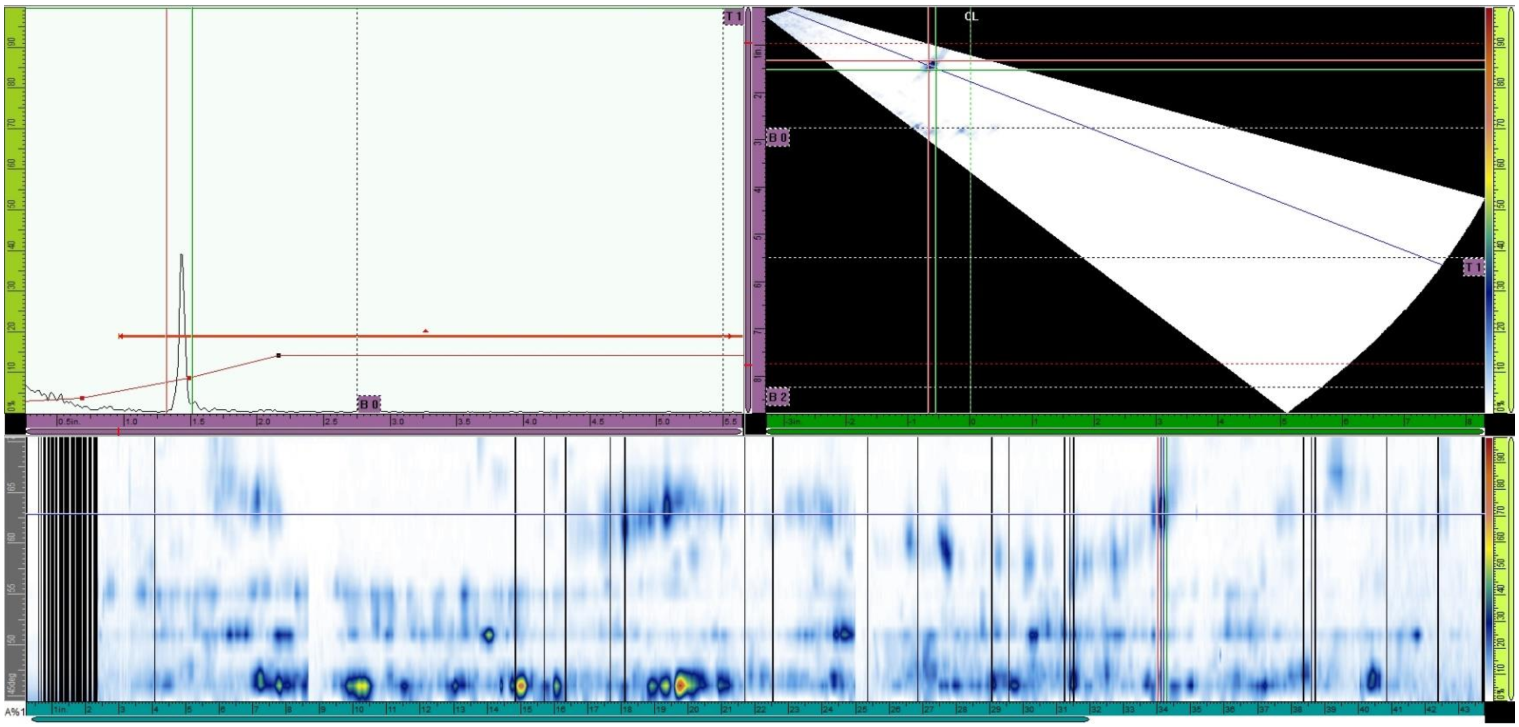
Gain (dB)	Indication #	Scan (in)	Index (in)	Group	Channel	A%1 (%)	DA/1 (in)	PA/1 (in)	SA/1 (in)	U(m-r) (in)	I(m-r) (in)	I•U(m-r) (in)	S(m-r) (in)	Type
40.66	1	6.741	-6.500	PA 1	57.00º	113.0	1.971	2.485	3.619	0.195	0.162	0.253	0.244	LOF
40.66	2	9.461	-6.500	PA 1	65.00º	57.2	1.576	2.929	3.730	0.195	0.175	0.262	0.207	LOF
40.66	3	13.876	-6.500	PA 1	67.00º	71.4	1.515	3.140	3.878	0.195	0.189	0.271	0.432	LOF



