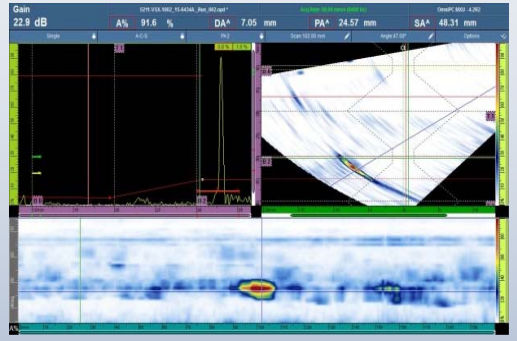
NDT in Canada NDTIC 2017 Canada's NDT Conference | June 6 - 8 Centre des congrès de Québec Québec City, Québec

WELD PENETRATION MONITORING USING PAUT FOR ORTHOTROPIC DECKS & STRUCTURAL BOXES



DALY SOUISSI B.ENG., M.SC.

NUCLEOM
INNOVATION • INTEGRATION

Presentation overview

- Introduction
- Standard/client specification
- PAUT description
- Inspection methodology
- Validation
- Encoding
- Reporting
- Conclusion

Weld penetration monitoring alternatives

- Destructive testing (Macro etch testing): Involves sectioning and/or breaking the welded section.
- Conventional UT: Several limitations (Poor beam coverage, unreasonable inspection time, subjective interpretation, etc.)
- **Phased Array UT: Large beam coverage, recordable data, multiple views, repeatability, etc.**

Introduction

Scope:

Canam Bridges requested Nucleom services for the determination of the weld penetration on PP in two different projects.

Ribs to deck assembly: The top part of the orthotropic steel deck.

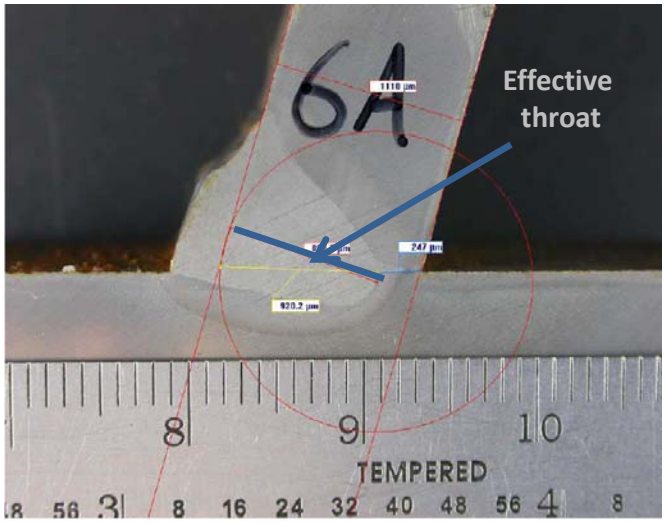
Structural boxes: Components of BMO Field's roof support beams (Toronto).

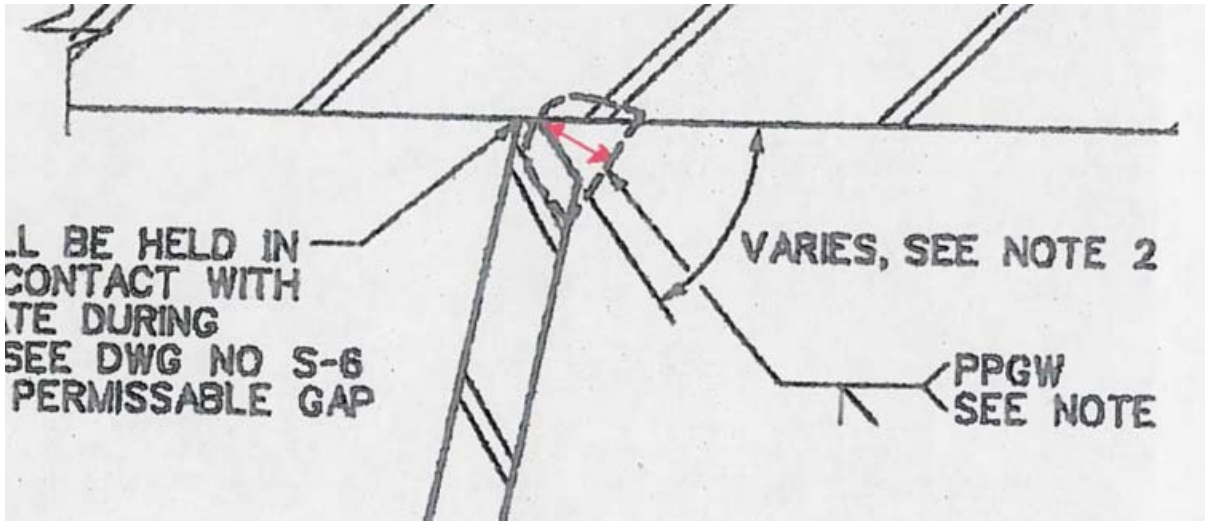
Ribs to deck assembly
(Canam, Quebec)

Roof support beams
(BMO Field, Toronto)

Joints description:

