RECENT IMPROVEMENTS REGARDING ULTRASONIC CRACK INSPECTION OF PIPELINES

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OUTLINE

- ***Inspection Task***
- ***Inspection Technology***
- ***Influence of Pipeline Medium***
- ***Resolution & Inspection Speed***
- ***Enhanced Depth Sizing***
- ***Summary***

OBJECTIVE OF INLINE CRACK INSPECTION

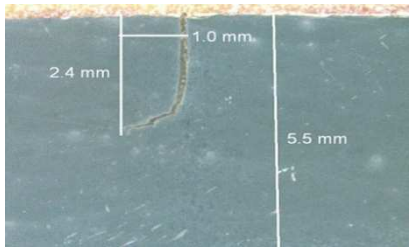
Detection & Sizing of

- ***Crack-like weld anomalies (ERW, SAW, DSAW,....)***
- ***Fatigue cracks***
- ***Stress corrosion cracks (SCC)***

with axial *or* circumferential orientation and

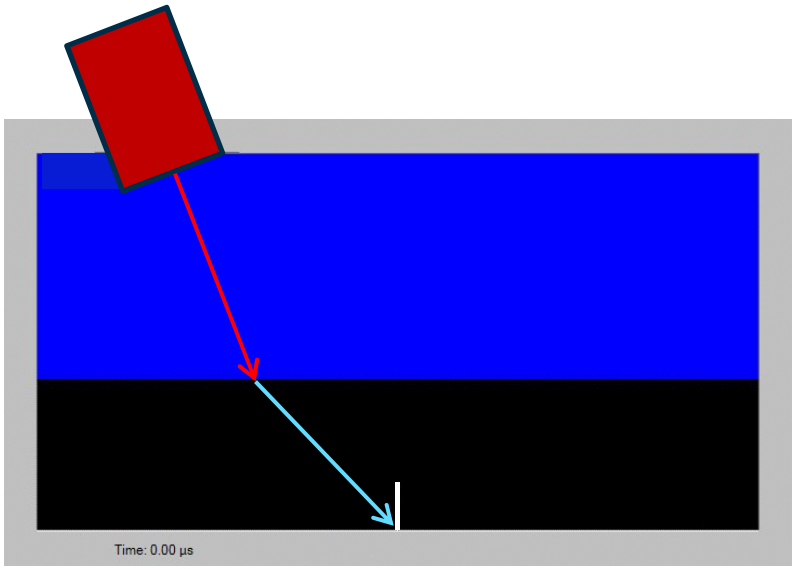
- ***Length ≥ 20 mm (0.8 in) resp. ≥ 30 mm (1.2 in)***
- ***Depth ≥ 1 mm (0.4 in) resp. ≥ 2 mm (0.8 in)***

➔ **Provide reliable input data for crack assessment!**



CRACK INSPECTION USING 45° SHEAR WAVES

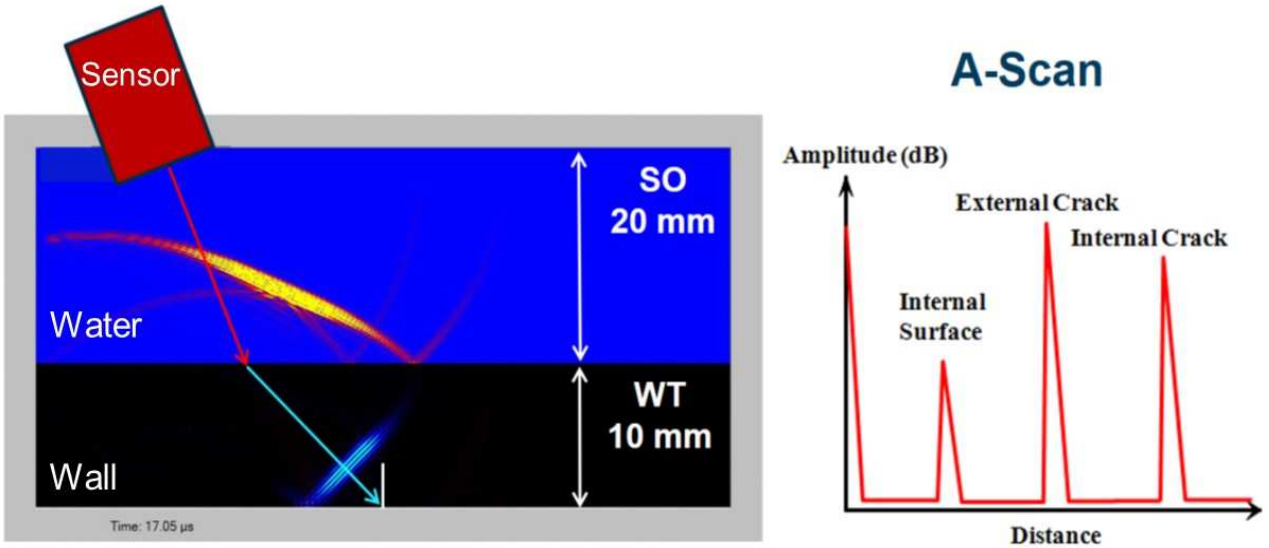
Modelling Result



Modelling using FD-method (ultrasonic frequency: 4 MHz)

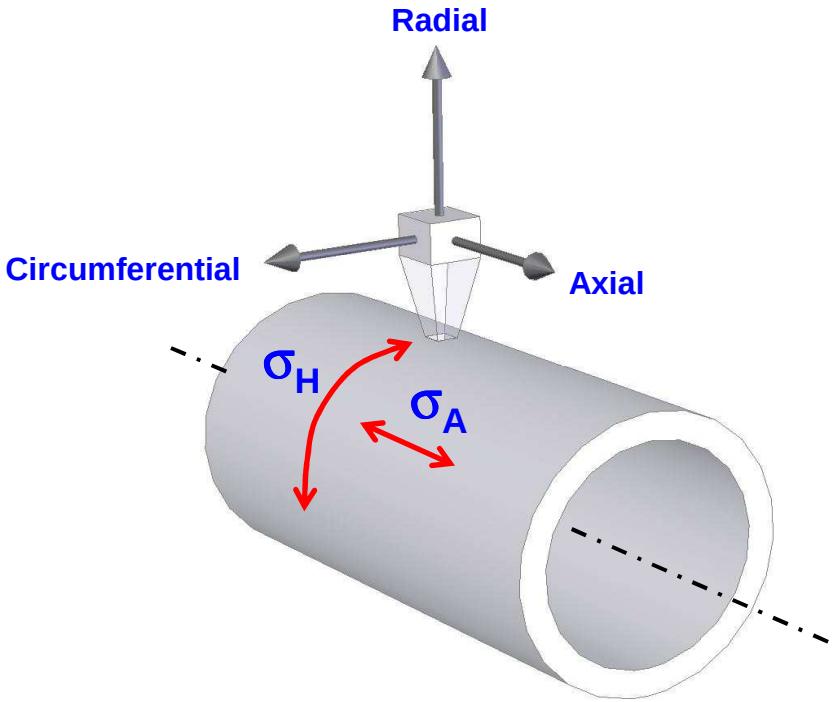
INSPECTION PRINCIPLE

45° Shear Wave / Pulse-Echo Inspection



works for most liquids: crude oil, products, water, liquid gas....
min. depth: 1 mm / 0.04 in, min. length 25 mm / 1 in (opt. 20 mm / 0.8 in)

