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1.8 Recommended AUT Procedure and Guidance

Two procedures were developed at the end of this project. The recommended generic procedures are described in the following sections.

1.8.1 Recommended AUT Procedure for Girth Welds

1.8.1.1 Scope

The purpose of this document is to outline general procedures for AUT of carbon steel pipe girth welds. This procedure is applicable for pipe diameters of 150 mm (6 in.) and greater having a wall thickness in the range of 7 to 40 mm (0.28 to 1.40 in.). Detailed procedures shall be developed and validated for each pipe diameter and wall thickness to be inspected.

1.8.1.2 References

The following references form a part of this procedure as specified herein:

1. SNT-TC-1A (ASNT Recommended Practice) – "Personnel Qualification and Certification in Nondestructive Testing".

2. API 1104 Welding of Pipelines and Related Facilities, 19th Edition, 1999.

1.8.1.3 Personnel

Personnel performing to this procedure shall as a minimum be qualified to the Level II requirements of SNT-TC-1A or equivalent.

1.8.1.4 Equipment

- PA UT instrumentation with a minimum capability of 16/64 channels and pulser receiver in the range of 1 to 15 MHz.

- Two linear PA probes having a 4- to 10-MHz center frequency and a minimum of 60 elements. Element pitch shall be in the range of 0.8 to 1.2 mm (0.03 to 0.05 in.). The PA probes shall be mounted on wedges having a wedge angle of 31 to 35 degrees.

- Pair of TOFD probes 3 to 6 mm (0.12 to 0.24) in diameter having a 5- to 15-MHz center frequency. TOFD probes shall be mounted on wedges that will provide 60- to 70-degree refracted L-waves in the material.

- Pair of single-element probes 6 to 12 mm (0.3 to 0.5 in.) in diameter having a 4- to 10-MHz center frequency. The probes shall be mounted on wedges that will provide a 45- to 60-degree refracted shear wave in the material. These probes will be used for detecting transverse weld flaws.

- Automated variable speed, two-axis scanner with 2-mm position resolution minimum.

- Computer with PA control and analysis software, as well as scanner control software.

- Data collection and analysis software with capabilities to image and merge A-, B-, C-, D-, S-scan and polar view.

- Calibration sample containing notches and 2-mm (0.08-in.) diameter FBHs (Figure 1.8.1-1).

