Defined Procedure

For

Manual Ultrasonic Phased Array Crack Sizing

API-UT-11

This Procedure Defines the Recommended Methods and Techniques for Manual Ultrasonic Phased Array Crack Sizing

Rev.0 Jan. 2017

1.0 PURPOSE

1.1 This procedure is applicable only to ultrasonic examinations conducted for American Petroleum Institute (API) Qualification of Ultrasonic Examiners Certification Program.

1.2 The following procedure addresses equipment and evaluation techniques for opposite side crack height sizing examinations using 0.375” through 1.00” thick butt welded carbon steel specimens.

1.3 This procedure provides guidelines and techniques for ultrasonic height sizing of planar cracks which originate at the opposite side of the scanning surface or the inside diameter (ID).

1.4 This procedure is limited to manual ultrasonic phased array crack sizing for non-encoded contact methods using refracted longitudinal wave and shear wave techniques.

1.6 Other ultrasonic phased array methods and techniques may be used when an appropriate sizing calibration block is utilized.

1.7 Special longitudinal and/or shear wave search units, and special ultrasonic sizing calibration blocks may be used for the sizing examinations provided that they meet the requirements of this procedure.

2.0 REFERENCES

2.1 American Society for Nondestructive Testing (ASNT), SNT-TC-1A

2.2 American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section V

2.3 ASTM E 2491-08 Standard Guide for Evaluating Performance Characteristics of Phased-Array Ultrasonic Testing Instruments and Systems

2.4 ASTM Crack Sizing Standard ASTM E-2192

3.0 PERSONNEL REQUIREMENTS

3.1 Personnel performing the sizing examination should be, as a minimum, certified to UT Phased Array Level II or III in accordance with ASNT TC1A or equivalent industry certification scheme.

4.0 EQUIPMENT

4.1 Ultrasonic Instruments

4.1.1 Any conventional beam forming ultrasonic phased array instrument may be used provided that it satisfies the requirements of this procedure. Ultrasonic instruments should be equipped with a calibrated dB gain or attenuation control stepped in increments of 2db or less.

4.1.2 Phased array instrumentation and probe selection can be a factor in PAUT crack sizing performance. Data quality is improved with a higher number of PAUT channels. PAUT instruments and probes used for this procedure should have 16 channels or greater.

4.1.3 Ultrasonic instrument linearity shall be verified at intervals not to exceed 3 months in accordance with ASTM E 2491-08.

4.2 Search Units

4.2.1 Phased array search units shall be in the frequency range of 1.0 to 15.0 MHz

4.2.2 Phased array search units should have a minimum of 16 elements.

4.2.3 Phased array search units may be of the single or dual element type, which may produce shear and/or longitudinal waves.

4.2.4 Phased array search unit wedges, in combination with the capabilities of the phased array instrument, should be capable of producing 40-70 shear or compression waves in carbon steel.

4.2.5 Phased array straight beam search unit wedges, in combination with the capabilities of the phased array instrument should be capable of producing -30 to +30 degree compression waves.

4.2.6 Phased array search units should be capable of appropriate wave physics for the crack sizing methods described in this procedure.

4.2.7 A dead element check should be performed per the equipment manufacturers instructions prior to the inspection or when the probe does not produce the response that's expected. A search unit with more than 2 dead elements in a row and more than 25% more that the active aperture should not be used.

4.2.8 Other phased array search units and techniques may be used provided that the methods and techniques comply with the requirements of this procedure.

4.3 Cabling

4.3.1 Any convenient type and length of PAUT probe cable may be used.

4.4 Couplant

4.4.1 Any couplant material may be used.

4.5 Calibration and Reference Blocks

4.5.1 Crack Sizing Calibration Blocks shall be used to establish specific calibrations for the sizing methods identified in this procedure.

4.5.2 Sizing calibration blocks shall contain notches and/or side drilled holes (SDH) reflectors at specific known depths for calibration of the applicable sizing method.