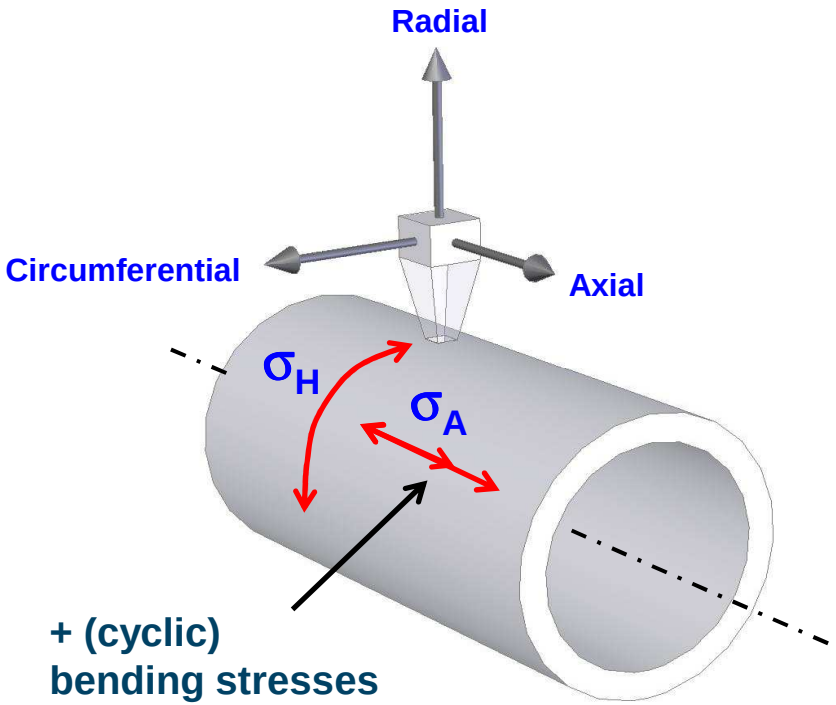
STRESSES IN PRESSURIZED PIPE



$\sigma_H \approx 2\ \sigma_A$

Axial cracking

STRESSES IN PRESSURIZED PIPE



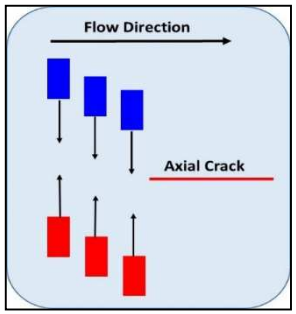
$\sigma_A > \sigma_y$

Circ. cracking?

INSPECTION TYPES

Axial Inspection

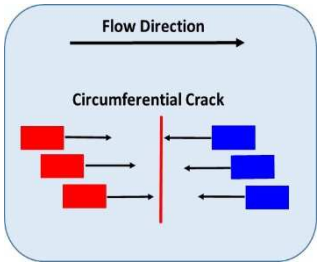
Inspection Geometry



Sensor Carrier (section)

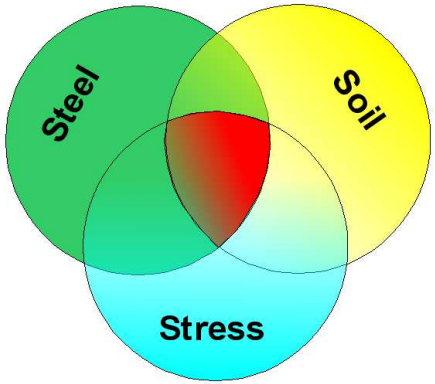
Circumferential Inspection

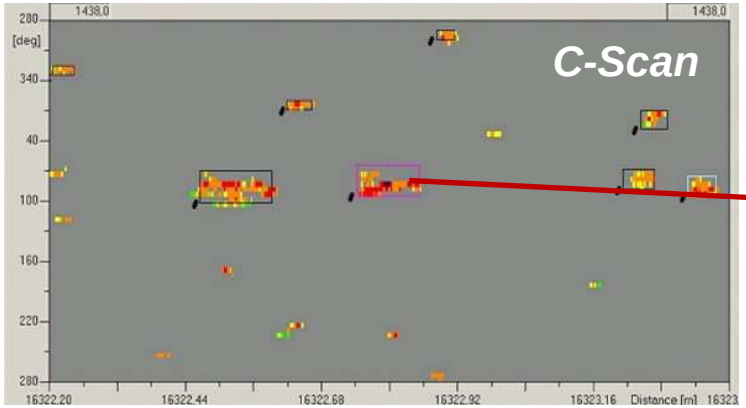
Inspection Geometry



Sensor Carrier (section)