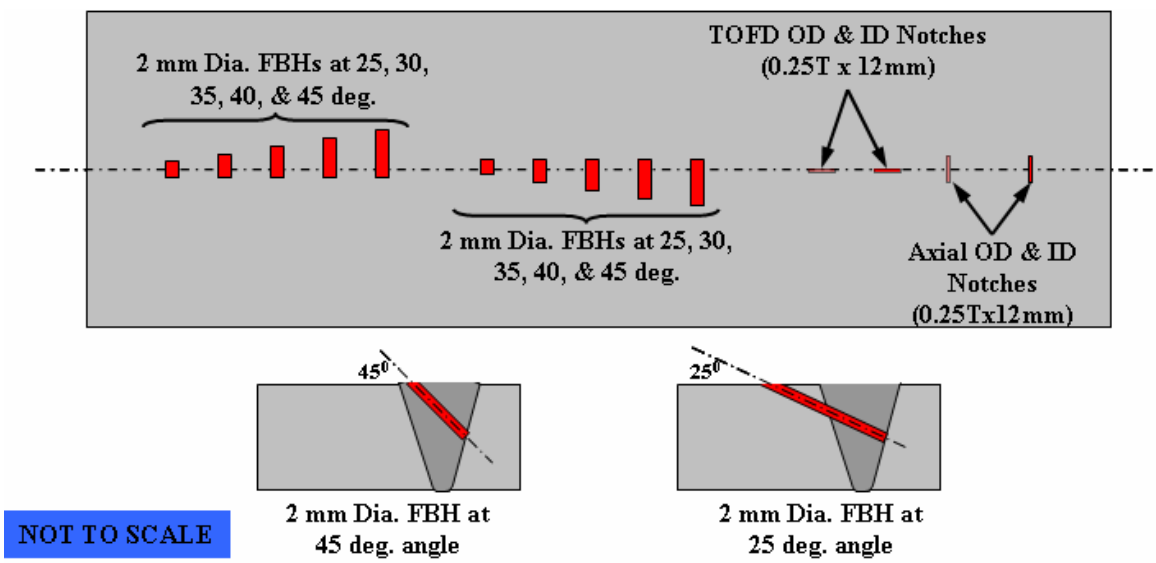

Figure 1.8.1-1. Example Calibration Reference Sample Layout

1.8.1.4.1 Calibration

1.8.1.4.1.1 PA Probe Channels

- A minimum of two channels shall be used for each PA probe; a 0-degree L-wave and a 45- to 65-degree shear wave angle sweep with a minimum resolution of 5 degrees per step. The 0-degree L-wave is to be used as a check for delaminations in the pipe wall that would affect the shear wave scans, as well as verification that the probe is adequately coupled to the pipe during the inspection. As an alternative, the

delamination check may be performed using a separate scan with a single-element or PA probe. All shear wave PA sensitivity and distance calibrations performed in accordance with this procedure shall be accomplished using the second leg reflection from the face (bottom) of the FBHs in the calibration sample.

- Calibration of each PA probe shall be performed using the following steps:

    1. Before setting up the individual inspection channels, perform a verification of the setup parameters. To accomplish this, input the probe and wedge variables into the PA software and calculate focal laws to electronically steer the sound beam through 45- to 70-degree refracted shear wave angles in 1-degree increments. The beam should be electronically focused, as needed, to provide a sharp distinct signal from the calibration reflectors. For the probe specified in this procedure, focal depths of less than 12 mm (0.5 in.) are not recommended. Typical focal depths should be in the range of 13 to 76 mm (0.5 to 3.0 in.) depending on the pipe wall thickness.

    2. Determine if the focal laws are accurate by manually scanning the probe over the FBH in the calibration sample while viewing the S-scan display. The image from the face of the FBHs should appear at the appropriate depth and should move horizontally across the S-scan as the probe is moved toward and away from the holes. Diagonal movement of the reflected signal image on the S-scan indicates that the focal laws are not correct.

    3. After verifying that the focal laws are correct, establish the 0-degree L-wave and the multiple angle sweep channels using the probe and wedge parameters verified in Step 2.

    4. Establish the focal law for the 0-degree channel to have an aperture of approximately 6 to 15 mm (0.24 to 0.59 in.) and to electronically scan the full length of the probe.

    5. Adjust the time baseline to include a minimum of two back reflections and calibrate the back reflections to appear on the A-scan at multiples of the pipe wall thickness and then adjust the signal amplitude so that the second back reflection is approximately 80% of FSH.

    6. Setup the shear wave multiple-angle sweep channel by establishing a shear wave sector scan law to cover the angles from 45 to 65 degrees.

7. Display the 55-degree beam angle data in an A- and S-scan format and move the probe to maximize the reflected signal from the 35-degree FBH.

8. When the signal is maximized, adjust the gain so that the signal amplitude is 80% FSH or greater. This gain setting, referred to in this procedure as the “PA baseline gain setting”, is the minimum gain for shear wave inspection purposes.

9. With the signal still maximized, adjust the time baseline so that the signal is at the correct depth within ±0.1 mm (0.004 in.).

10. Select the 65-degree beam angle and verify that the reflection from the 25-degree FBH is has an amplitude of at least 40% FSH, and that the displayed depth on the A- and S-scan is within ±0.1 mm (0.004 in.) of the actual depth. If necessary, add additional gain so that the reflection from the 25-degree FBH is at an amplitude of at least 40% FSH. If additional gain is required, the new gain setting will become the PA baseline gain.

11. Repeat Step 10 for the 45-degree beam angle using the 45-degree FBH.

1.8.1.4.1.2 TOFD Channel

- Calibrate the TOFD channel as follows:

    1. Adjust the spacing of the TOFD probes so that the sound beam is focused approximately 70% of the pipe wall thickness.

    2. Use the 25% through-wall circumferential ID notch in the calibration sample for distance calibration. Adjust the gain setting to produce a clean distinct tip signal from the notch with a background noise level of approximately 10% FSH. This gain setting will be the TOFD baseline gain.