Valve 5 Downstream Side

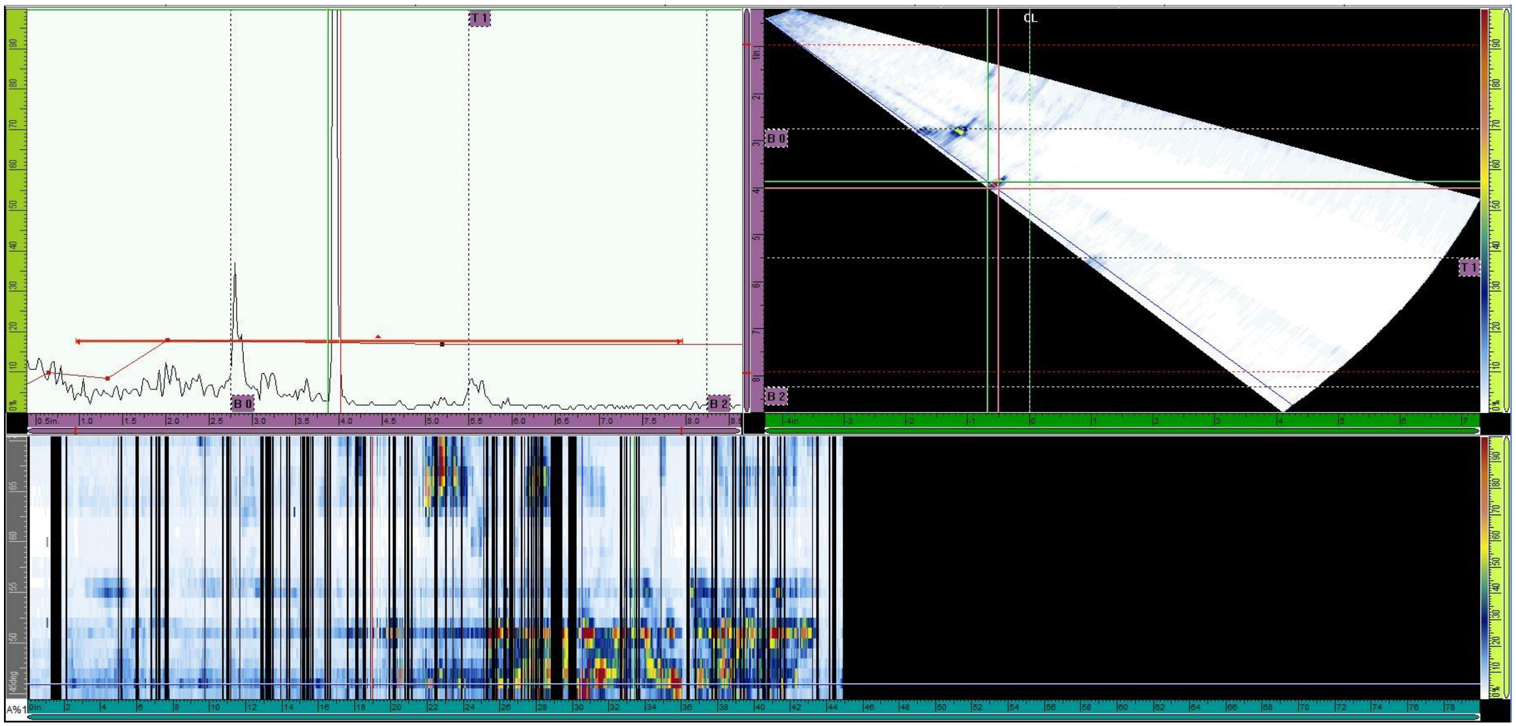
Weld	Comments
O3b	

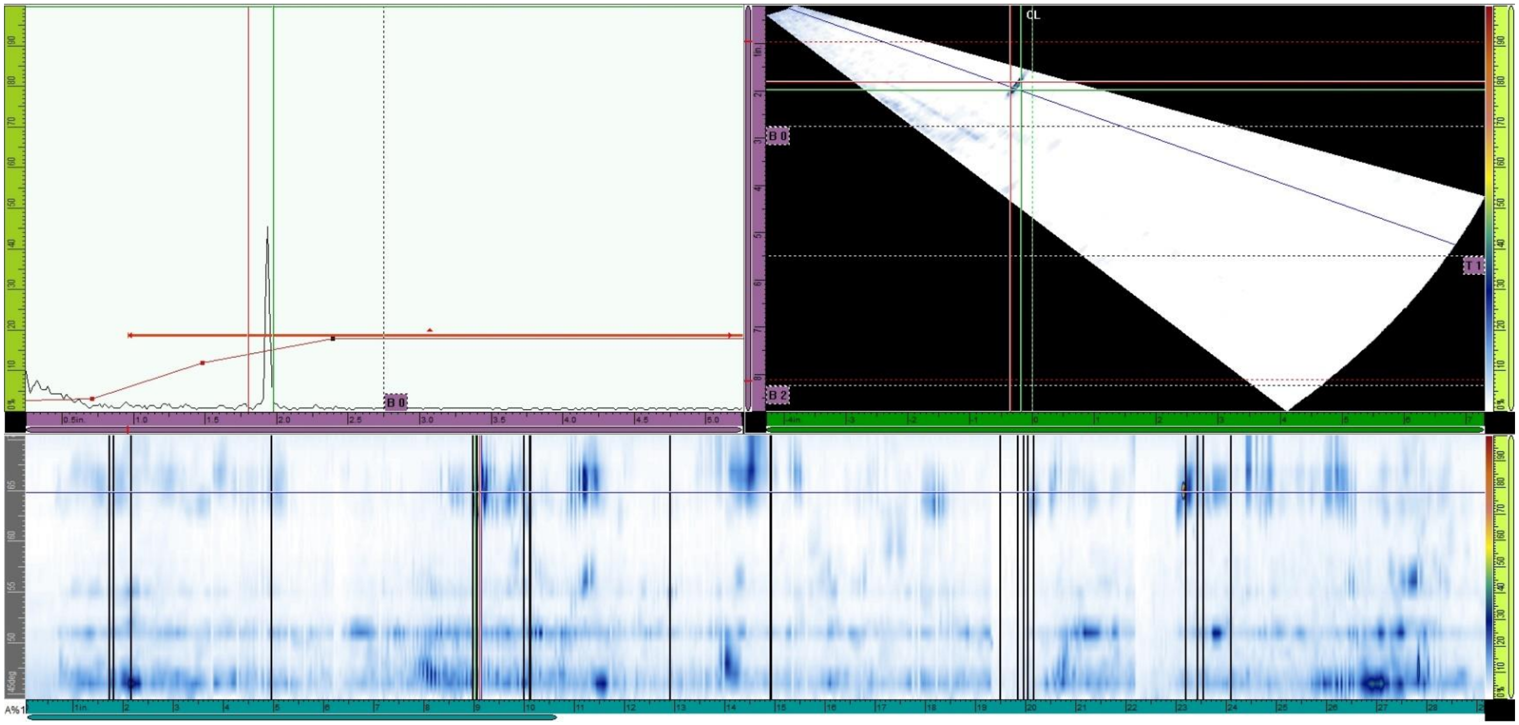
Gain (dB)	Indication #	Scan (in)	Index (in)	Group	Channel	A%1 (%)	DA/1 (in)	PA/1 (in)	SA/1 (in)	U(m-r) (in)	I(m-r) (in)	I•U(m-r) (in)	S(m-r) (in)	Type
40.66	1	19.396	-6.500	PA 1	63.00º	34.0	1.676	2.815	3.693	0.213	0.108	0.239	0.200	LOF
40.66	2	34.179	-6.500	PA 1	63.00º	38.8	1.424	2.319	3.137	0.195	0.121	0.230	0.275	LOF



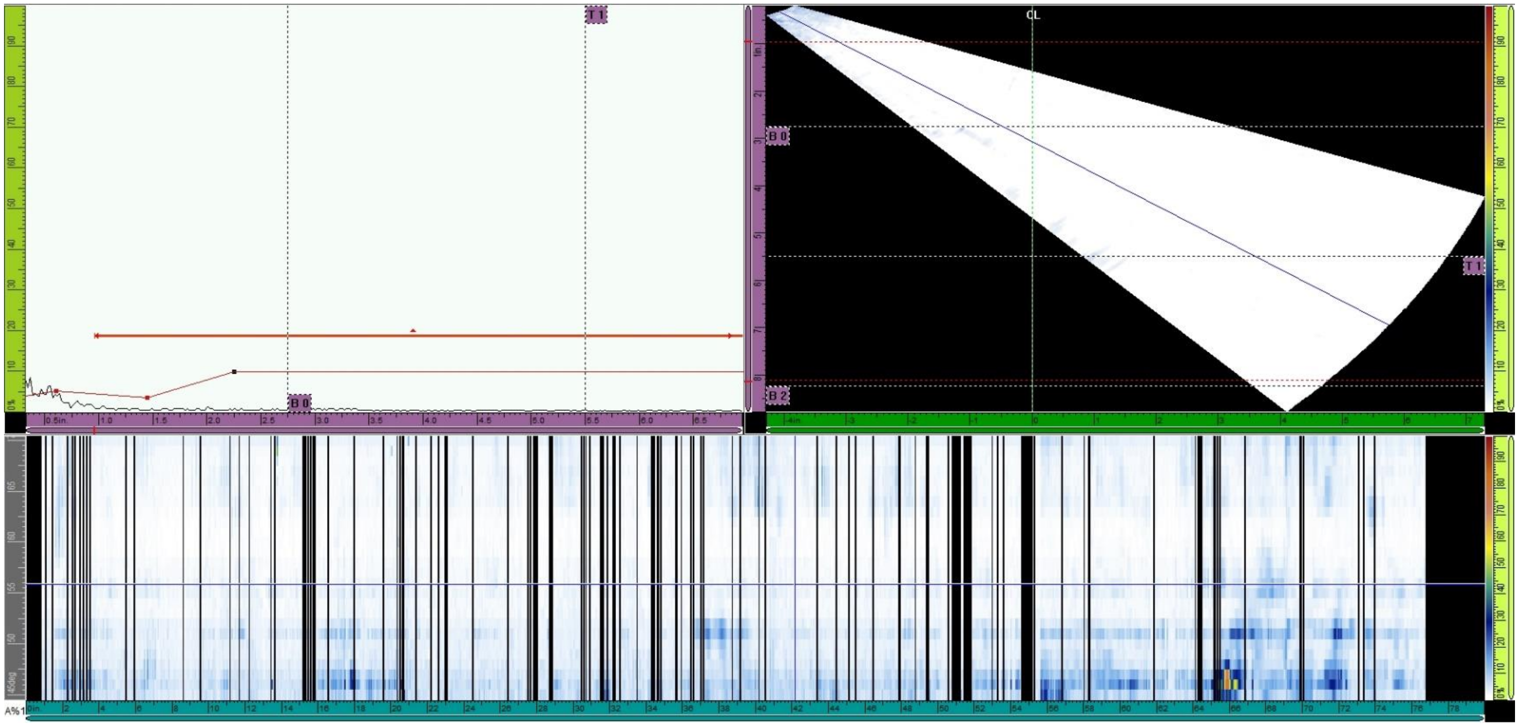
Valve 5 Downstream Side	
Weld	Comments
O4a	