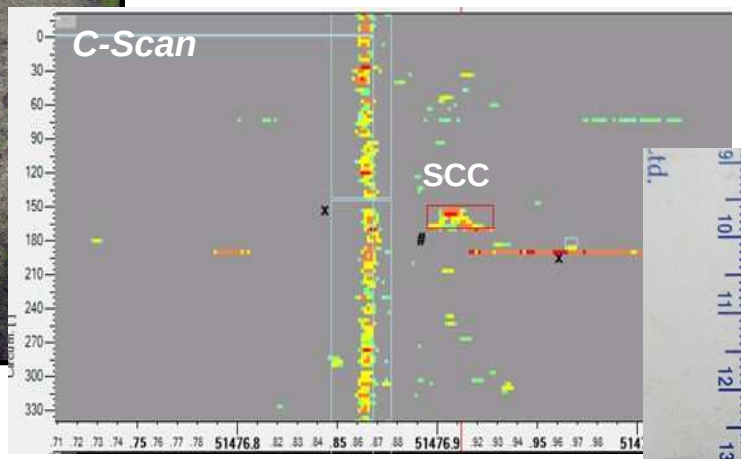
AXIAL SCC IN BASE MATERIAL

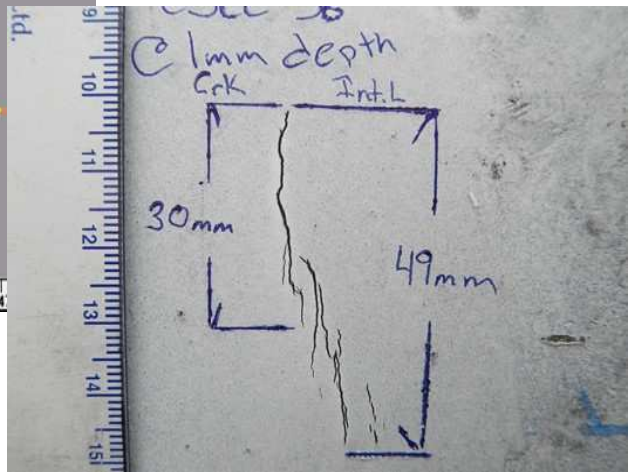




CIRCUMFERENTIAL SCC DETECTED IN STEEP TERRAIN

Girth Weld





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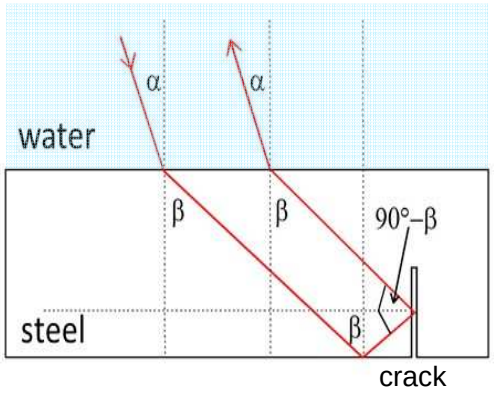
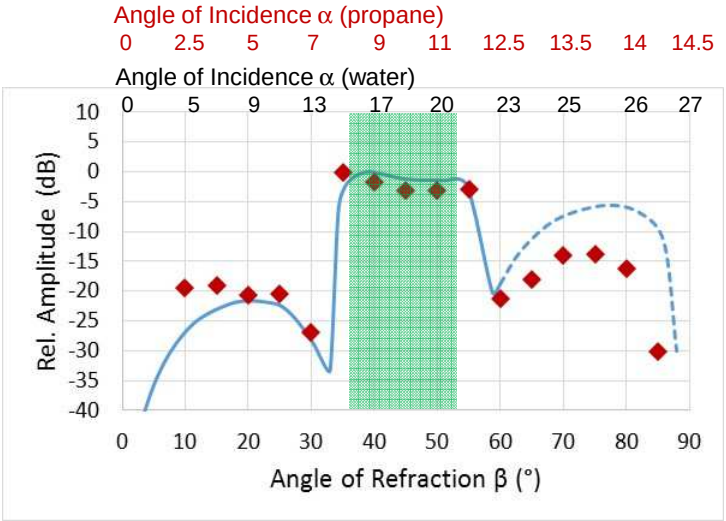
INSPECTION PRINCIPLE