1.8.1.4.1.3 Single-Element Transverse Flaw Channel

- Calibrate the single-element transverse flaw channel as follows:

    1. Use the ID and OD transverse notches in the calibration sample to setup the single-element probes for detection of transverse flaws. The transverse baseline

gain setting shall be established by setting the received reflection from the notches at a minimum amplitude of 80% FSH.

2. Using the established baseline gain settings and distance calibration, scan the calibration sample with the scanner speed and resolution settings that will be used for the actual AUT inspection of production welds. In no case, however, shall the circumferential scan speed exceed 20 cm per second (8 in. per second) and scan resolution shall not exceed 3 mm (0.12 in.). Make adjustments as needed to detect calibration flaws at the minimum baseline amplitudes for each channel and to assure that the data acquisition rate is appropriate for the scan speed.

1.8.1.4.2 Scanning

- Scanning shall be accomplished by mechanically moving the probes around the pipe circumference while the probes are held stationary, relative to the weld centerline. The PA probes shall be electronically scanned perpendicular to the weld to produce a raster scan pattern. Scanner speed and resolution shall be the same as that used for calibration sample scans.

- Position the probes at distances from weld centerline that are appropriate to achieve the required inspection coverage. For the PA probes, the shortest surface distance from weld centerline will be determined by the 45-degree beam and the furthest point will be determined by the 55-degree beam. Geometry permitting, the PA probe should be close enough to the weld so that the 45-degree beam will at least intersect the opposite root bevel on the first leg. At the same time, the probe should be far enough from the weld that the 55-degree beam will intersect the near bevel cap on the second leg. Refer to Figure 1.8.1-2.

- TOFD probes shall be equal distance from weld centerline at a point calculated to focus the beam at approximately 70% of the wall thickness and verified on the calibration sample.

- Transverse flaw probes shall be equal distance from weld centerline at a spacing and orientation that detects the transverse notches in the calibration sample.

- Additional gain of up to 10 dB can be added to the baseline gain settings during inspection of production welds.

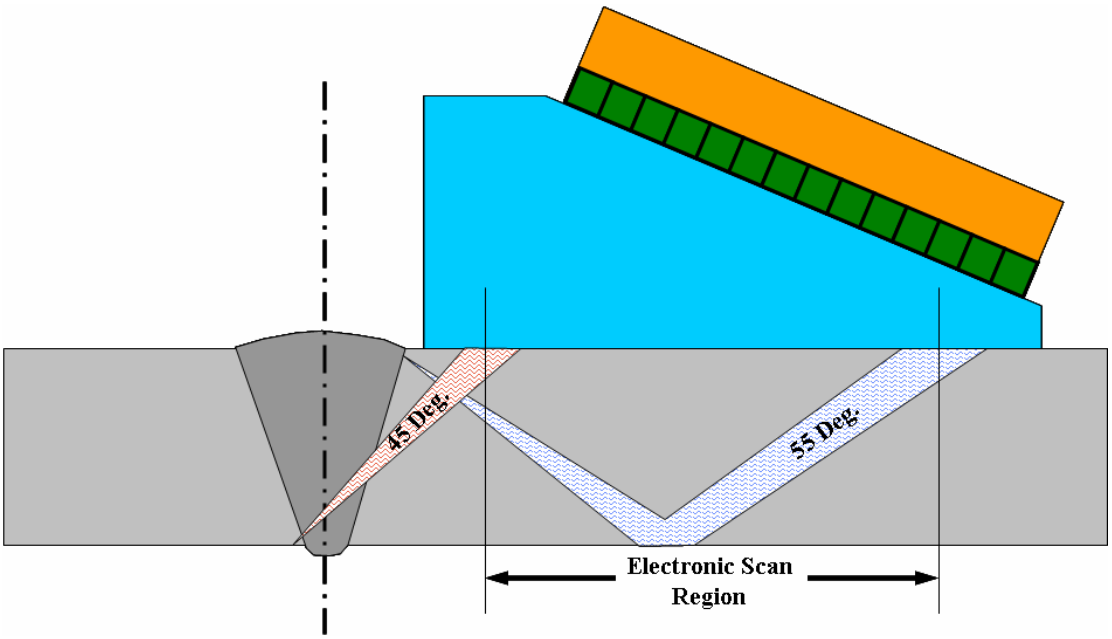

Figure 1.8.1-2. Electronic Scan Limits

1.8.1.5 Evaluation

Evaluation can be performed using strip D-scan views to image the data from each angle separately. It is recommended that the D-scans be oriented so that all five shear wave scans can be viewed simultaneously (Figure 1.8.1-3) for a quick field evaluation. More precise evaluations can be performed using a combination of available A-, B-, C-, D-, and S-scans as needed.