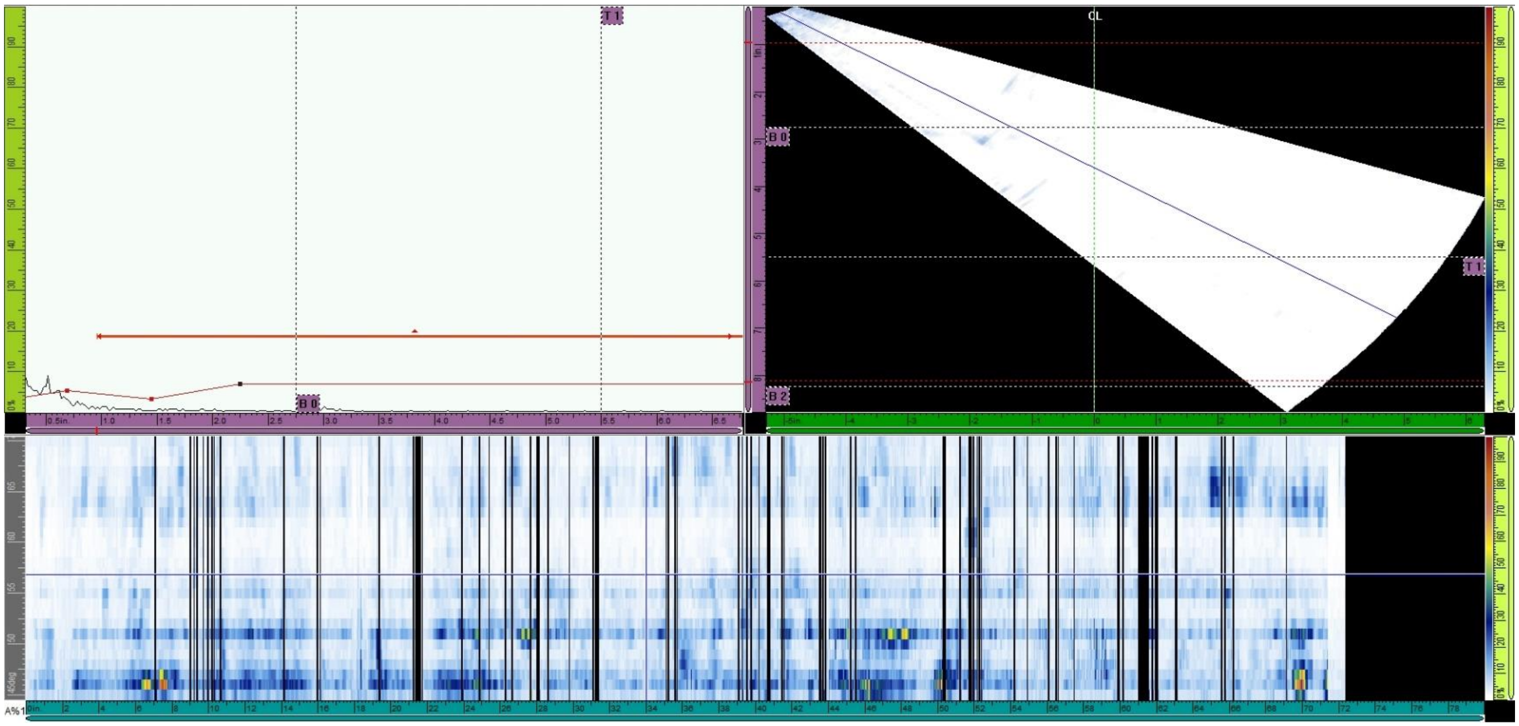
Gain (dB)	Indication #	Scan (in)	Index (in)	Group	Channel	A%1 (%)	DA/1 (in)	PA/1 (in)	SA/1 (in)	U(m-r) (in)	I(m-r) (in)	I•U(m-r) (in)	S(m-r) (in)	Type
46.66	1	22.835	-6.500	PA 1	67.00º	55.0	1.631	3.413	4.174	0.230	0.162	0.282	1.616	LOF
46.66	2	30.472	-6.500	PA 1	46.00º	106.1	1.570	3.380	5.657	0.213	0.135	0.252	0.333	LOP

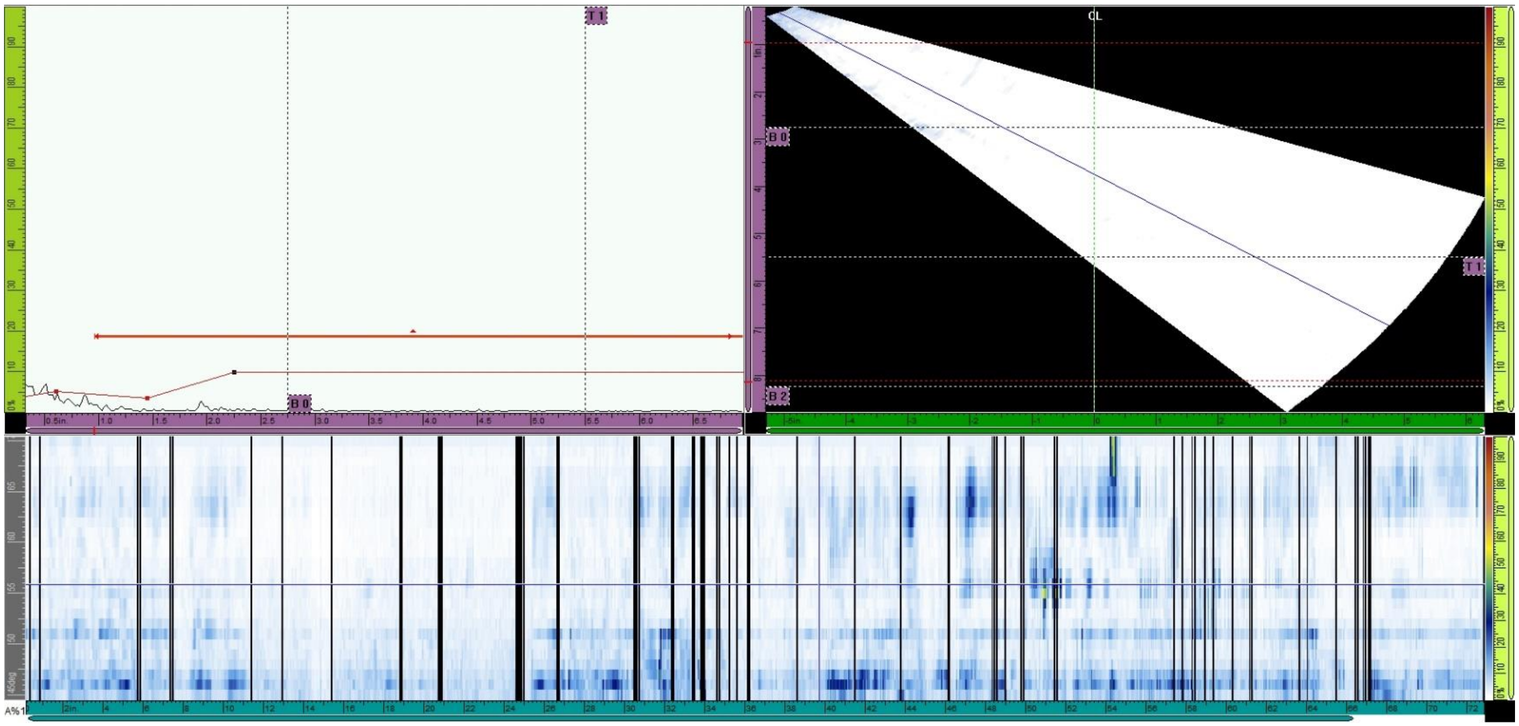


Valve 5 Downstream Side	
Weld	Comments
O4b	No reportable indications 

TechKnowServ
TECHNOLOGY, KNOWLEDGE, SERVICE

Valve 5 Downstream Side	
Weld	Comments
X1a	No reportable indications. 

Valve 5 Downstream Side	
Weld	Comments
X1b	No reportable indications. 