Angular Dependency of Corner Reflection

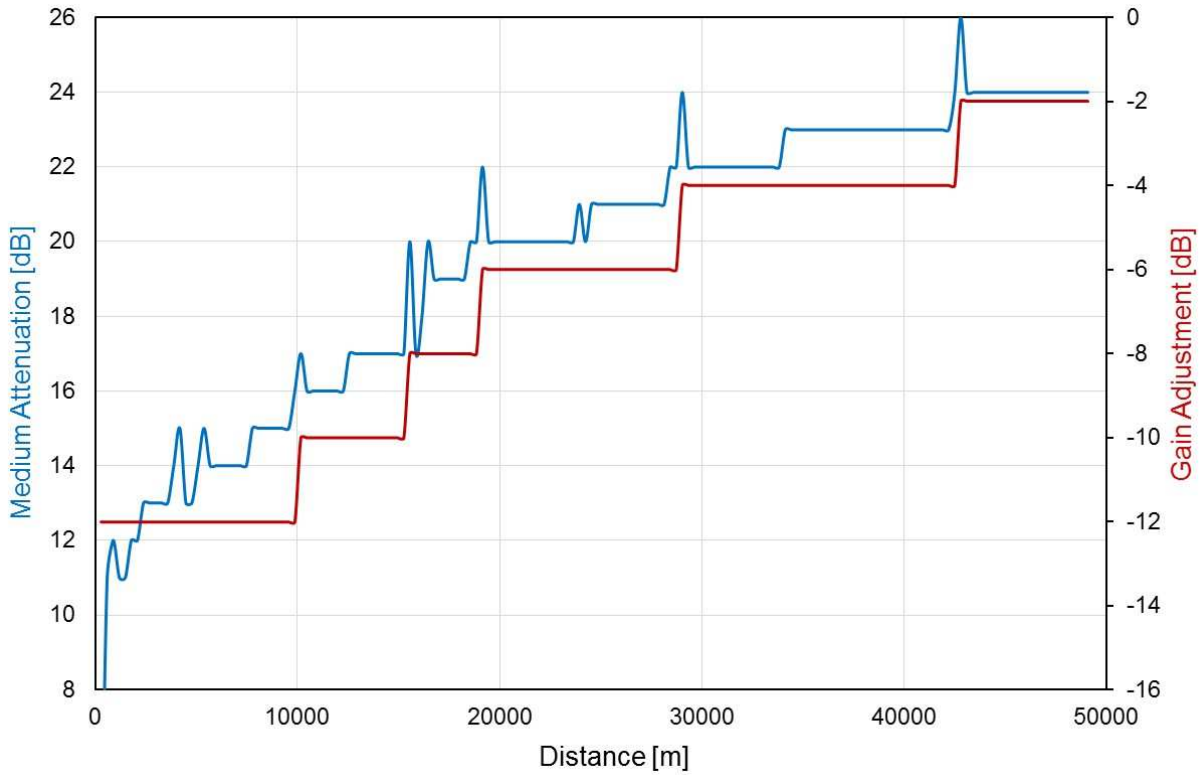


Inspection Geometry



Signal Amplitude vs. Refraction Angle

MEDIUM ATTENUATION
On-Board Recording



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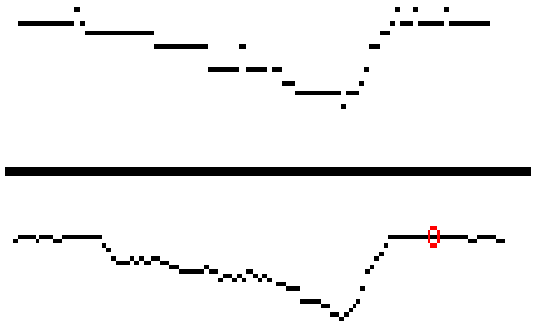
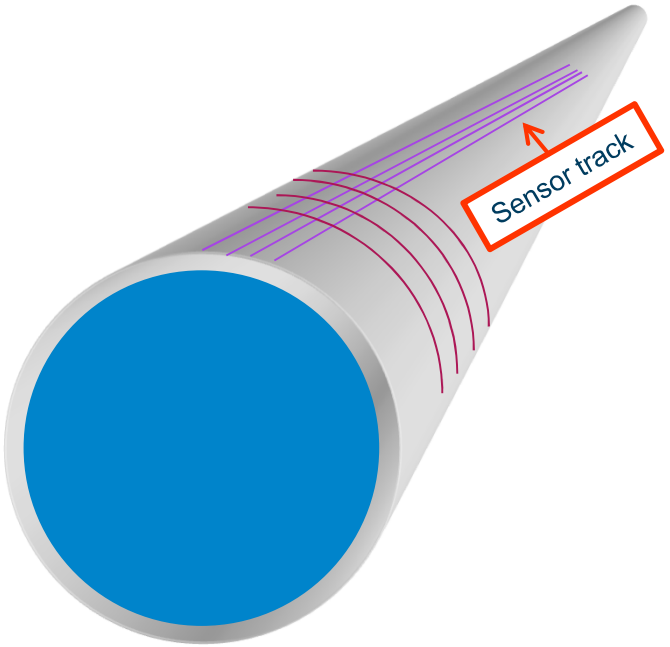
THREE DIMENSIONS OF RESOLUTION

1. **Circumferential Resolution**
   Higher number of sensors

2. **Axial Resolution**
   Shorter Shot Distance

3. **Depth Resolution**
   Larger Data Format

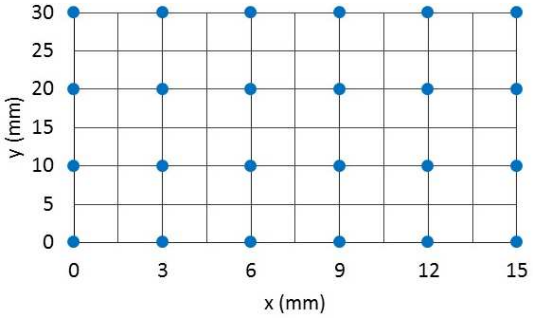




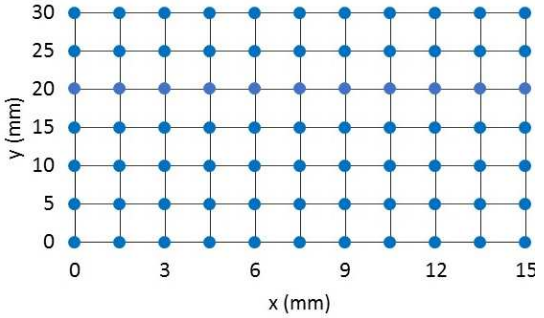
AXIAL CRACK INSPECTION

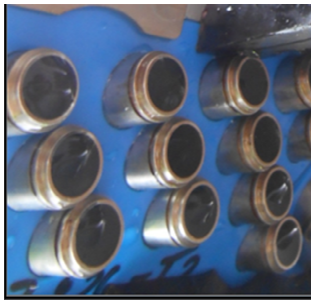
Improvement of Scanning Grid

UC (3mm x 10mm)



UCx (1.5mm x 5mm)