Weld acceptance shall be in accordance with the applicable specification.

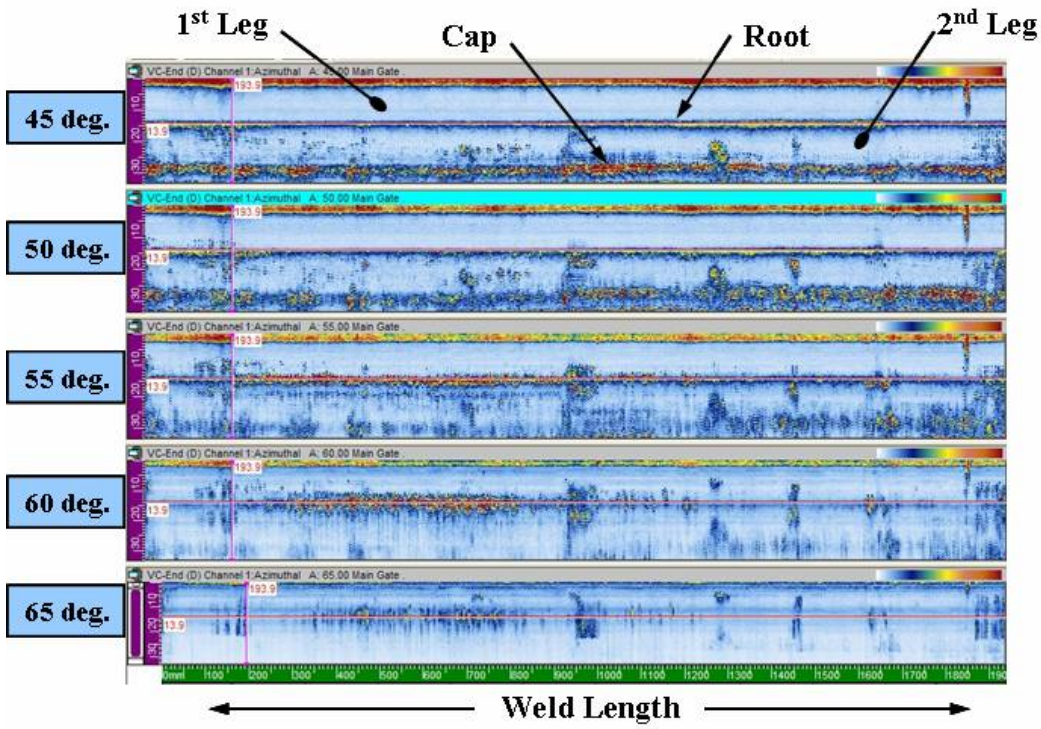

Figure 1.8.1-3. Example of Display Technique for Multiple Shear Wave Angles

1.8.1.6 Records

The following items shall be included in the inspection records for each weld tested:

- Instrument description (make, model, and serial number)
- Ultrasonic software version number
- Setup file name, revision number, and revision date
- Applicable instrument settings necessary to duplicate test
- Probe descriptions (frequency, part number, and probe serial number)
- Name of operator
- Name of data file reviewers
- Weld description (line number, weld number, etc.)
- Electronic data files from each weld
- Documentation of locations that could not be inspected due to obstructions, inadequate surface conditions, etc. Documentation can be in the form of written descriptions, sketches, and/or pictures.
- Summary of test results including the location, depth, length, and height of rejectable flaw indications.

1.8.2 Recommended AUT Procedure for Hot Tap Welds

1.8.2.1 Scope

The purpose of this document is to outline general procedures for AUT of hot tap branch connection welds in carbon steel pipe. This procedure is applicable for pipe diameters of 15 cm (6 in.) and greater having a wall thickness in the 7- to 40-mm (0.28- to 1.40-in.) range. Detailed procedures shall be developed and validated for each pipe diameter and wall thickness to be inspected.