4.5.3 The sizing calibration blocks shall be fabricated from the carbon steel materials.

4.5.4 Normally, a flat plate with notches or side drilled holes ranging from 20% to 80% through-wall in 20 % steps is used to calibrate the screen range in depth. Other blocks thicknesses in the range of the material being examined may be used.

4.5.5 Crack sizing calibration blocks shall be used for calibration of other sizing methods.

4.5.6 Reference blocks (i.e. IIW, NAVSHIP, DSC, Rompas, etc.) may be used for establishing material velocity, linear screen ranges, determining refracted angles, exit point information and Time Corrected Gain (TCG).

4.5.7 Calibration blocks should be made of carbon steel material.

4.5.8 The calibration and reference blocks should be identified by type, part number or serial number on the system calibration record.

5.0 CALIBRATION

5.1 The temperature of the calibration block material shall be within 25 degrees F of the component to be examined.

5.2 Phased Array System Calibration

5.2.1 Phased array system calibrations shall be performed for wedge delay, screen range (velocity) and system sensitivity. DAC or TCG calibrations are optional.

5.2.2 Any changes in search unit, wedges, instrumentation, aperture, focus, or couplant or power supply shall be cause for recalibration.

5.2.3 Calibration for screen range may be accomplished by either direct sound path or actual depth.

5.3.2 The initial system calibration shall be made using a basic calibration block. If a reference block e.g., Rompas, block is used to perform system calibration verification, the location and amplitude of the simulator reflector(s) shall be documented on the calibration record.

5.3.3 Screen distance calibration should be at least 1 full V-path for the maximum angle that will be used during the examination.

5.3.4 Wedge Delay (Zero offset) Calibration shall be performed per the equipment manufacturer instructions for all focal laws using a side drilled hole at a known depth.

5.3.5 Sensitivity or ACG (Angle Corrected Gain) shall be performed per the equipment manufacturer instructions using a 0.039-0.079 inch (1-2 mm) side drilled hole from a NAVSHIP, IIW, PACS or ASME calibration block.

5.3.6 Time Corrected Gain (TCG) or Distance Amplitude Correction DAC) may be used by continuing the same process over a series of side drilled holes to calibrate reflectors at different depths or metal paths so they are all detected at the same amplitude (typically 80% amplitude).

5.3.4 Other sizing techniques or variations of the techniques may be used in accordance with this procedure.

6.0 EXAMINATION

6.1 Scanning Requirements

6.1.1 The same instrument, contact wedge, focal laws and focusing used during calibration shall be used for the examination.

6.1.2 The phased array beam should be focused just beyond the component thickness. The beam may be re-focused at the depth of an indication and evaluated in accordance with the requirements of this procedure.

6.1.3 Each crack specimen shall have a unique identification number.

6.1.4 Sectoral S-Scans and electronic E-Scans may be used for the appropriate angles that ensure complete coverage of the weld and heat affected zone.

6.1.5 Before performing the angle beam examinations, a straight beam examination or caliper measurement of the actual crack specimen base metal thickness should be performed and used in PAUT crack height calculations when appropriate.

6.1.6 Scanning shall be performed using a Raster or Line Scan Technique. Each Line scan shall be parallel to the weld using a Sector Scan. Raster scans should overlap by at least 10% of the beam diameter.

6.6.7 The crack sizing examination shall be performed along the entire length of the crack to determine its ***maximum crack height***.

6.1.8 A minimum of two (2) line scans, one from each side of the weld at different index offsets from the center-line of the weld should be performed.

6.1.9 Weld crown configuration may restrict search unit movement for proper crack sizing using the specific technique. Select the appropriate crack sizing technique to accommodate this limitation.

6.1.10 UT instrument gain may be increased as necessary to obtain crack tip signals so long as background noise is not excessive. Scanning sensitivity should maintain a maximum noise level of 5% to 10% FSH.

6.1.11 The sizing method and search unit shall be appropriate for establishing the maximum crack height within each crack specimen. Each sizing technique has certain advantages, disadvantages and limitations. No one sizing technique is best for sizing cracks of any through-wall depths in all material types or thicknesses.