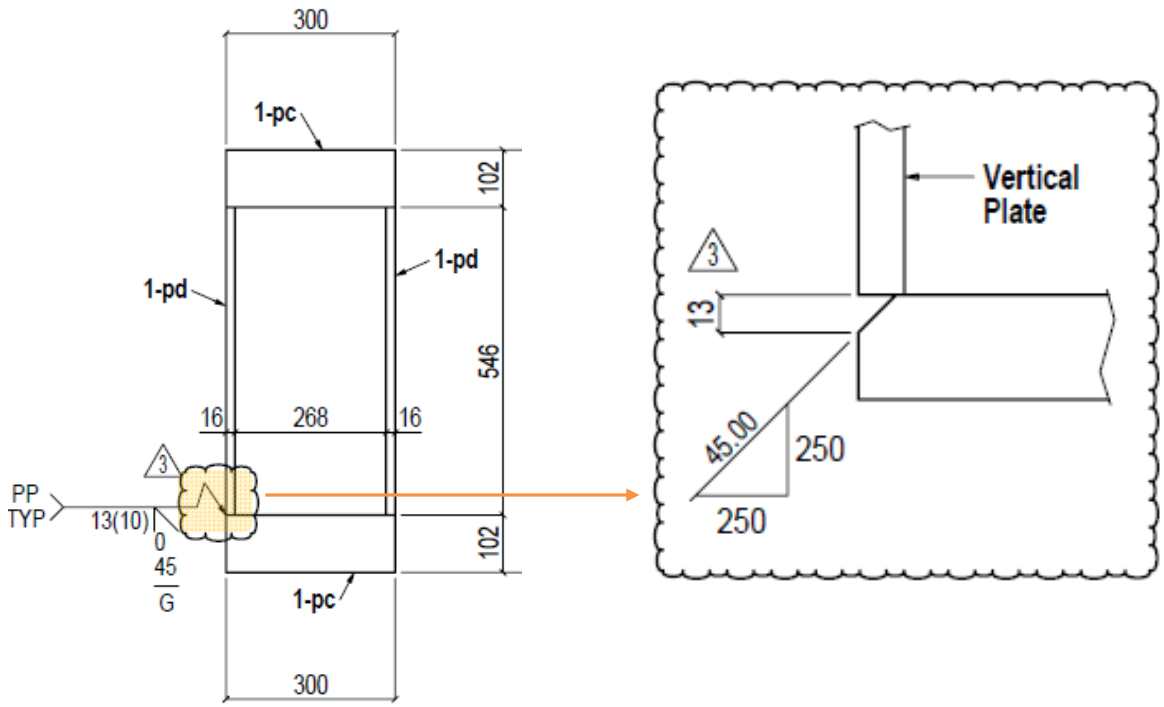
Ribs are connected to the deck with a PP welding prepared in half V (connexion angle within 60°-80°). Rib's wall thickness and its connection angle to the deck may vary depending on client and project specifications.





Joints description:

Boxes are fabricated using 4 panels with two different thickness. Panels are connected with half V PP L joints. Preparation is done on the thicker panel.



Rib Welding AASHTO 9.8.3.6.2 june 2012

LRFDUS-6-E1: June 2012 Errata to LRFD Design

SECTION 9: DECKS AND DECK SYSTEMS

9.8.3.6.2—Closed Ribs

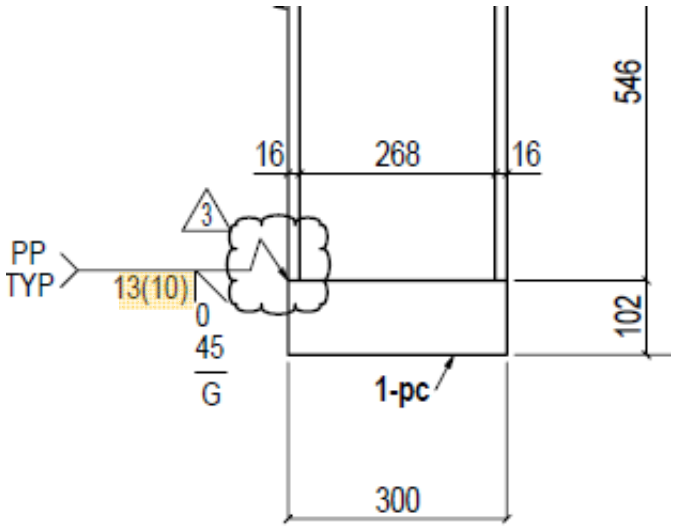
The one-sided weld between the web of a closed rib and the deck plate **shall have a target penetration of 80 percent, with 70 percent minimum** and no blow-through, and shall be placed with a tight fit of less than 0.02 in. gap prior to welding.