1.8.2.2 References

The following references form a part of this procedure as specified herein:

1. SNT-TC-1A (ASNT Recommended Practice) – "Personnel Qualification and Certification in Nondestructive Testing".

2. API 1104 Welding of Pipelines and Related Facilities, 19th Edition, 1999.

1.8.2.3 Personnel

Personnel performing to this procedure shall as a minimum be qualified to the Level II requirements of SNT-TC-1A or equivalent.

1.8.2.4 Equipment

- PA UT instrumentation with a minimum capability of 16/64 channels and pulser receiver in the 1- to 15-MHz range.

- Two linear PA probes having a 4- to 10-MHz center frequency and a minimum of 60 elements. Element pitch shall be in the range of 0.8 to 1.2 mm (0.03 to 0.05 in.). The PA probes shall be mounted on wedges having a 31- to 35-degree wedge angle.

- Automated variable speed, two-axis scanner with 2-mm position resolution minimum.

- Computer with PA control and analysis software, as well as scanner control software.

- Data collection and analysis software with capabilities to image and merge A-, B-, C-, D-, S-scan, and polar view.

- Carrier pipe calibration sample containing 2-mm (0.08-in.)-diameter FBHs drilled at 25- and 35-degree angles to mid-wall on the weld bevel. FBHs on the carrier pipe shall be located at both the crotch and saddle positions (see Figure 1.8.2-1).

- Branch pipe calibration sample containing 2-mm (0.08-in.)-diameter FBHs drilled at 25- and 35-degree angles to mid-wall on the weld bevel (see Figure 1.8.2-1).

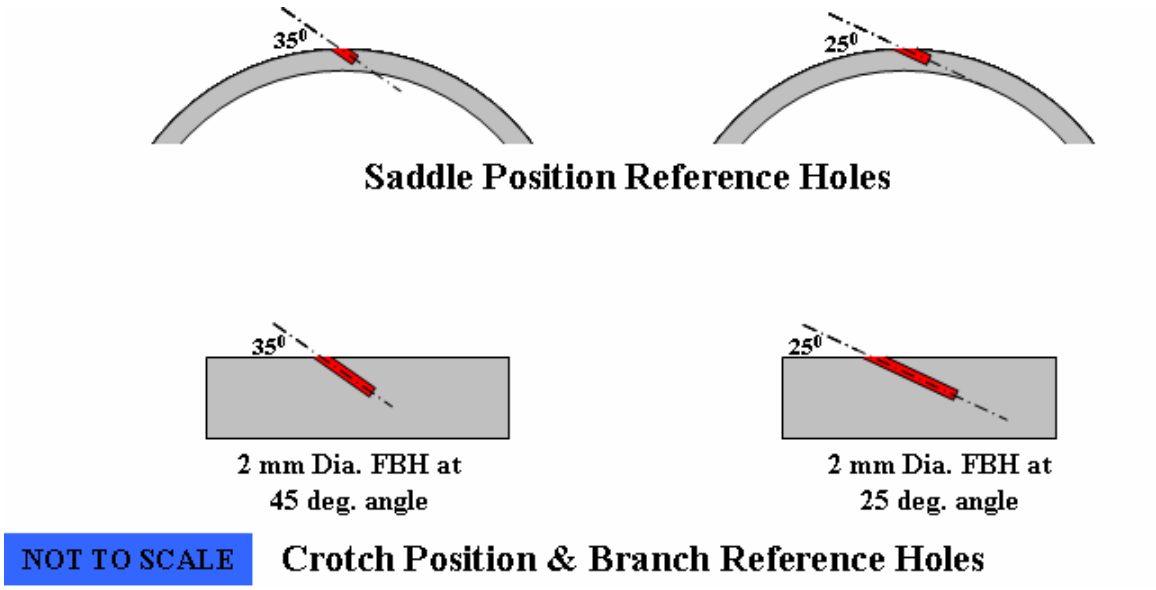

Figure 1.8.2-1. Example of Reference Reflectors for Angle Beam Inspection

1.8.2.4.1 Calibration

1.8.2.4.1.1 PA Probe Channels

- A minimum of two channels shall be used for each PA probe; a 0-degree L-wave and a 45- to 65-degree shear wave angle sweep with a minimum resolution of 5 degrees per step. The 0-degree L-wave is to be used as a check for delaminations in the pipe wall that would affect the shear wave scans, as well as, verification that the probe is adequately coupled to the pipe during the inspection. As an alternative, the delamination check may be performed using a separate scan with a single-element or PA probe. All shear wave PA sensitivity and distance calibrations performed in accordance with this procedure shall be accomplished using the second leg reflection from the face (bottom) of the FBHs in the calibration sample.