6.1.12 Whenever practical, the through wall crack height should be verified by more than one sizing technique.

7.0 SIZING EVALUATION

7.1 Sizing Application: Tip Diffraction

7.2 Description: The Tip Diffraction Method is based upon the diffracted sound energy from the tip of a crack. The true depth or time-of-flight, (TOF) sound path distance from the crack tip, is measured from the entry surface or referenced to crack opening at the ID.

7.3 The two basic Tip Diffraction Techniques are:

7.3.1 Time of Flight (TOF), or, AATT (Absolute Arrival Time Technique). See figure 1.

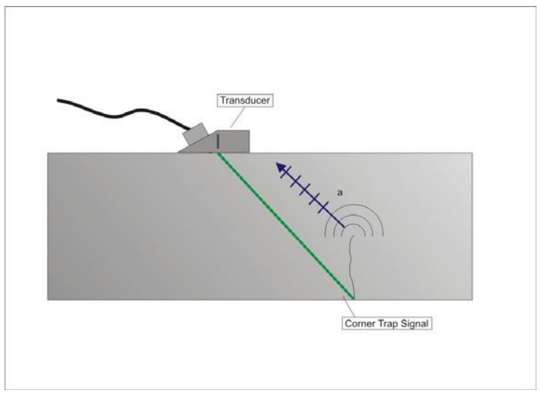

Figure 1: Absolute Arrival Time Technique

7.3.2 RATT (Relative Arrival Time Technique) or Delta Time of Flight (Δ TOF) Technique. See figure 2.

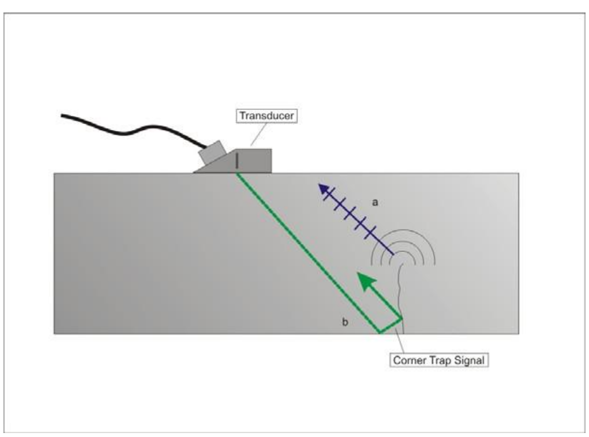

Figure 2: Relative Arrival Time Technique

7.3.3 Straight Beam L-Wave Technique for AAT or RATT. See figure 3.

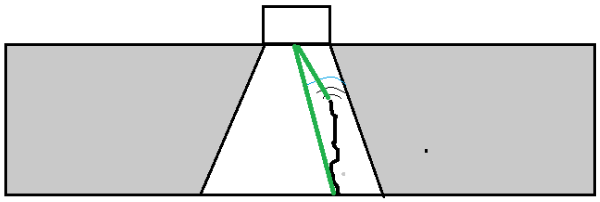

Figure 3: Straight Beam L-Wave Technique

7.3.4 AAT Evaluation

7.3.4.1 Position the PAUT probe so that the top of the crack is within the sectoral image. See figure 3.

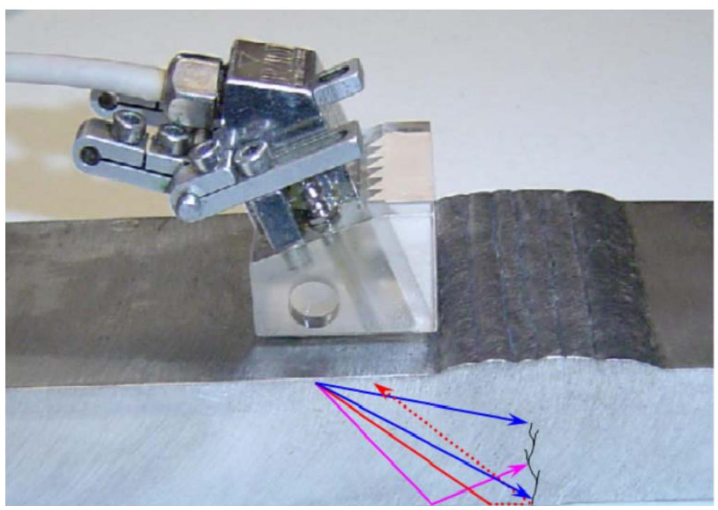

Figure 3: PAUT probe position relative to crack position

7.3.4.2 Use short probe motions in the scan and index axis to identify the crack tip signal from the highest point of the crack from the ID surface.