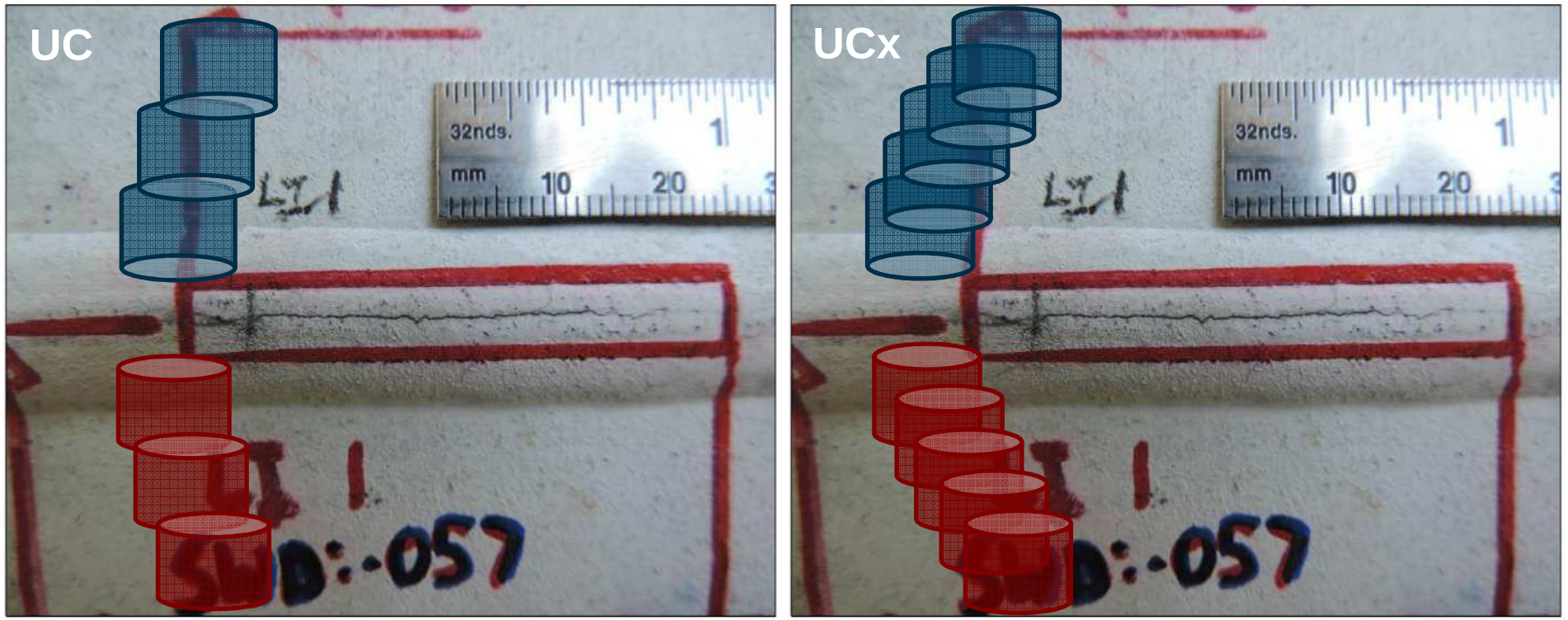




Circumferential direction

Flow direction

IMPROVED CIRCUMFERENTIAL RESOLUTION

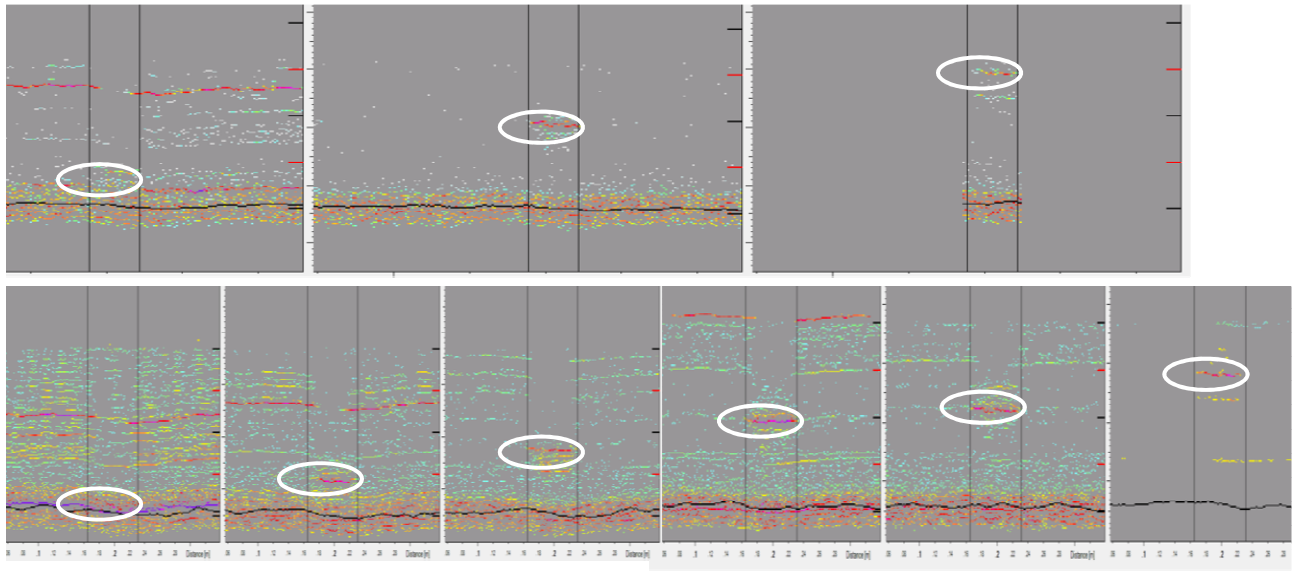


IMPROVED CIRCUMFERENTIAL RESOLUTION

B-scans from two different inspections, same anomaly

RUN 1 (UC)

RUN 2 (UCx)



RESOLUTION & MAX. INSPECTION SPEED

INSPECTION TYPE	AXIAL RES. (mm)	CIRC. RES. (mm)	MIN. LENGTH (mm)	MAX. SPEED* (m/s)
Axial Crack Inspection				
UC	*3.0 / 1.5*	*10*	*25 / 20*	***4.0 / 2.0***
UCx	*1.5*	*5*	*20*	***2.0***
Circumferential Crack Inspection				
UCc	*1.5*	*10*	*30*	***2.0***

at given axial resolution

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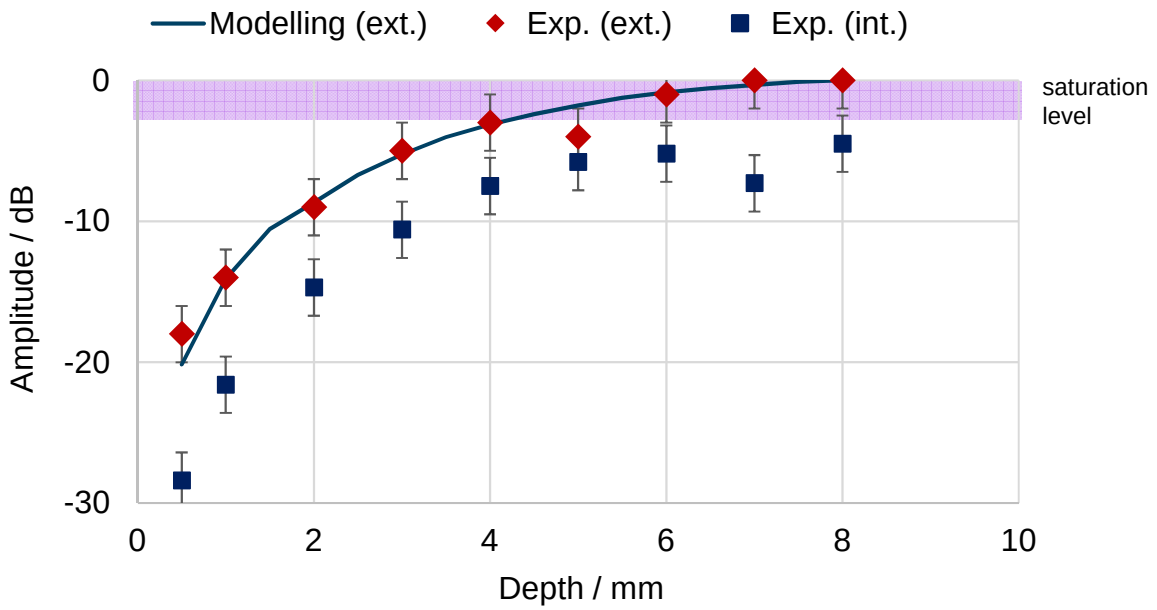
CRACK DEPTH SIZING