- Calibration of each PA probe shall be performed using the following steps:

    1. Before setting up the individual inspection channels, perform a verification of the setup parameters. To accomplish this, input the probe and wedge variables into the PA software and calculate focal laws to electronically steer the sound beam through 45- to 70-degree refracted shear wave angles in 1-degree increments. The beam should be electronically focused as needed to provide a sharp distinct signal from the calibration reflectors. For the probe specified in this procedure, focal depths of less than 12 mm (0.5 in.) are not recommended. Typical focal depths should be in the 13- to 76-mm (0.5- to 3.0-in.) range depending on the pipe wall thickness.

    2. Determine if the focal laws are accurate by manually scanning the probe over the FBH in the branch pipe calibration sample while viewing the S-scan display. The image from the face of the FBHs should appear at the appropriate depth and should move horizontally across the S-scan as the probe is moved toward and away from the holes. Diagonal movement of the reflected signal image on the S-scan indicates that the focal laws are not correct.

    3. After verifying that the focal laws are correct, establish the 0-degree L-wave and the multiple angle sweep channels using the probe and wedge parameters verified in Step 2.

    4. Establish the focal law for the 0-degree channel to have an aperture of approximately 6 to 15 mm (0.24 to 0.59 in.) and to electronically scan the full length of the probe.

    5. Adjust the time baseline to include a minimum of two back reflections and calibrate the back reflections to appear on the A-scan at multiples of the pipe wall thickness and then adjust the signal amplitude so that the second back reflection is approximately 80% of FSH.

    6. Setup the shear wave multiple angle sweep channel for inspection from the carrier pipe side of the weld by establishing a shear wave sector scan law to cover the angles from 45 to 65 degrees.

    7. Display the 55-degree beam angle data in an A- and S-scan format and move the probe to maximize the reflected signal from the 35-degree FBH in the carrier pipe at the crotch position.

8. When the signal is maximized, adjust the gain so that the signal amplitude is 80% FSH or greater. This gain setting, referred to in this procedure as the “PA baseline gain setting”, is the minimum gain for shear wave inspection purposes.

9. With the signal still maximized, adjust the time baseline so that the signal is at the correct depth within ±0.1 mm (0.004 in.).

10. Move the probe to the 35-degree FBH at the saddle position and verify that the reflected amplitude is at least 80% FSH. Add additional gain to the PA baseline gain setting, if needed. Note that curvature correction will have to be applied to determine that the flaw depth is correct.

11. Select the 65-degree beam angle and verify that the reflections from the 25-degree FBHs at both the crotch and saddle positions have amplitudes of at least 40% FSH, and that the displayed depth on the A- and S-scan is within ±0.1 mm (0.004 in.) of the actual depth. If necessary, add additional gain so that the reflections from the 25-degree FBHs are at amplitudes of at least 40% FSH. If additional gain is required, the new gain setting will become the PA baseline gain.

12. Setup for shear wave scans from the branch pipe side of the weld shall be performed the same as that for the carrier pipe setup except that the FBHs in the branch pipe shall used as the calibration reflectors.

- Using the established baseline gain settings and distance calibration, scan the calibration sample(s) with the scanner speed and resolution settings that will be used for the actual AUT inspection of production welds. In no case, however, shall the circumferential scan speed exceed 20 cm per second (8 in. per second) and scan resolution shall not exceed 3 mm (0.12 in.). Make adjustments as needed to detect calibration flaws at the minimum baseline amplitudes for each channel and to assure that the data acquisition rate is appropriate for the scan speed.

1.8.2.4.2 Scanning

- Scanning shall be accomplished by mechanically moving the probes around the repair weld circumference while the probes are maintained at a constant distance from the weld centerline. One PA probe shall be positioned on the carrier pipe while the second probe shall be positioned on the branch pipe. These scans can be performed using two different scans and only one PA probe per scan if desired.