Note: Crack tip signals can be significantly lower in amplitude than crack base or crack facet signals. Adjust instrument gain as needed. See figure 4.

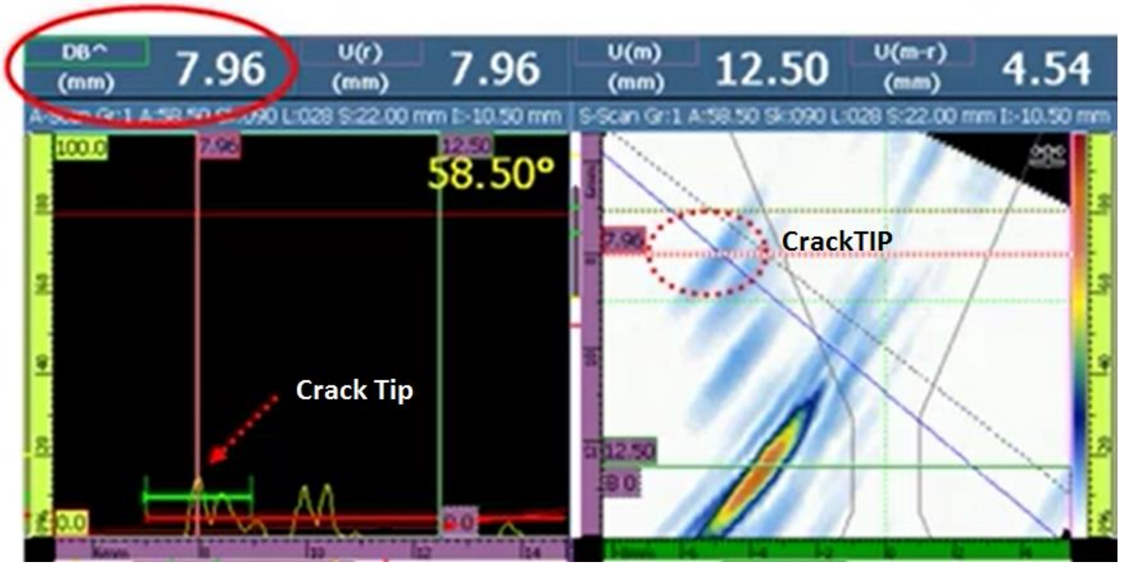

Figure 4: Crack tip signal

7.3.4.3 Move the search unit and angle curser to obtain the maximum peak amplitude. Note the minimum depth of the crack tip or last facet. See figure 5.