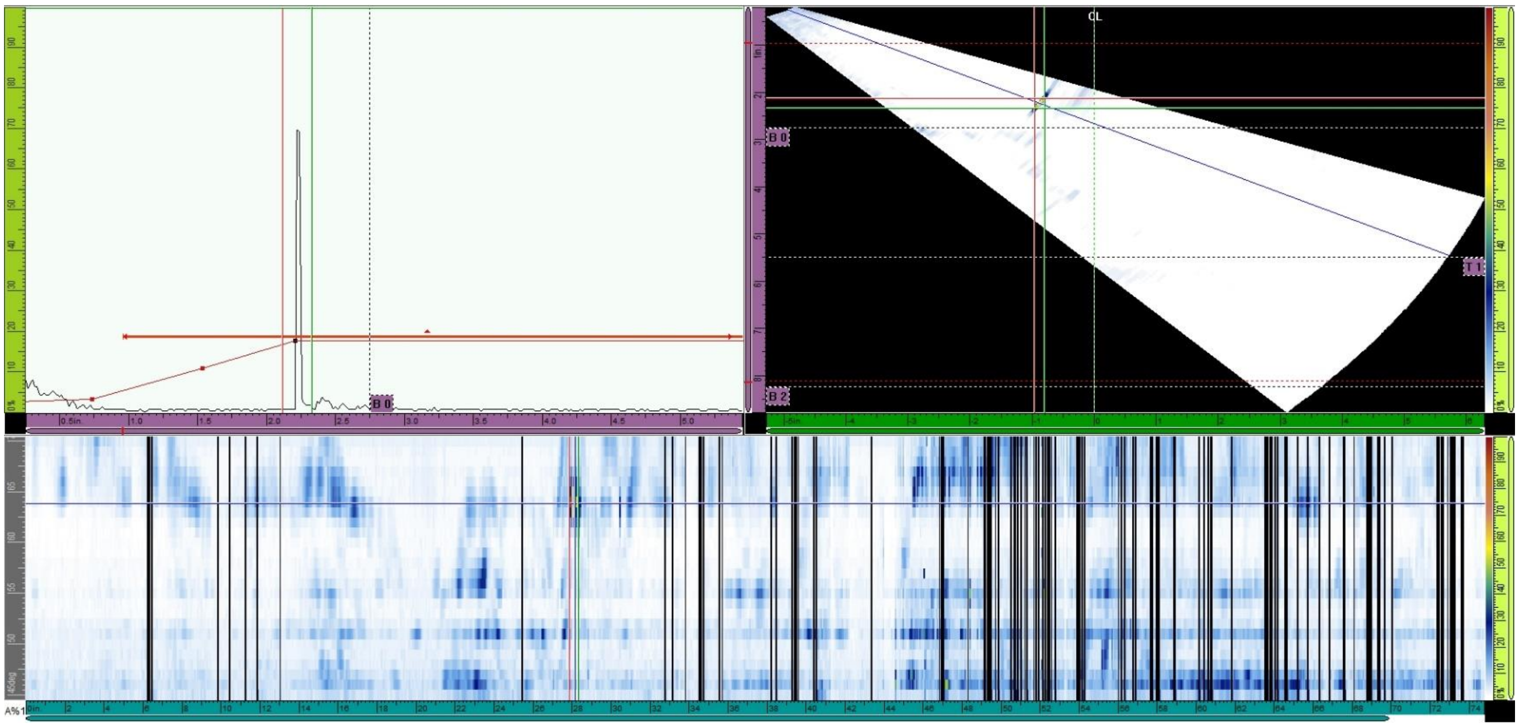
Valve 5 Downstream Side	
Weld	Comments
X2a	No reportable indications. 

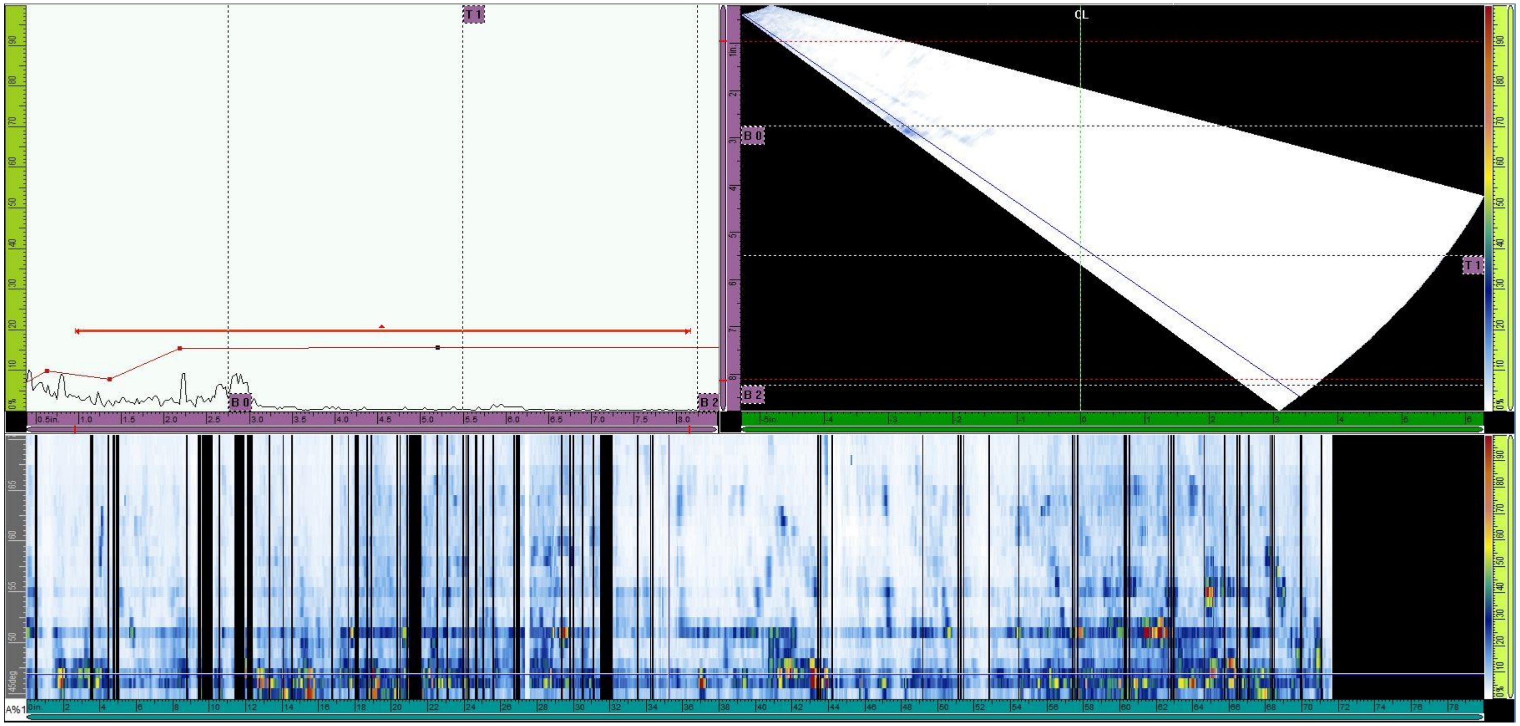
TechKnowServ™
TECHNOLOGY, KNOWLEDGE, SERVICE