- The PA probes shall be electronically scanned perpendicular to the weld to produce a raster scan pattern. Scanner speed and resolution shall be the same as that used for calibration sample scans.

- Position the probes at distances from weld centerline that are appropriate to achieve the required inspection coverage. For the PA probes, the shortest surface distance from weld centerline will be determined by the 65-degree beam and the furthest point will be determined by the 55-degree beam. Geometry permitting, the PA probe should be close enough to the weld so that the 65-degree beam will at least intersect the root bead on the first leg. At the same time, the probe should be far enough from the weld that the 55-degree beam will intersect the weld toe on the second leg (see Figure 1.8.2-2).

- Additional gain of up to 10 dB can be added to the baseline gain settings during inspection of production welds.

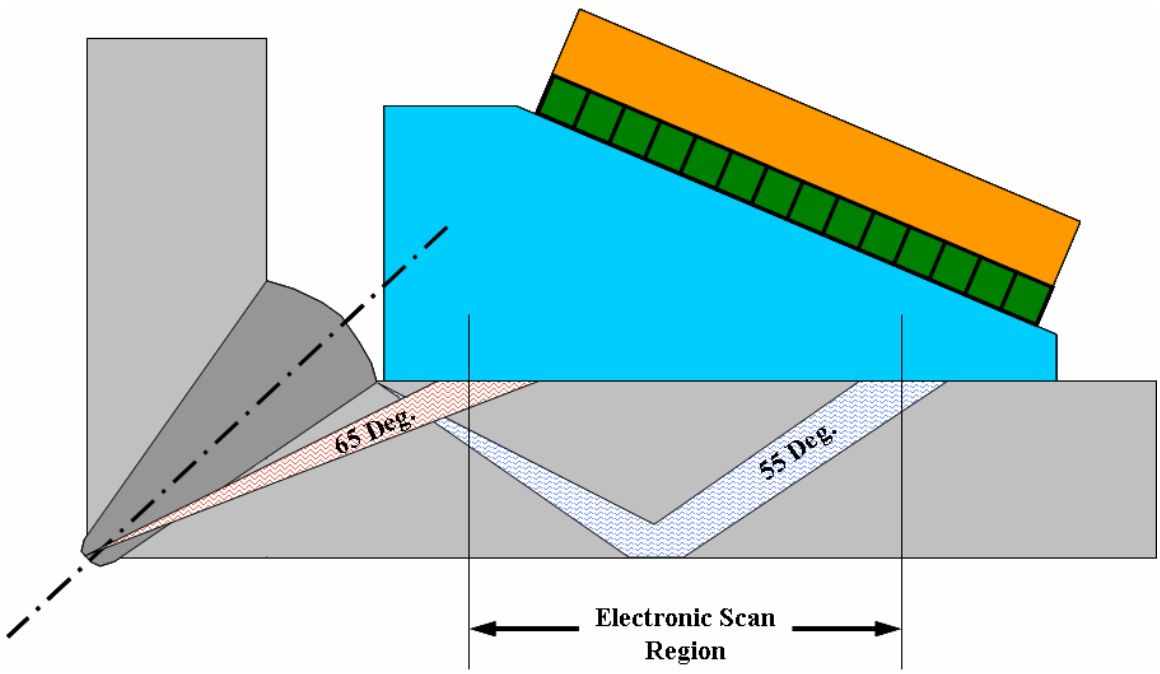

Figure 1.8.2-2. Electronic Scan Limits

1.8.2.5 Evaluation

- Evaluation can be performed using strip D-scan views to image the data from each angle separately. It is recommended that the D-scans be oriented so that all five shear wave scans can be viewed simultaneously (Figure 1.8.2-3) for a quick field evaluation. More precise evaluations can be performed using a combination of available A-, B-, C-, D-, and S-scans as needed.

- Weld acceptance shall be in accordance with the applicable specification.