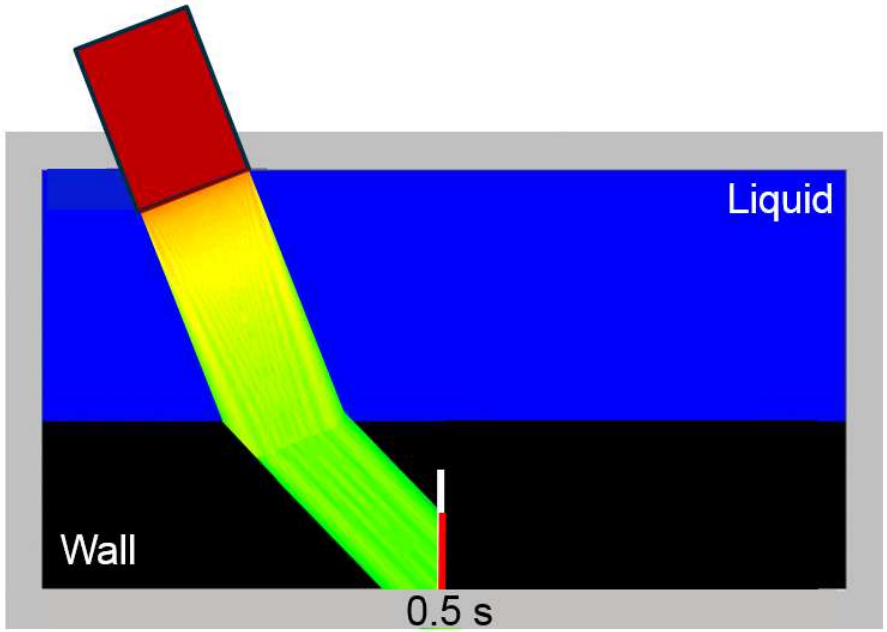
Depth Dependency of Corner Reflection



◆ EDM notches in 10 mm plate

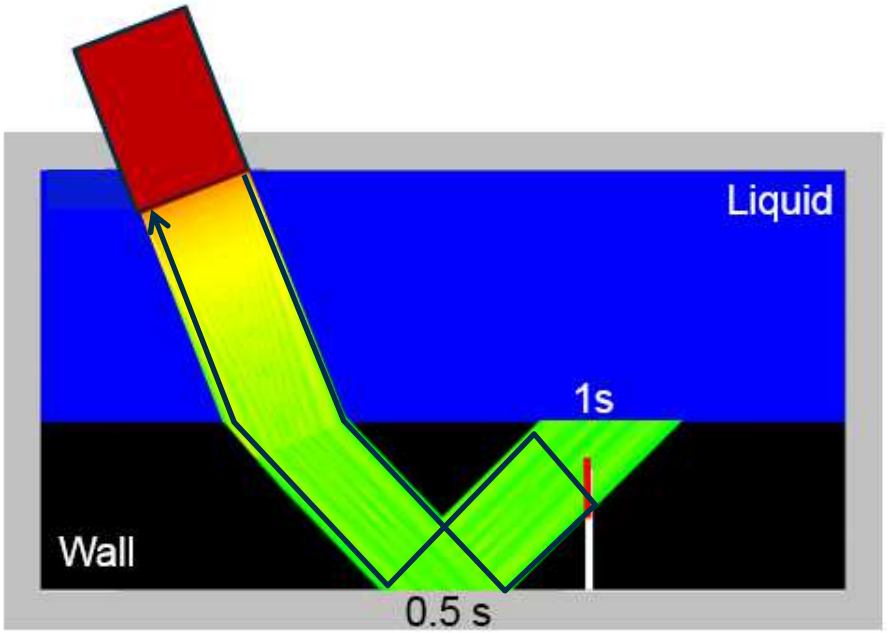
CRACK DEPTH SIZING

Saturation Effect (schematic)



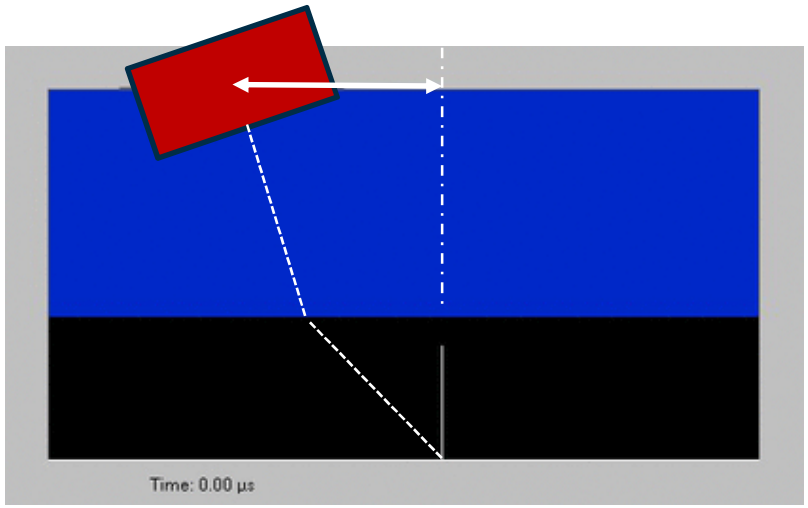
CRACK DEPTH SIZING

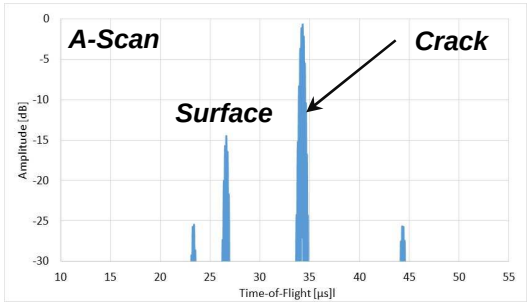
Indirect Signal from External Crack (schematic)