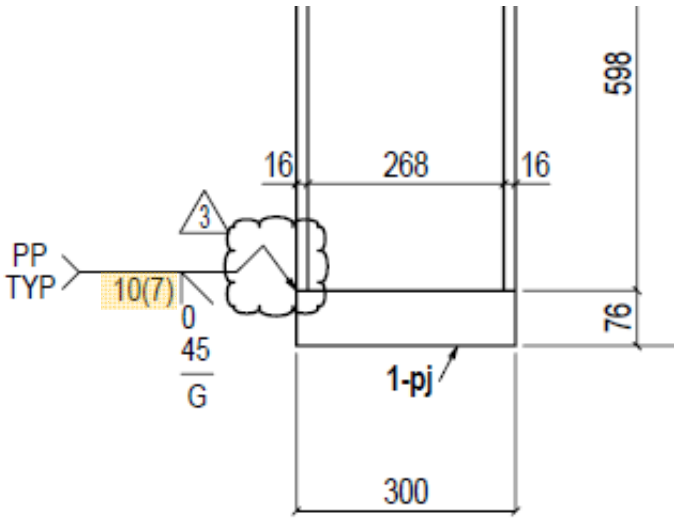
C9.8.3.6.2

Historically,
specified as a or
minimum 80 perce
80 percent pene
difficult and fabri

Client specification:

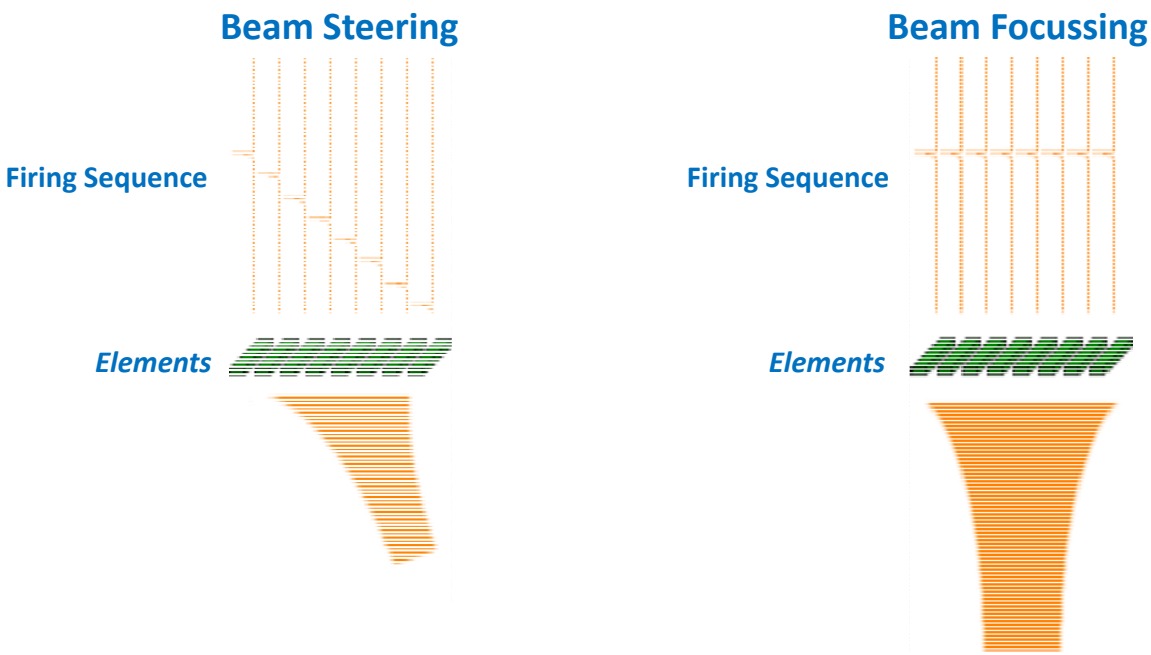
For each type of boxes, the client welding engineering department required a specified penetration. For example: for preparation of 10mm, The effective throat should be 7mm at minimum.





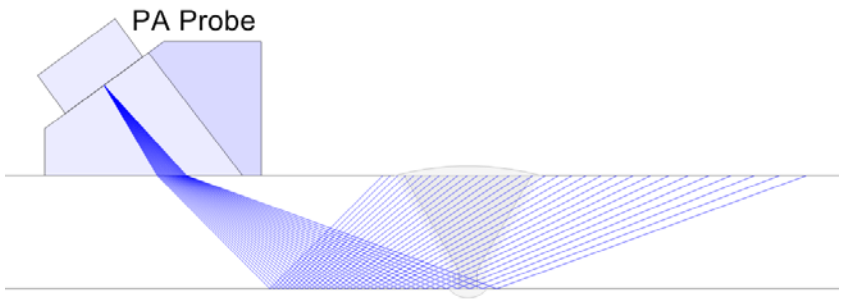
Definition (PAUT = Phased Array Ultrasonic Testing)

- A mosaic of piezoelectric elements where the timing of each pulser/receiver excitation can be controlled electronically and independently
- The same physical principles than conventional UT apply

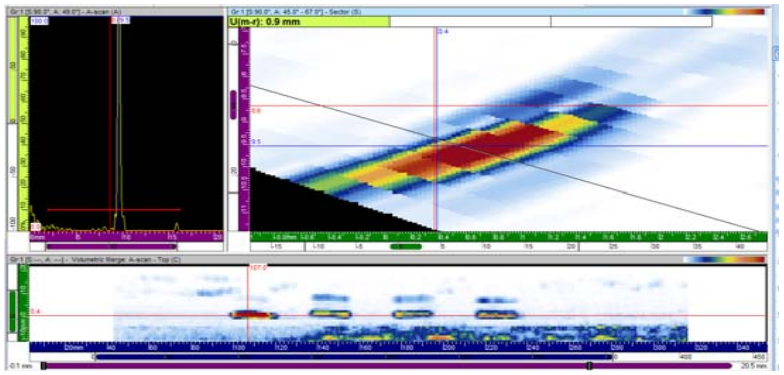


PAUT technology

- A number of ultrasonic beams is fired at the same time at different angles (e.g. 45°-70°).