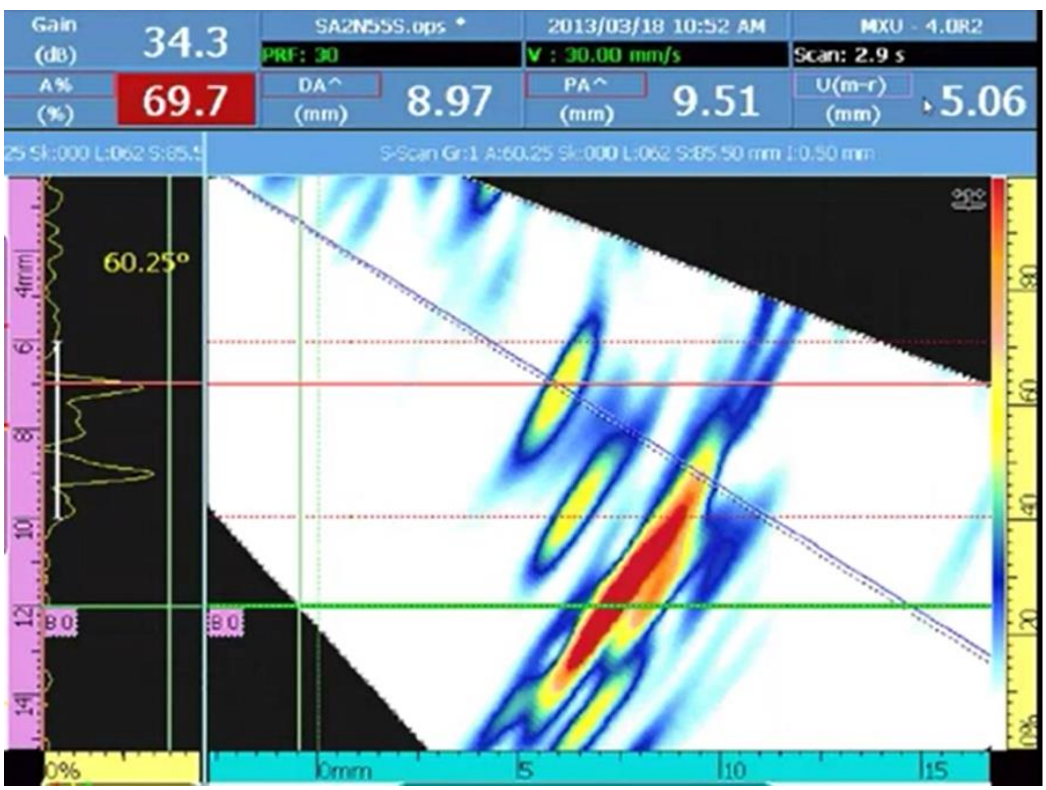

Figure 5: Maximum amplitude tip or last facet signal

7.3.4.4. Adjust the instrument gain to identify the center of energy point of the tip signal by the changes in color amplitude. See figure 6.

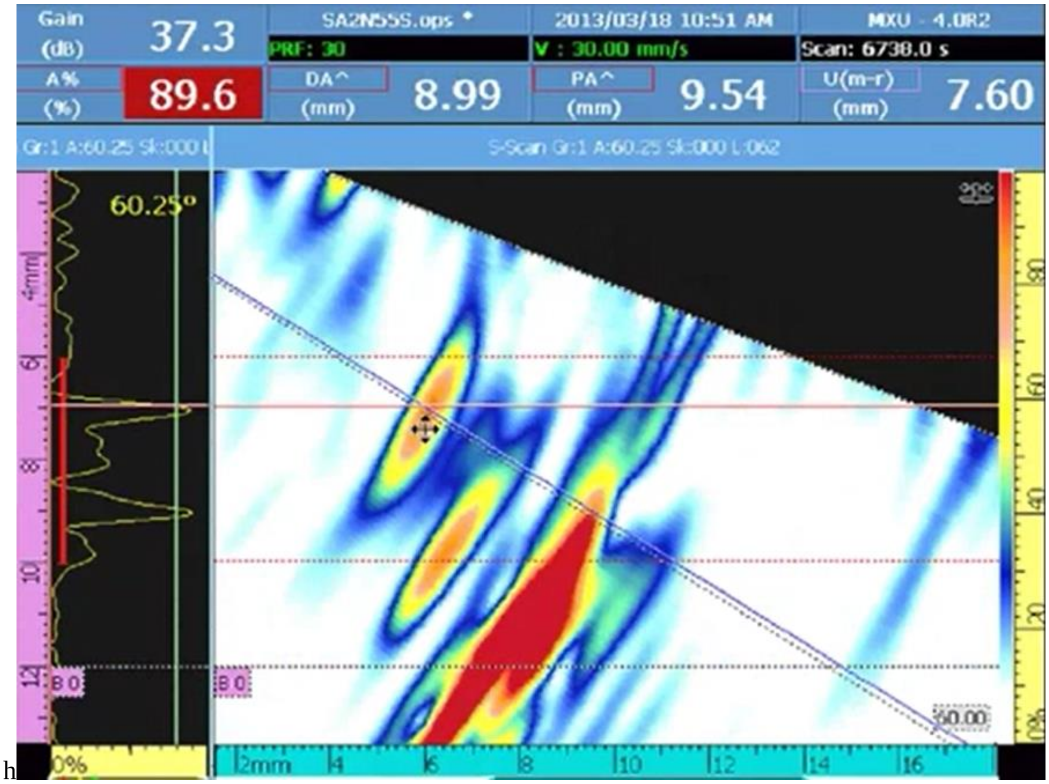

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Figure 6: Determining the center of energy (orange) of a tip signal