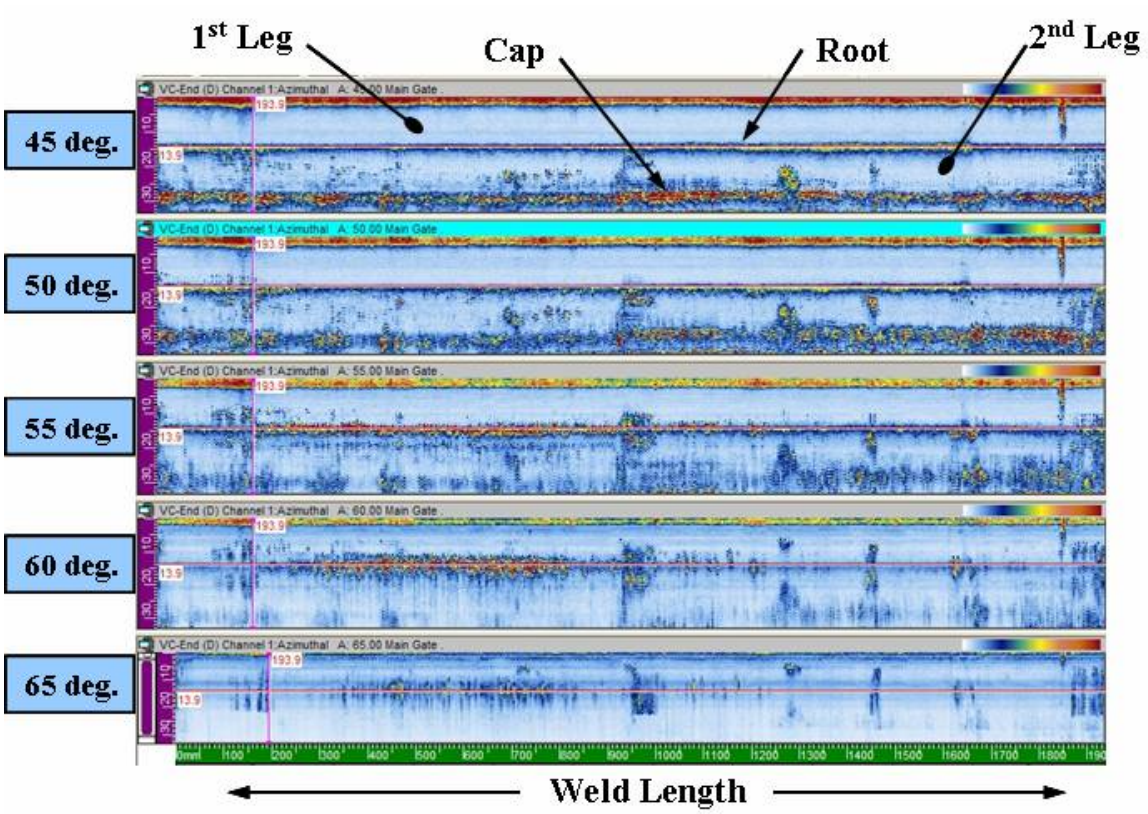

Figure 1.8.2-3. Example of Display Technique for Multiple Shear Wave Angles

1.8.2.6 Records

The following items shall be included in the inspection records for each weld tested:

- Instrument description (make, model, and serial number)
- Ultrasonic software version number
- Setup file name, revision number, and revision date

- Applicable instrument settings necessary to duplicate test
- Probe descriptions (frequency, part number, and probe serial number)
- Name of operator
- Name of data file reviewers
- Weld description (line number, weld number, etc.)
- Electronic data files from each weld
- Documentation of locations that could not be inspected due to obstructions, inadequate surface conditions, etc. Documentation can be in the form of written descriptions, sketches, and/or pictures
- Summary of test results including the location, depth, length, and height of rejectable flaw indications.

1.9 Technology Demonstrations and Implementation

Some of the results of this project were presented during the EWI Technology Workshop organized in May 2005 in Columbus, OH, with more than 240 attendees (Appendix A 1.9 and Appendix B 1.9) and to the industrial sponsors of the project in August-November 2005 time frame (Appendix C 1.9). A video as a summary of the project work involving improved AUT of girth welds conducted by EWI was developed (see Appendix D 1.9). A video conference seminar with DOT OPS field inspectors is schedule for February 2006. Some of the results of the project will be presented at the 6th International Pipeline Conference in Calgary, Canada, September 2006 and will be published in a pipeline-related journal.