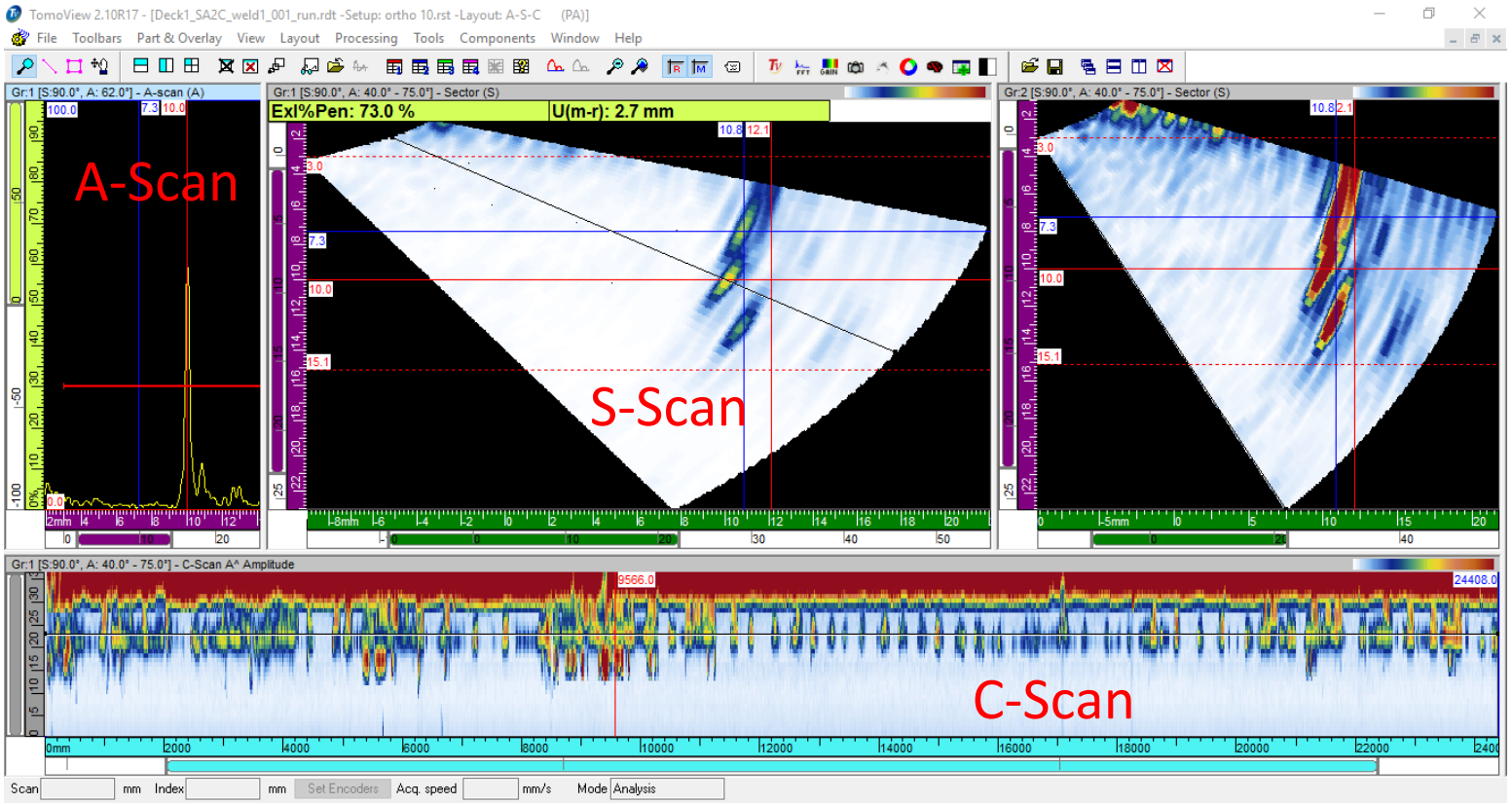


- Encoded inspection allows recording data along the scan for further analysis and verification. Different views are generated, A-Scan, S-Scan, C-Scan etc.