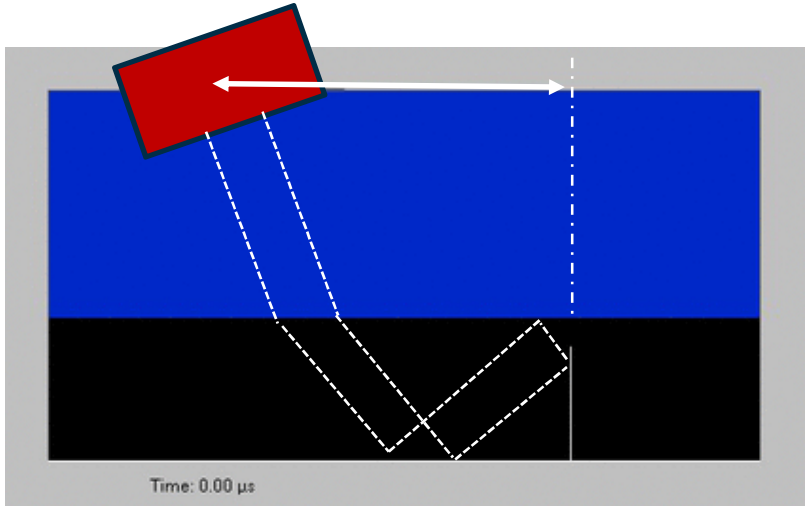


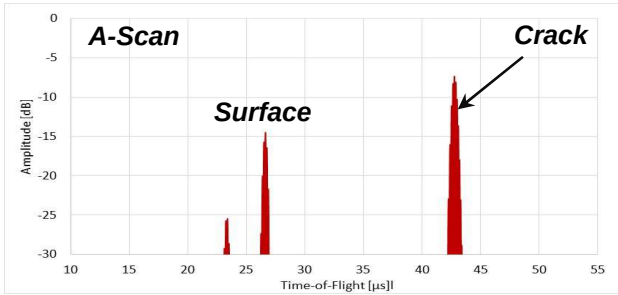
MODELLING RESULT

Corner Echo & Indirect Crack Echo



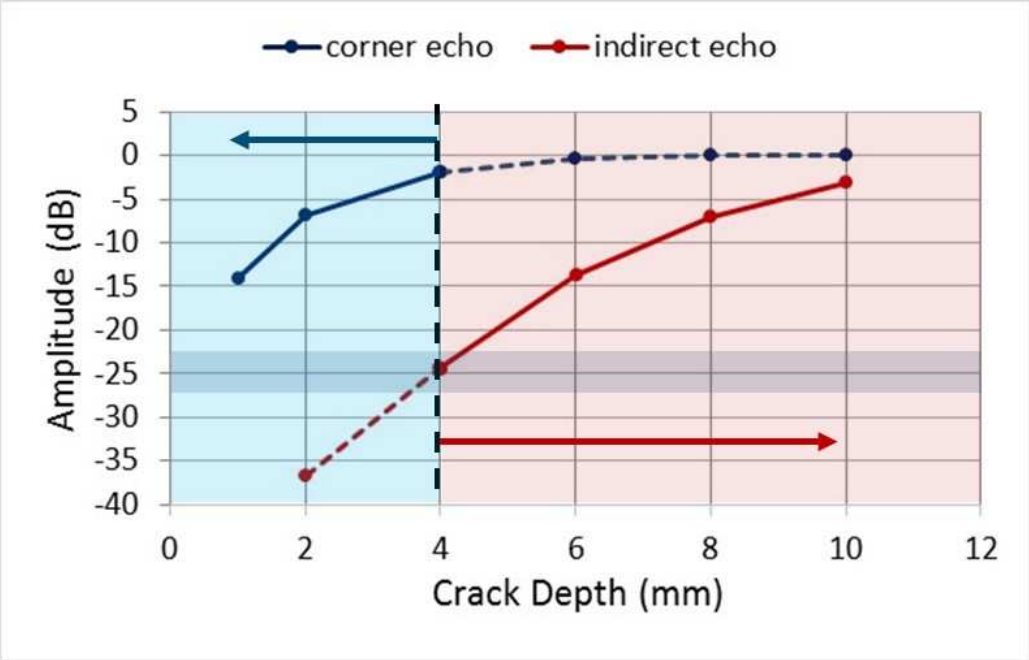






CRACK DEPTH SIZING

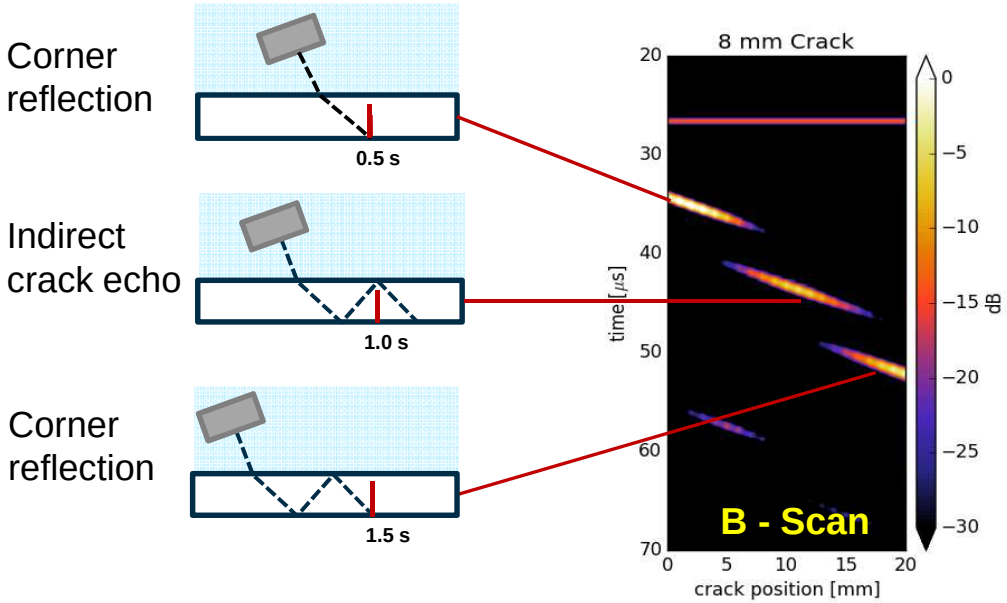
Corner Reflection & ICE Signal (Modelling Result)



10 mm plate

CRACK DEPTH SIZING

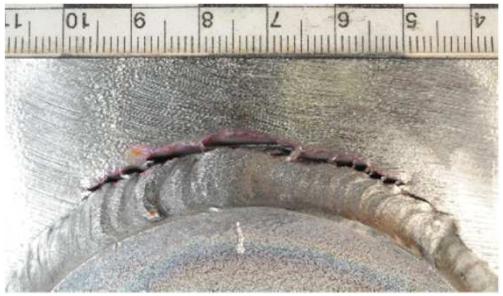
Reflections from External Crack (modelling)