7.3.4.5 AAT Crack Height Measurement: Move the angle curser to the highest signal peak at the tip signal center of energy. Subtract this depth reading from the actual specimen thickness for the correct maximum crack height.

7.4. RATT Evaluation:

7.4.1 Use the Ur reference curser and Um measurement curser to measure the maximum crack height by the difference in their true depth readings. Move the reference curser to the depth of the ID surface (Bo reference line). Move the measurement curser to the tip signal center of energy per 7.3.4.4. Read the maximum crack height directly from the U (m-r) data reading. See figure 6.

7.5 When using the half-V technique for very high cracks, the crack tip signal may not readily discernible due to near field and other effects such as weld crown probe positioning limitations. A second leg crack height measurement is recommended.

7.6 Second leg crack height measurement: The probe index point is set to a distance where the second leg of the sectoral V-path is used to measure crack heights. See figure 7.

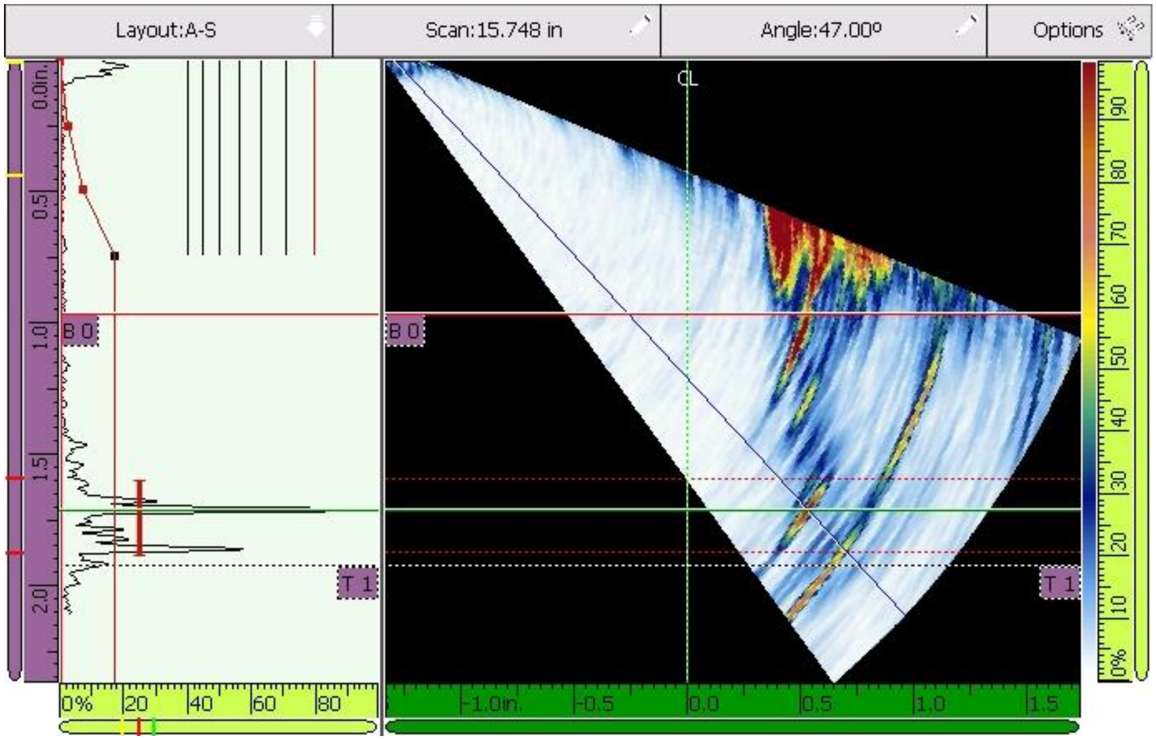

Figure 7: Second leg crack height measurement

7.6.1 Set the instrument screen range to 2.5 times the specimen thickness.

7.6.2. Establish the probe index for the crack base, crack facets and crack tips are contained in the second leg of the sound field.