Valve 5 Downstream Side

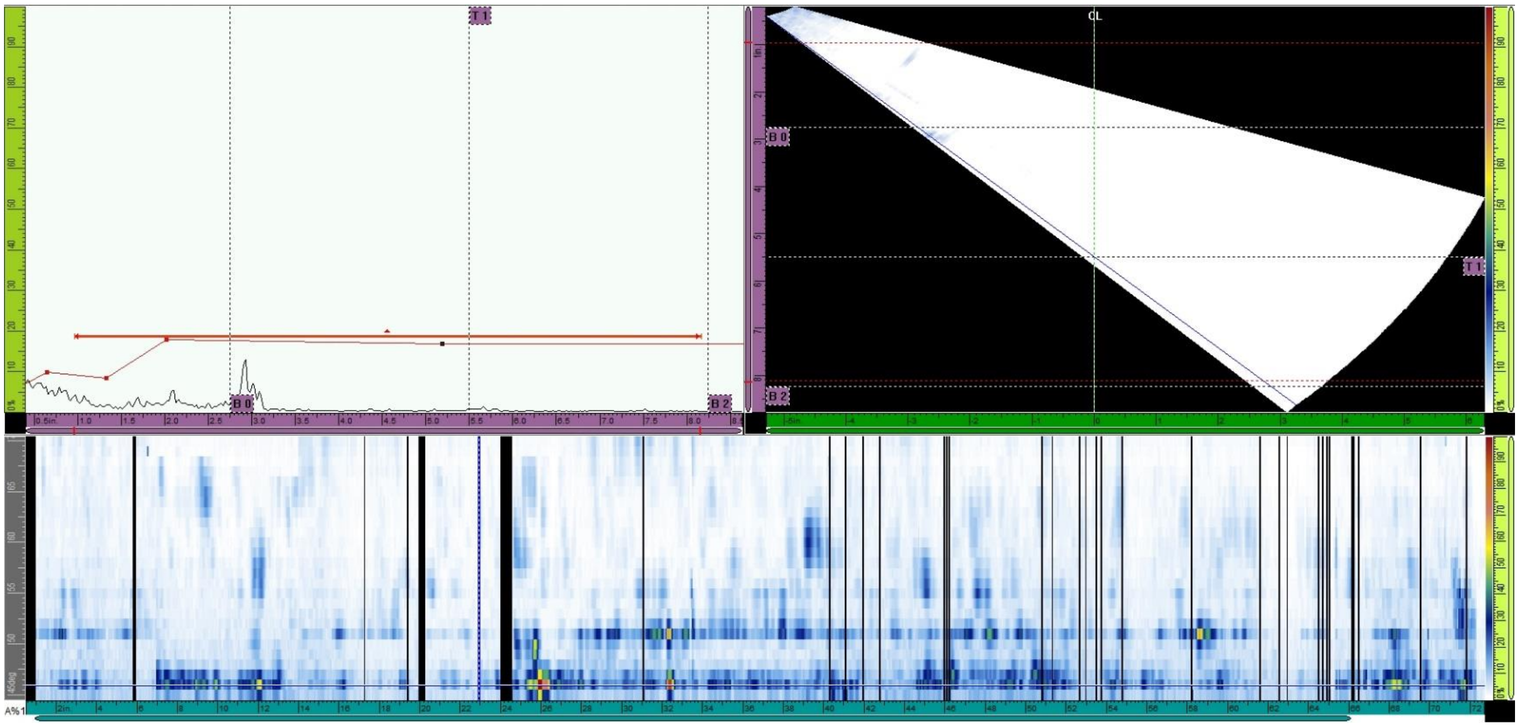
Weld	Comments
X2b	

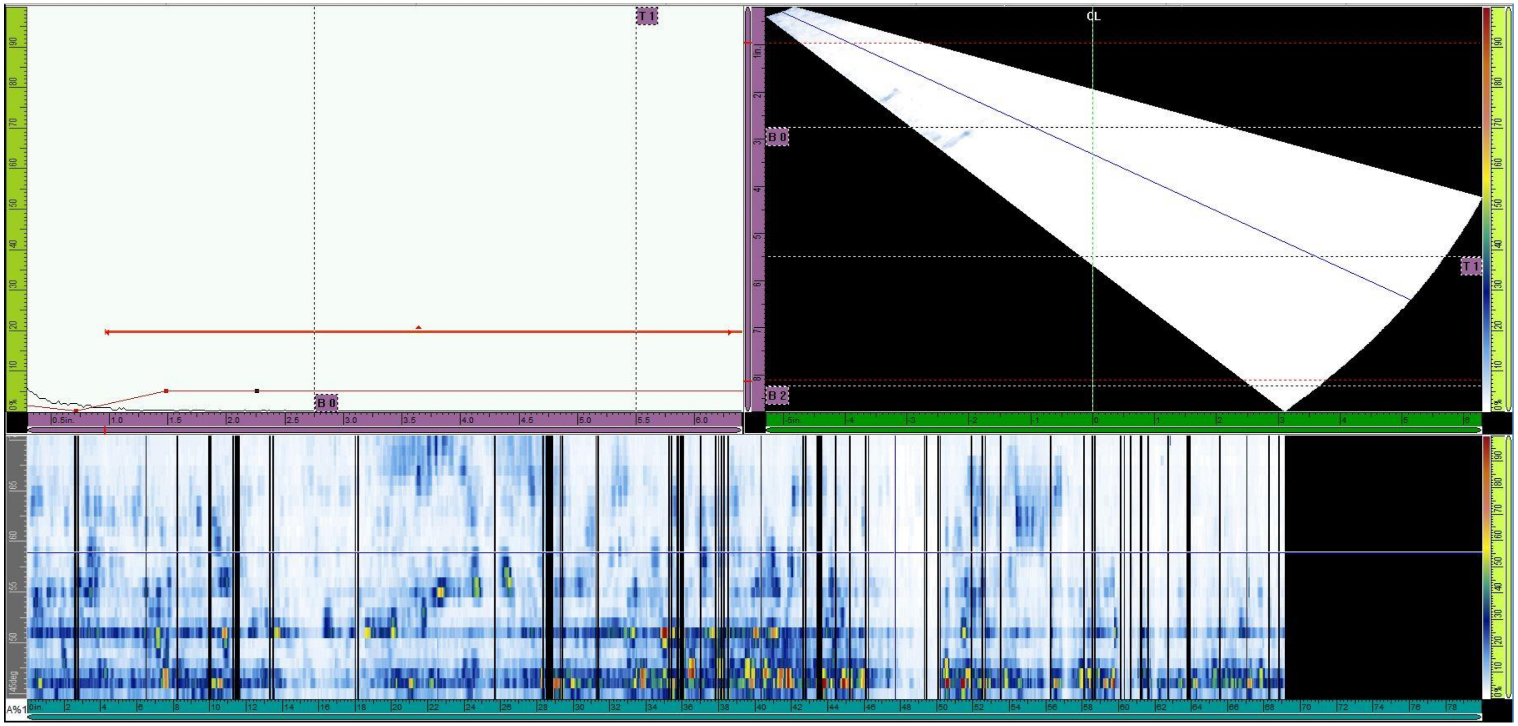
Ref.	Indication #	Scan (in)	Index (in)	Group	Channel	A%1 (%)	DA/1 (in)	PA/1 (in)	SA/1 (in)	U(m-r) (in)	I(m-r) (in)	I•U(m-r) (in)	S(m-r) (in)	Type
46.66	1	28.110	-6.500	PA 1	64.00º	69.5	2.220	4.088	5.064	0.213	0.162	0.267	0.472	LOF