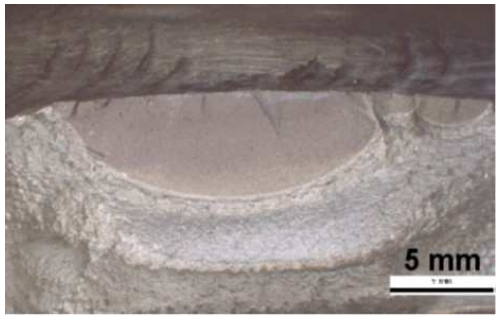
CRACK DEPTH SIZING

Example Circumferential Fatigue Crack

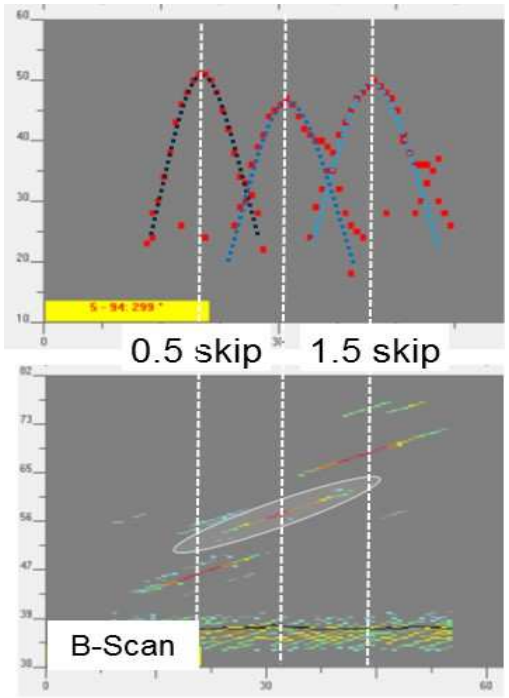
Surface Indication



Cross Section

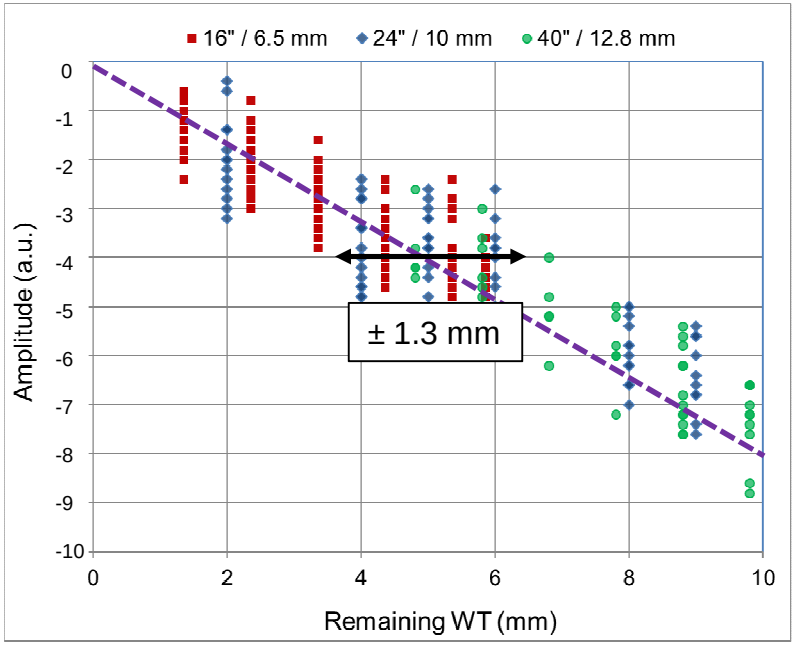


Ultrasonic Signals



CRACK DEPTH SIZING

ICE Signal (Results from Pulltests with UCx)

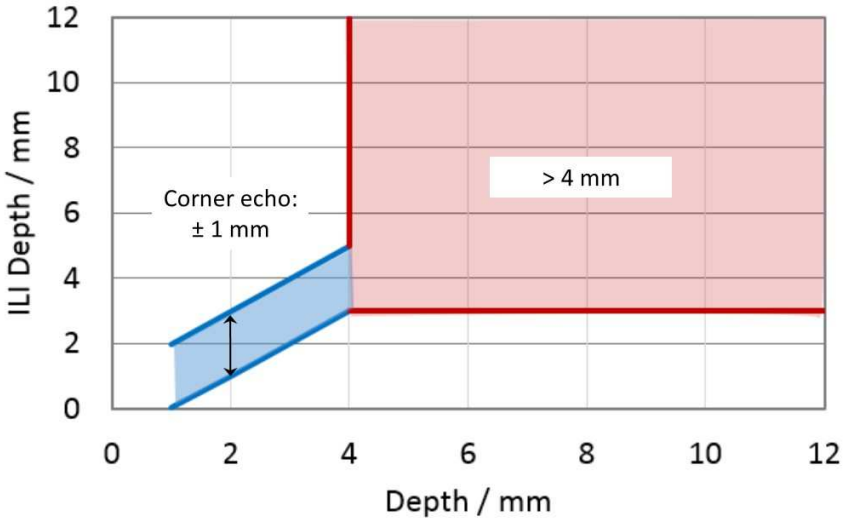


axial crack inspection

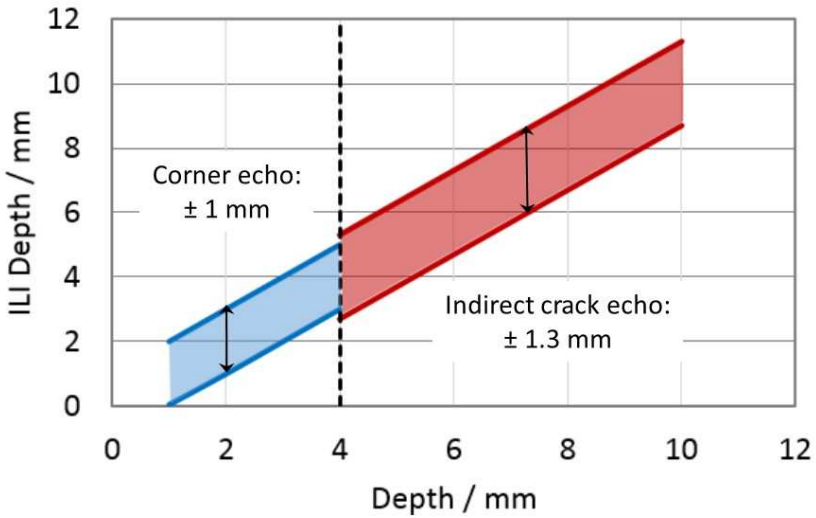
CRACK DEPTH SIZING

Old Specification vs. New Specification (Enhanced Sizing)

old



new



tolerance at 80% certainty: ± 1 mm / 0.04 in respectively ± 1.3 mm / 0.05 in

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SUMMARY

IMPROVEMENT	BENEFIT
Enhanced axial resolution	• *More detailed crack profiles* • *Smaller minimum crack length*
Enhanced circumferential resolution	• *Increased POD & POI* • *Reduced risk of incomplete coverage* • *More accurate maximum reflection amplitude*
Increased inspection speed	• *Reduced costs by avoiding loss of throughput during inspection run* • *Less operational interference*
Enhanced depth sizing	• *Full wall coverage of crack depths* • *More accurate and less conservative crack assessment* • *Reduction of excavation costs*
Online monitoring of medium properties	• *Reduced risk of failed run due to change of medium properties during inspection* • *Better data quality by adaptive signal gain*