7.6.3. Use small probe movements in the scan and index axis to establish the maximum crack height between the ID surface reference line (Bo) and the center of energy of the highest crack tip per 7.3.4.4.

7.6.4. Move the reference and measurement cursers to the ID reference (Bo) and measurement curser to the crack tip center of energy toward the OD surface (T1) reference line.

7.6.5 Establish the crack height readings using the AATT or RAAT techniques in 7.3.4.5 and 7.4.

7.7 Straight beam L-Wave Technique

Note: Straight beam techniques are typically used for welds with crowns removed.

7.7.1 When using longitudinal waves, they shall be limited to use with the half-V technique.

7.7.2 UT system for a zero degree PAUT probe with a straight beam delay wedge or a thin layer protective sheild on the face of the transducer.

7.7.3 Calibrate the PAUT system wedge delay, velocity, sensitivity and optional TCG as appropriate for a minimum angle range or -30 to +30 degrees. See figure 8.

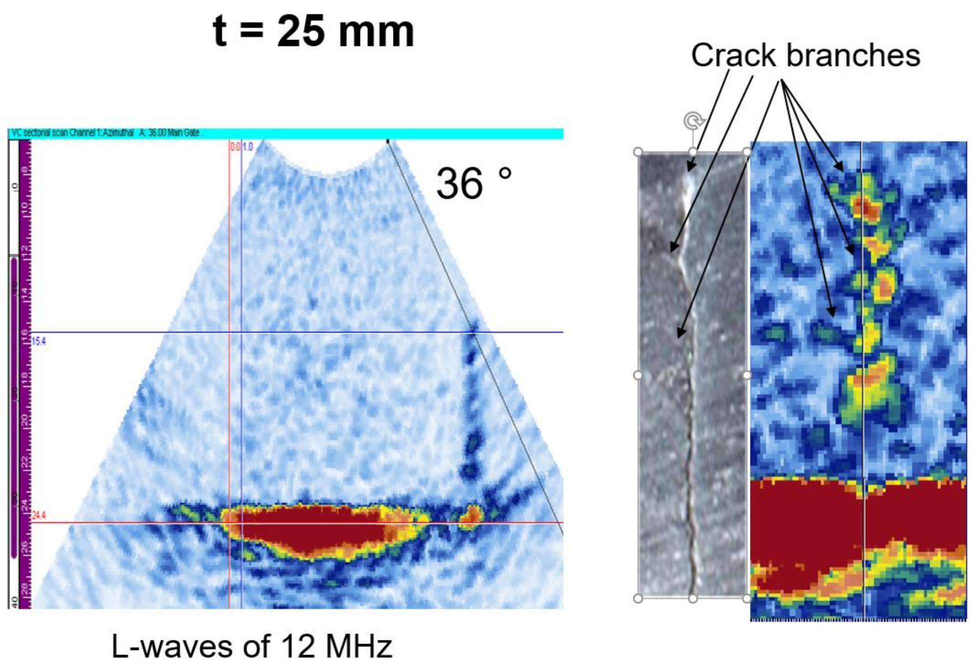

Figure 8" PAUT Straight Beam L-Wave crack image

7.3.4 Use small probe movements in the scan and the index axis to establish the maximum crack height.

7.3.5 Move the ID surface reference curser to the Bo reference line. Move the reference curser to the center of energy of the maximum height crack tip signal per 7.3.3.4.

7.3.6 Establish the crack height readings using the AATT or RAAT techniques in 7.3.3.5 and/or 7.4.

8.0 REPORTING

8.1 Record the maximum crack **height** for each crack sizing bar on the API Crack Sizing Data Report form.