PAUT Introduction

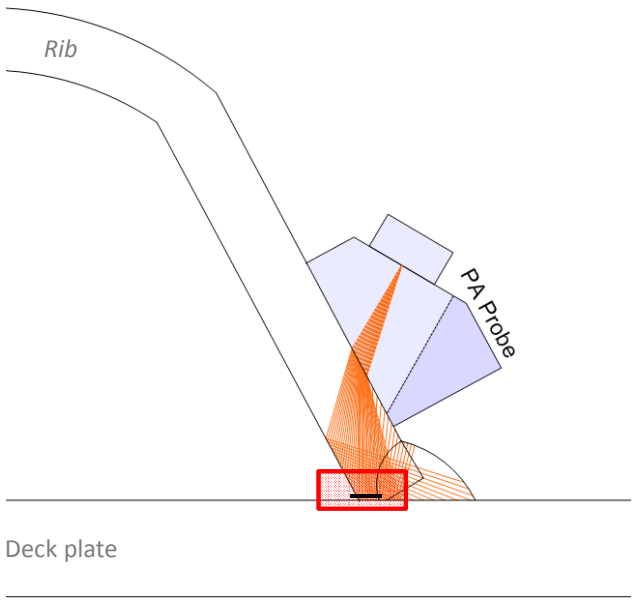
Main Views



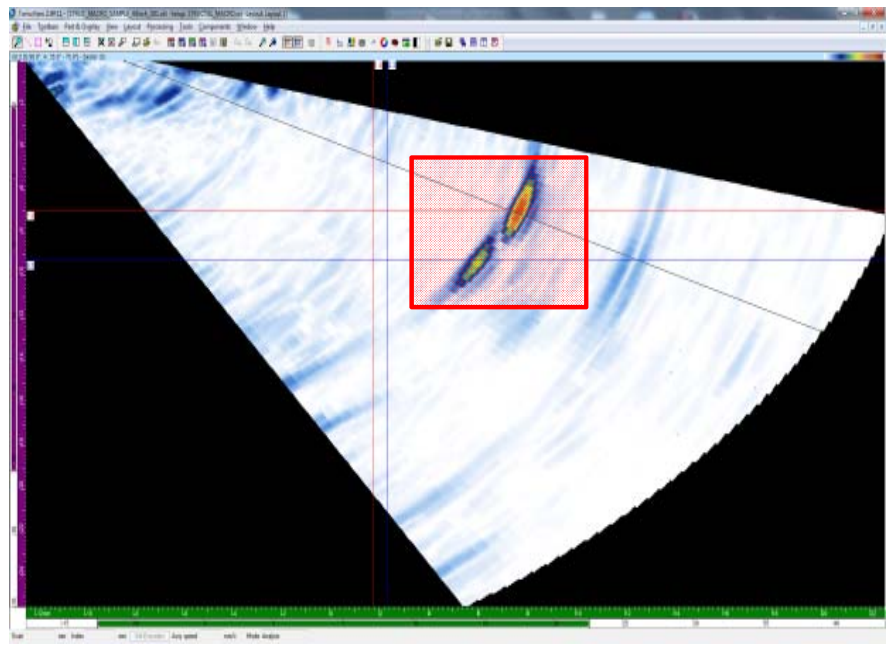
(TomoView screenshot)

PAUT scan plan (weld coverage strategy)

Orthotropic Deck



Suggested Scan Plan (ES Beam, Civa, etc.)

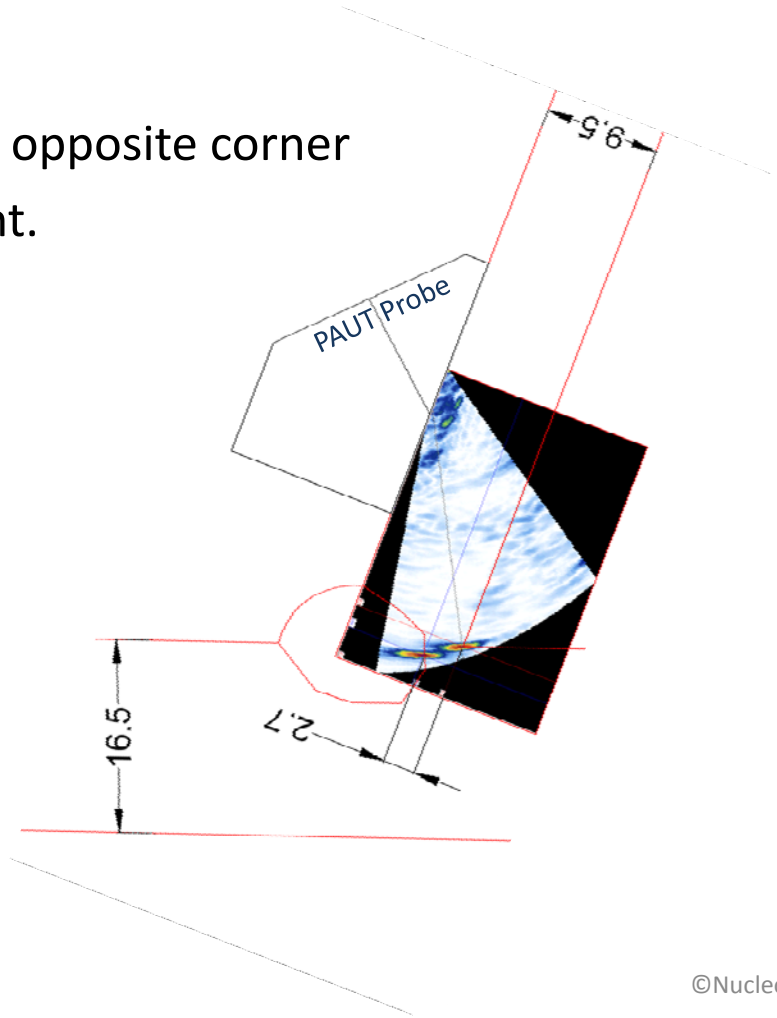


Resulting Sectorial scan (S-Scan View)