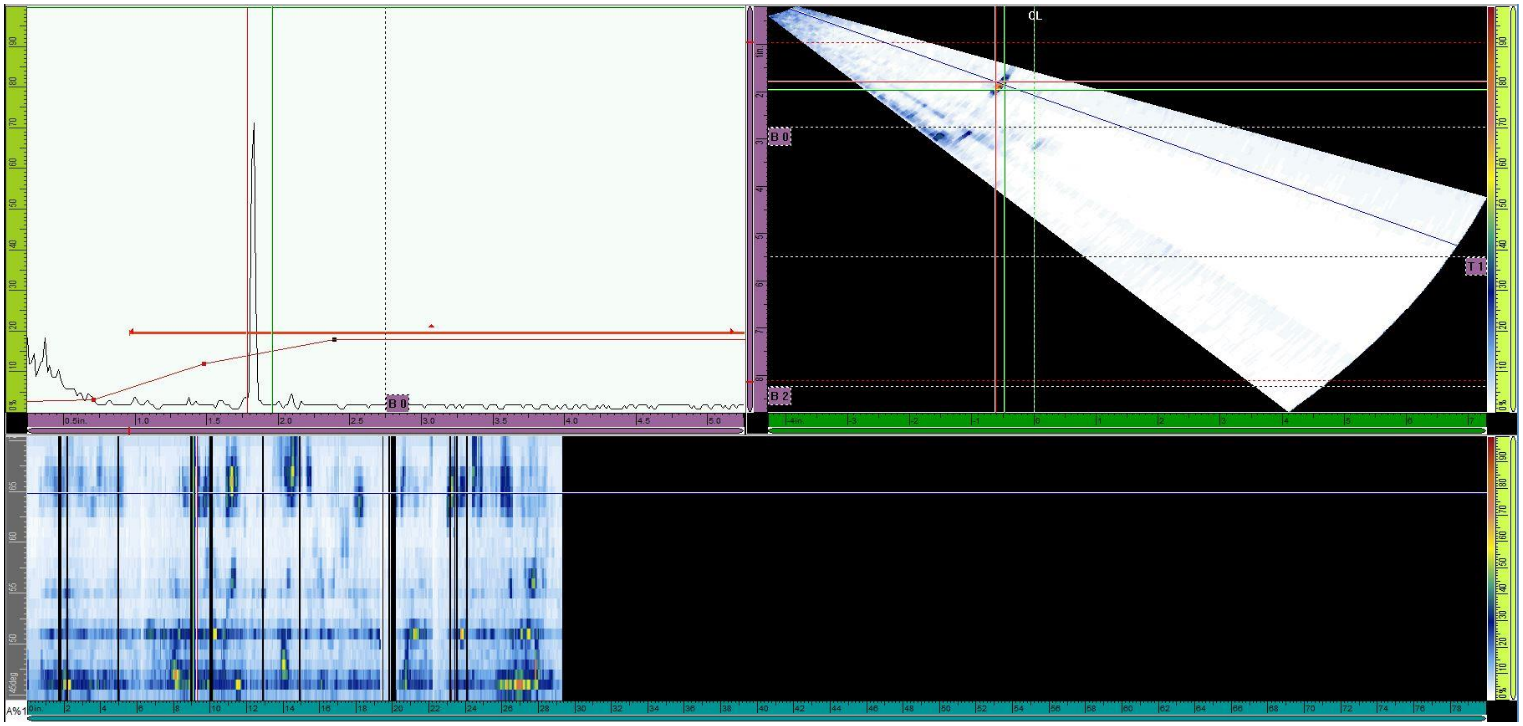


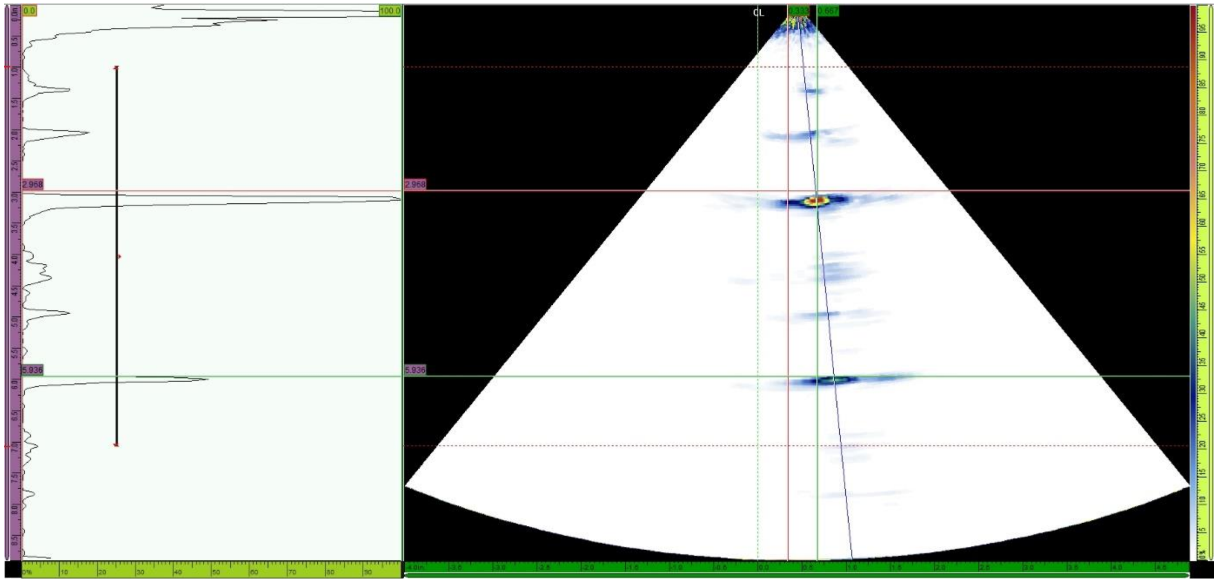
Valve 5 Downstream Side	
Weld	Comments
X3a	No reportable indications. 

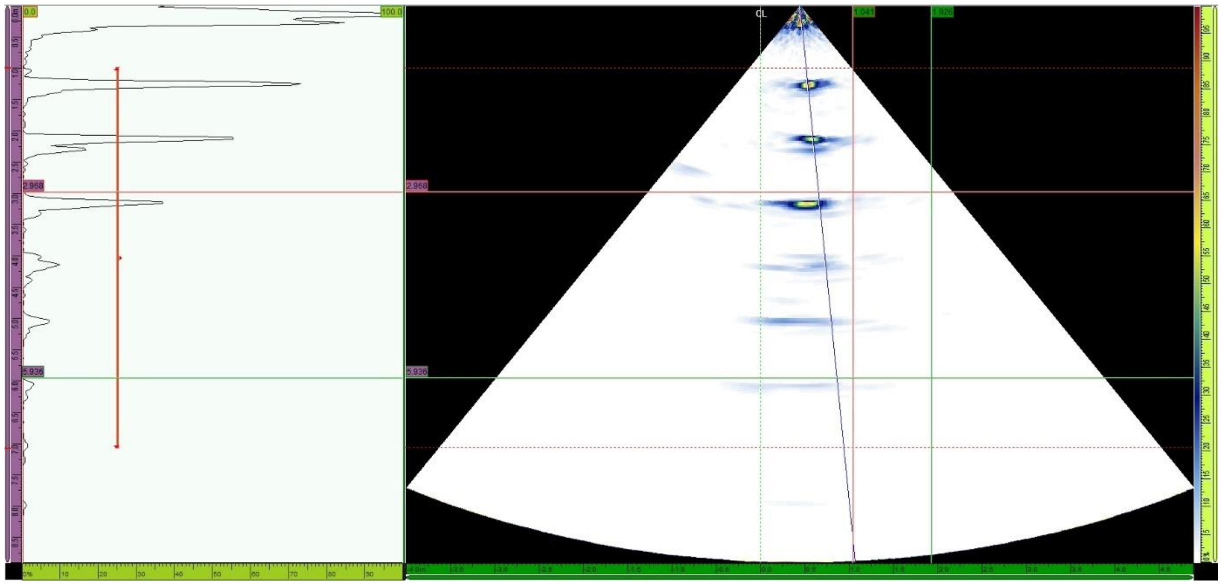
TechKnowServ
TECHNOLOGY, KNOWLEDGE, SERVICE

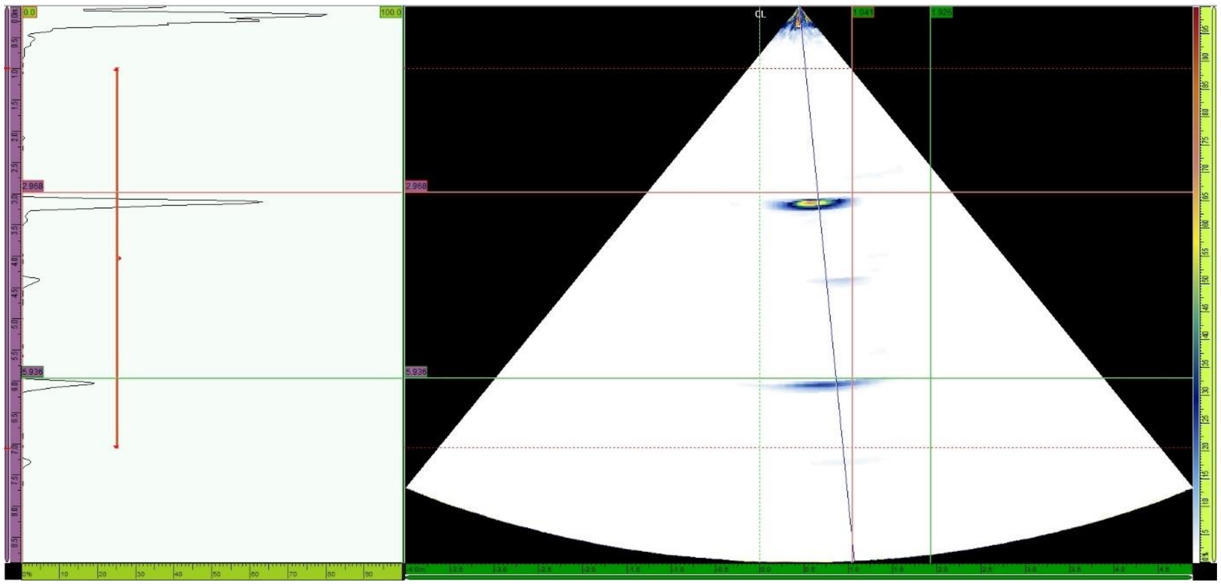
Valve 5 Downstream Side	
Weld	Comments
X3b	No reportable indications. 

Valve 5 Downstream Side	
Weld	Comments
X4a	No reportable indications. 

Valve 5 Downstream Side	
Weld	Comments
X4b	No reportable indications. 

Valve 5 Downstream Side	
Weld	Comments
C1	The C1 area shown in Figure 4.4 was inspected with manual PAUT. Approximately 15” of weld were inspected. No indications were detected. 

Valve 5 Downstream Side	
Weld	Comments
C2	The C2 area shown in Figure 4.4 was inspected with manual PAUT. Approximately 5" of weld were inspected. No indications were detected. 

Valve 5 Downstream Side	
Weld	Comments
C3	The C3 area shown in Figure 4.4 was inspected with manual PAUT. Approximately 40” of weld were inspected. No indications were detected. 
C4	The C4 area shown in Figure 4.4 was inspected with manual PAUT. Approximately 25” of weld were inspected. No indications were detected.
C5	The C5 area shown in Figure 4.4 was inspected with manual PAUT. Approximately 4” of weld were inspected. No indications were detected.
C6	The C6 area shown in Figure 4.4 was inspected with manual PAUT. Approximately 110” of weld were inspected. No indications were detected.