Inspection methodology

PAUT technique

- The probe is positioned so as to be able to detect the opposite corner and the upper tip of the non-fused portion of the joint.
  - The height from the corner to the upper tip represents the non-fused section of the weldment.
  - The **<u>percentage of non fused area</u>** is this height divided by the thickness of the plate.

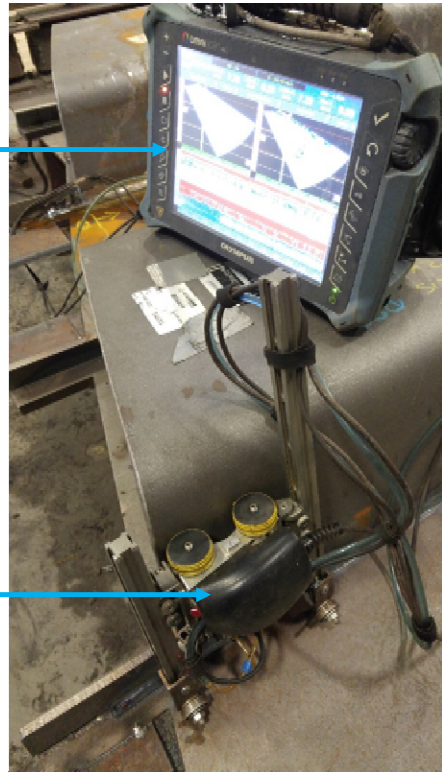


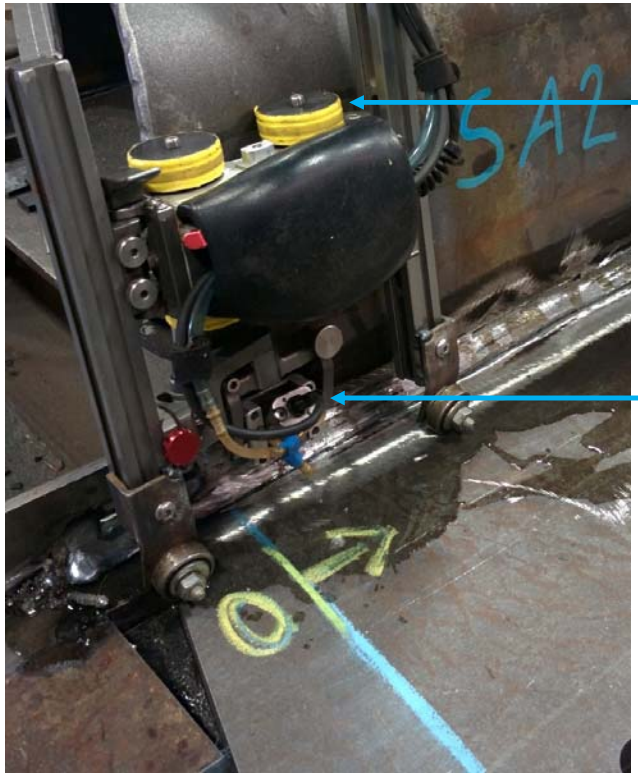
Inspection methodology

Equipment