6 Equipment Calibrations

6.1 Magnetic Particle Testing Equipment

TechKnowServ
TECHNOLOGY, KNOWLEDGE, SERVICE

Calibration Certificate

Issue Date: 11/30/2018

Expiry Date: 11/29/2019

Device: AC

Manufacturer: Parker Research Corp.

Model: Contour Probe ®

Serial Number: 26322

Weight Lift Test Bar: TB-10SP Special Weight Lift/Defect Test Bar S/N 001

***All equipment used in the evaluation of this instrument has been calibrated with traceability to NIST**

Applicable Standards

1. ASTM E709 - 08 Standard Guide for Magnetic Particle Testing
2. ASTM E1444 - 01 Standard Practice for Magnetic Particle Examination

Performance Summary

Test Weight (lb)	Leg Spacing (in)	Result
10	2-4	Pass

Certificate provided by:

TECHKNOWSERV CORPORATION

2134 Sandy Drive Ste 14

State College, PA 16803

814-237-0144

Thom Hay

Thomas R. Hay
President
ASNT Level 3 #107162

TECHKNOWSERV CORP, 2134 Sandy Drive Ste 14, State College PA 16803, 814-237-01044

TechKnowServ
TECHNOLOGY, KNOWLEDGE, SERVICE

TechKnowServ
TECHNOLOGY, KNOWLEDGE, SERVICE

Calibration Certificate

Issue Date: 11/30/2018

Expiry Date: 11/29/2019

Device: AC

Manufacturer: Parker Research Corp.

Model: Contour Probe ®

Serial Number: 20702

Weight Lift Test Bar: TB-10SP Special Weight Lift/Defect Test Bar S/N 001

***All equipment used in the evaluation of this instrument has been calibrated with traceability to NIST**

Applicable Standards

1. ASTM E709 - 08 Standard Guide for Magnetic Particle Testing
2. ASTM E1444 - 01 Standard Practice for Magnetic Particle Examination

Performance Summary

Test Weight (lb)	Leg Spacing (in)	Result
10	2-4	Pass

Certificate provided by:

TECHKNOWSERV CORPORATION

2134 Sandy Drive Ste 14

State College, PA 16803

814-237-0144

Thomas R. Hay
President
ASNT Level 3 #107162

TECHKNOWSERV CORP, 2134 Sandy Drive Ste 14, State College PA 16803, 814-237-01044

SPECTROLINE®
NDT

CERTIFICATE OF LIGHT OUTPUT

This is to certify the UV-A lamp referenced below meets the output measurements (UV and visible) for LED UV-A light as well as producing a Peak Wavelength at 360 - 370 nm (365 ± 5 nm) as measured with a spectroradiometer, in accordance with ASTM MPT/LPT and EN ISO 3059:2012(E) requirements.

Product Name: OPTI-LUX™ 365 High Intensity Series

Product Number: OLX-365

Serial Number: 2157677

The following measurements were obtained using a Spectroline® AccuMAX™ XR-1000 and XDS-1000 at 15" (38 cm) with battery-operated lights at full charge:

UV-A intensity reading @ 365nm: 9,000 – 10,000 microW/cm²

Visible light reading @ 555nm: With clear filter: 0.5 – 0.9fc (5.4 – 9.7 lux)
With black light filter: 0.4 – 0.5fc (4.3 – 5.4 lux)

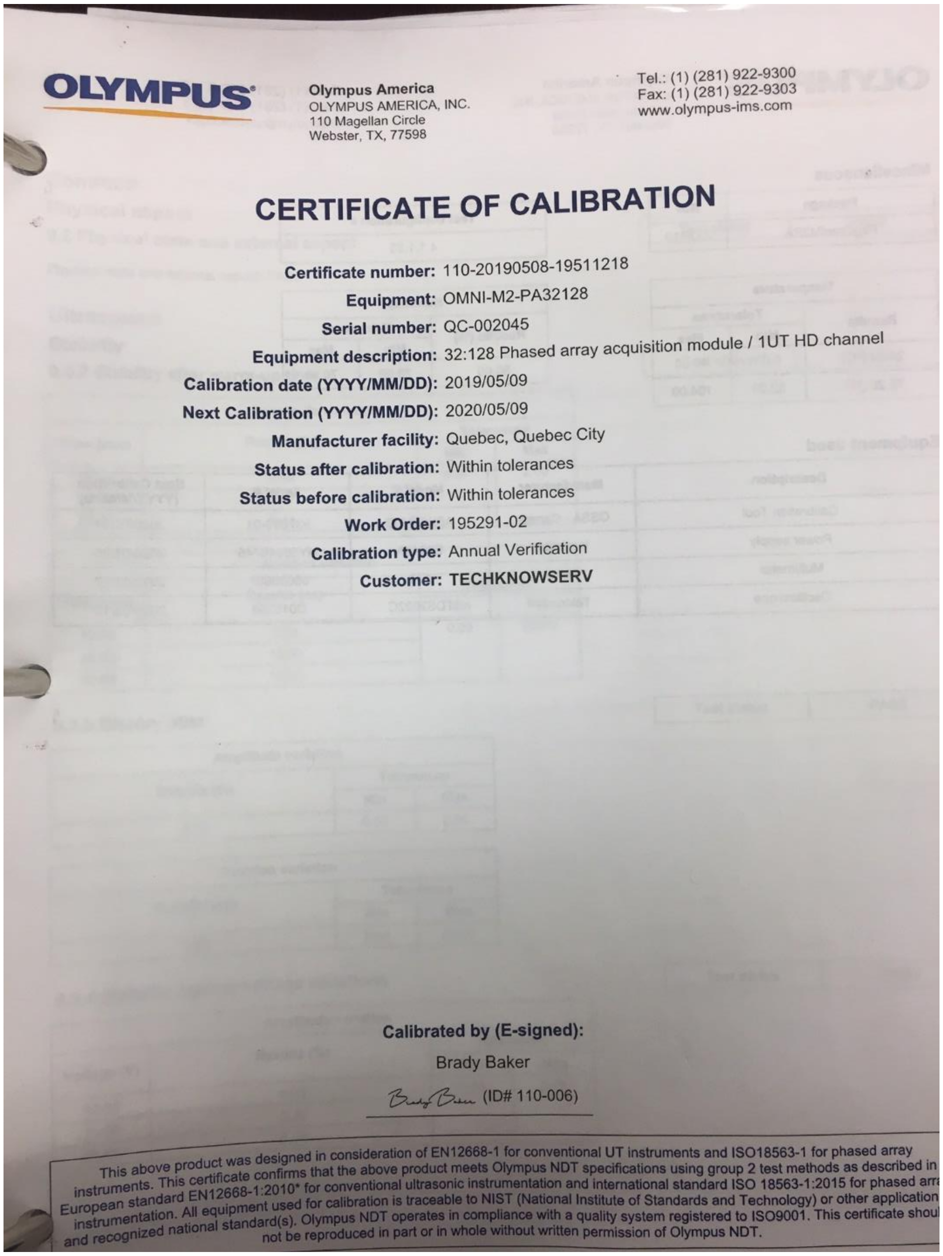
Inspector: ____________

Date: 08-06-2019

Steve Biondi
Quality Manager
April 2018 – AM12013

SPECTRONICS CORPORATION
956 BRUSH HOLLOW RD WESTBURY, NY 11590 • PHONE: 516-333-4840 • FAX: 516-333-4859 • WWW.SPECTROLINE.COM