PAUT unit

Scanner buggy



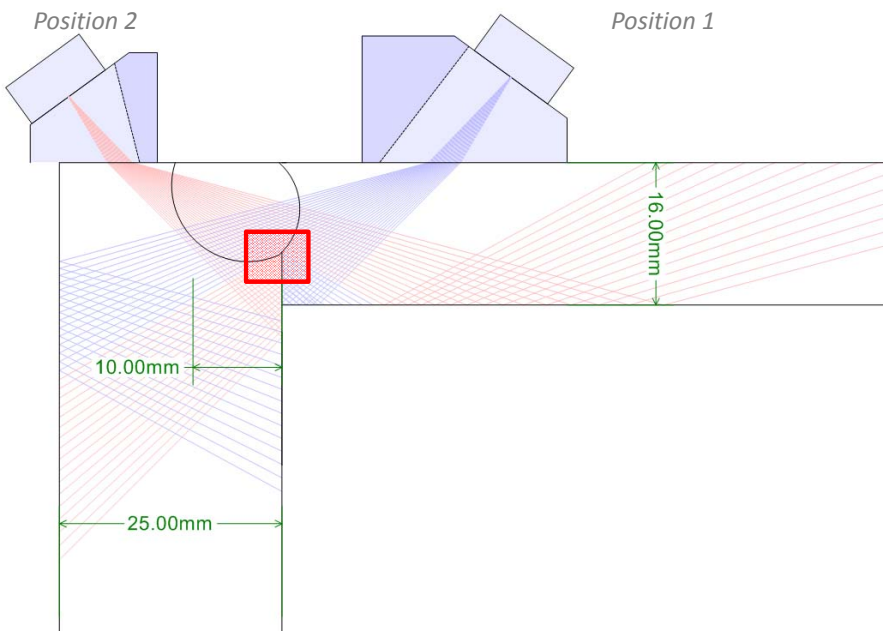


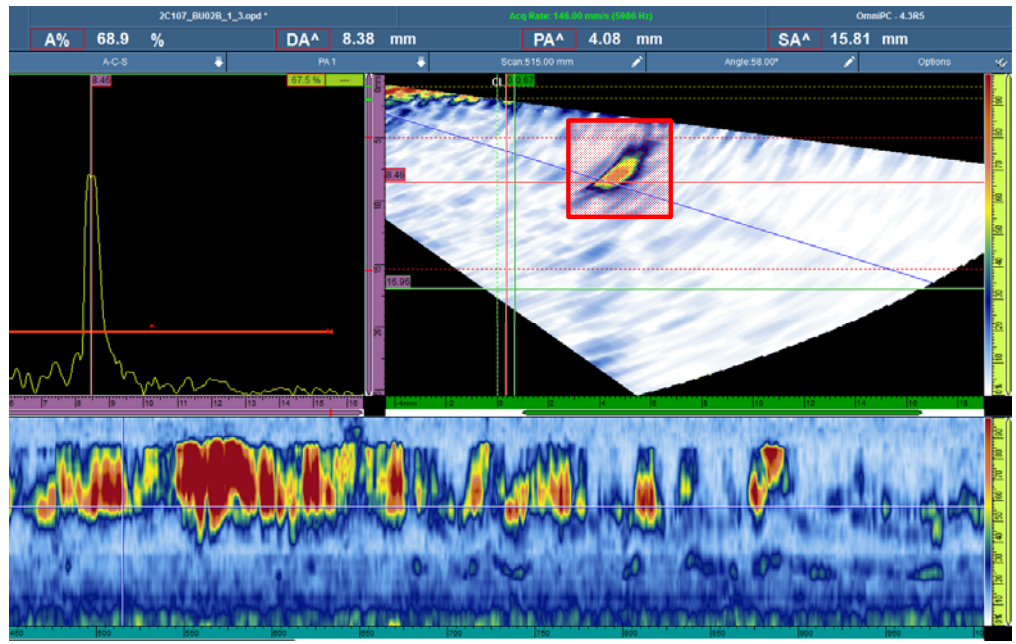
Magnetic wheels

PAUT probe/wedge

PAUT scan plan (weld coverage strategy)

Structural Boxes





Suggested Scan Plan (ES Beam, Civa, etc.) Deck plate

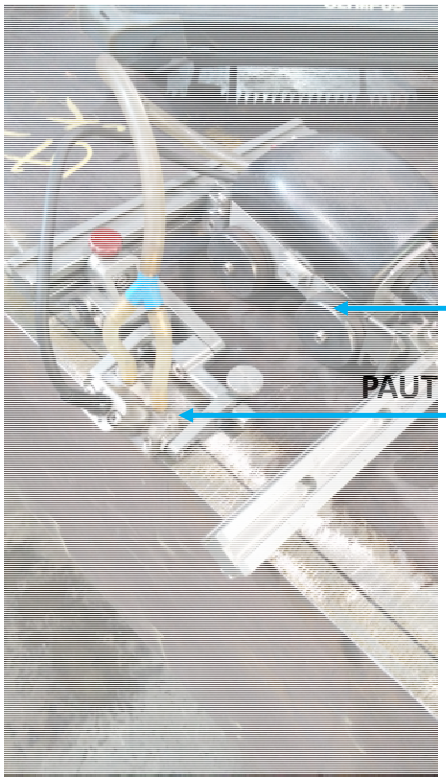
Resulting Sectorial scan (S-Scan View)

Inspection methodology

Equipment

Scanner buggy

PAUT unit



Magnetic wheels

PAUT probe/wedge

Validation
(orthotropic deck project)