6.2 Phased Array Testing Equipment



OLYMPUS

Olympus America
OLYMPUS AMERICA, INC.
110 Magellan Circle
Webster, TX, 77598

Tel.: (1) (281) 922-9300
Fax: (1) (281) 922-9303
www.olympus-ims.com

CERTIFICATE OF CALIBRATION

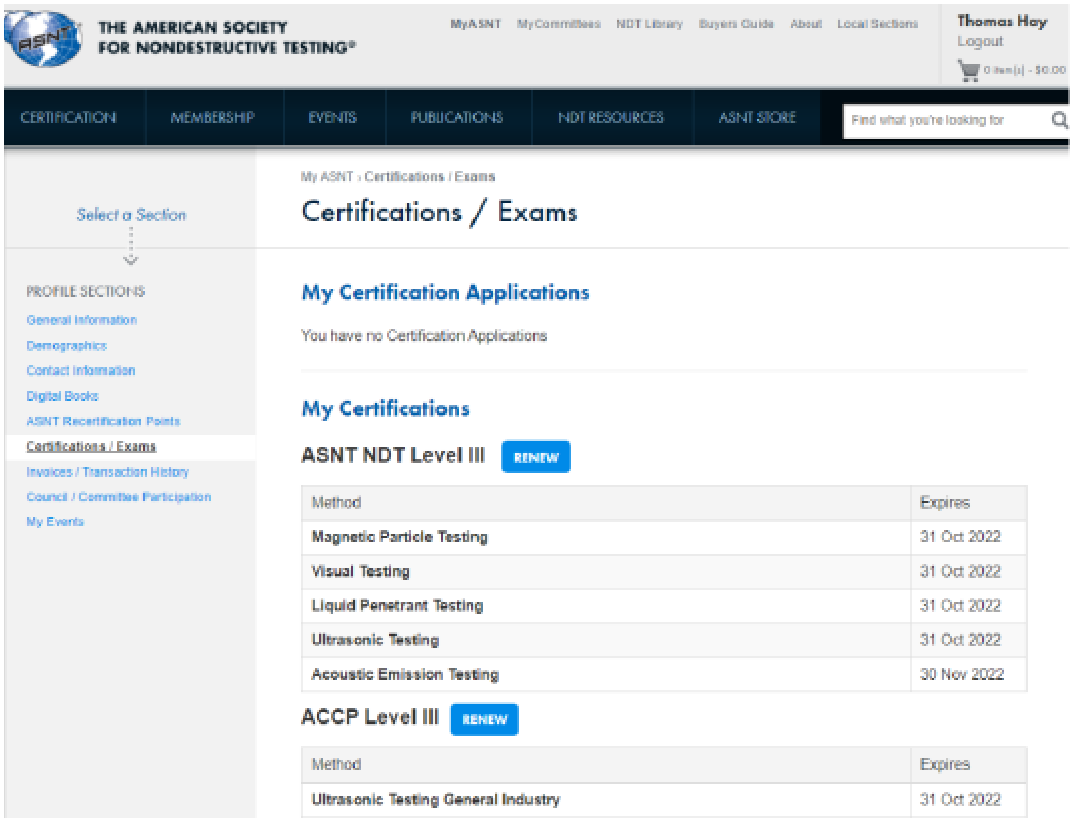
Certificate number:	110-20190508-19511218
Equipment:	OMNI-M2-PA32128
Serial number:	QC-002045
Equipment description:	32:128 Phased array acquisition module / 1UT HD channel
Calibration date (YYYY/MM/DD):	2019/05/09
Next Calibration (YYYY/MM/DD):	2020/05/09
Manufacturer facility:	Quebec, Quebec City
Status after calibration:	Within tolerances
Status before calibration:	Within tolerances
Work Order:	195291-02
Calibration type:	Annual Verification
Customer:	TECHKNOWSERV

Calibrated by (E-signed):
Brady Baker
(ID# 110-006)

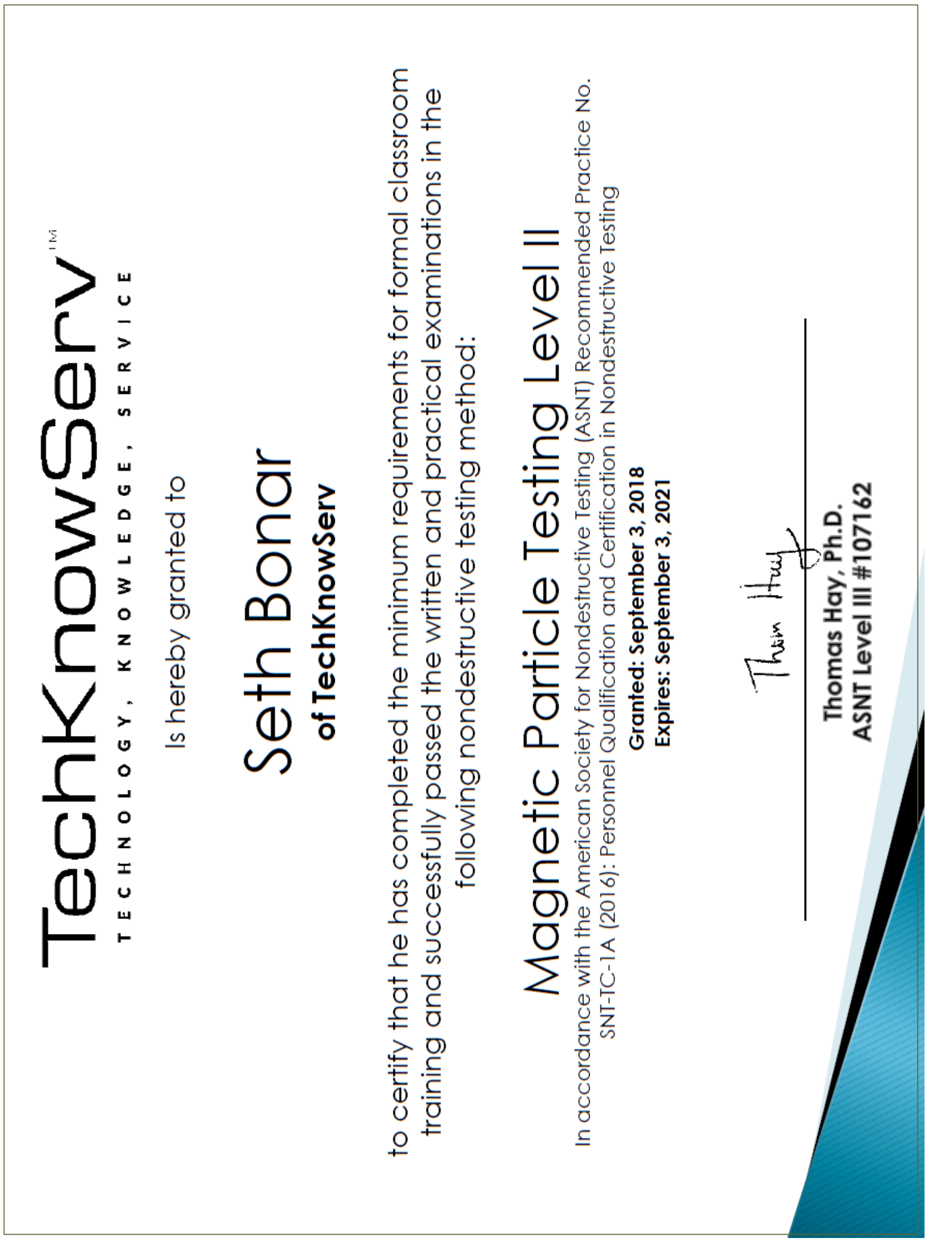
This above product was designed in consideration of EN12668-1 for conventional UT instruments and ISO18563-1 for phased array instruments. This certificate confirms that the above product meets Olympus NDT specifications using group 2 test methods as described in European standard EN12668-1:2010* for conventional ultrasonic instrumentation and international standard ISO 18563-1:2015 for phased arra instrumentation. All equipment used for calibration is traceable to NIST (National Institute of Standards and Technology) or other application and recognized national standard(s). Olympus NDT operates in compliance with a quality system registered to ISO9001. This certificate shoul not be reproduced in part or in whole without written permission of Olympus NDT.

7 Inspector Certifications

7.1 Visual and Phased Array Ultrasonic Testing



7.2 Visual and Phased Array Ultrasonic Testing


TechKnowServ™
TECHNOLOGY, KNOWLEDGE, SERVICE

Is hereby granted to

Seth Bonar

of TechKnowServ

to certify that he has completed the minimum requirements for formal classroom training and successfully passed the written and practical examinations in the following nondestructive testing method:

Magnetic Particle Testing Level II

In accordance with the American Society for Nondestructive Testing (ASNT) Recommended Practice No. SNT-TC-1A (2016): Personnel Qualification and Certification in Nondestructive Testing

Granted: September 3, 2018
Expires: September 3, 2021

Thomas Hay, Ph.D.
ASNT Level III #107162