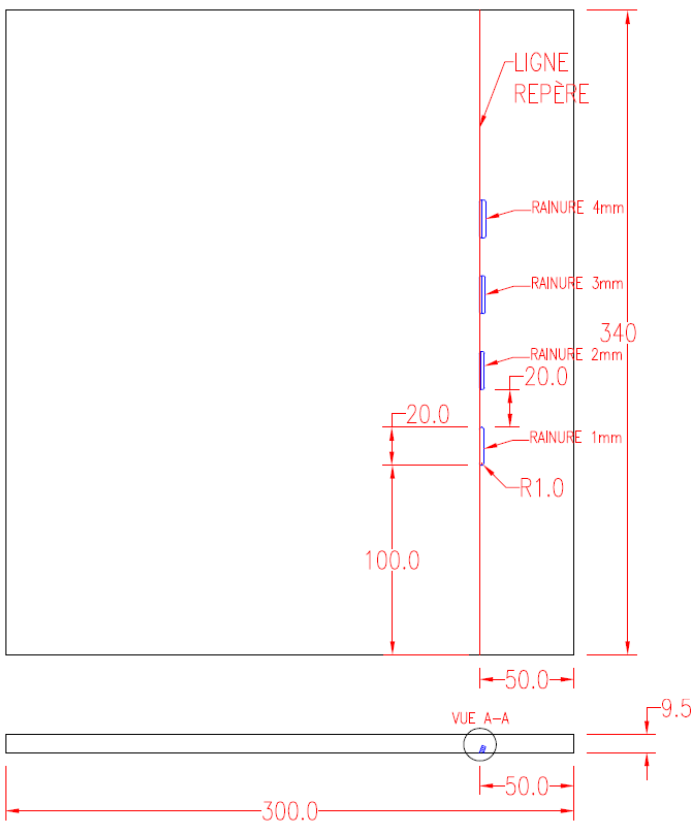
Demonstration Block

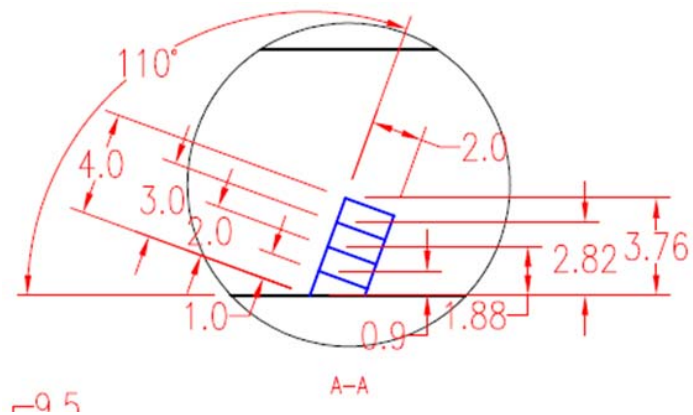
4 notches machined at different depths

Validation
(orthotropic deck project)

Demonstration Block configuration

Non fusion simulation: 4mm, 3mm, 2mm and 1mm

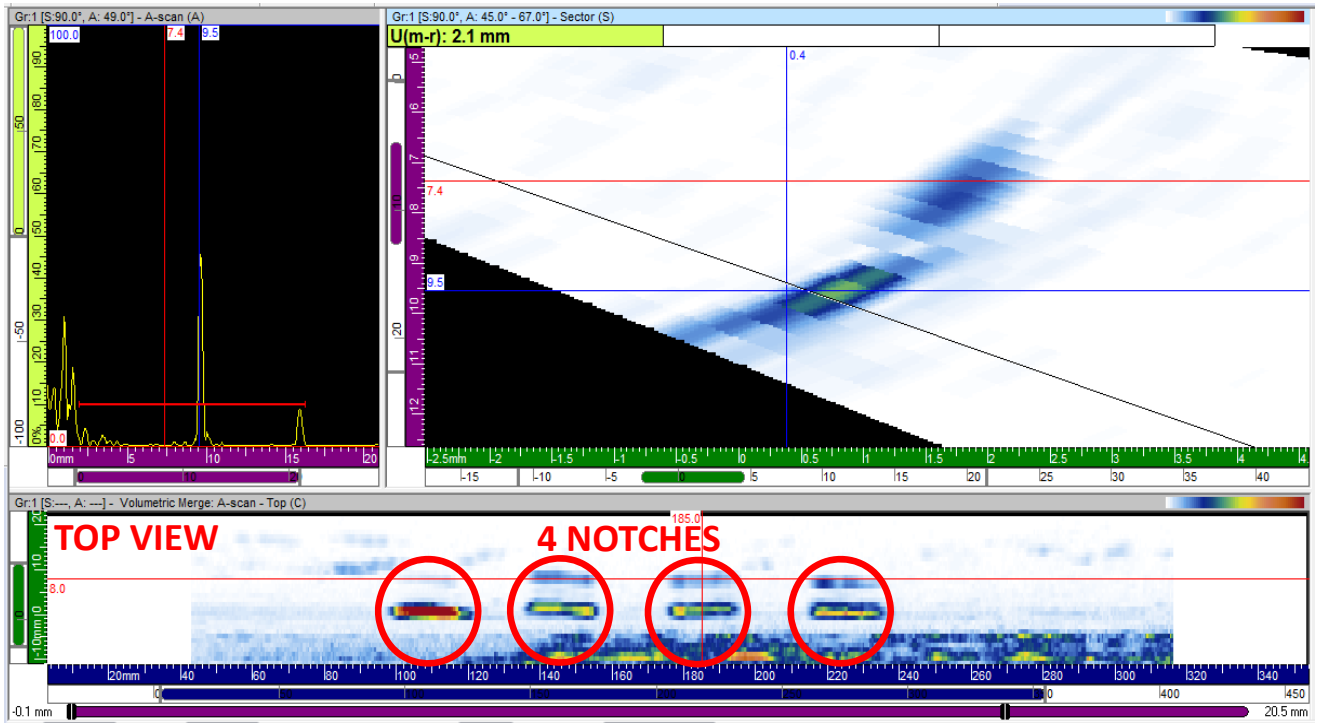




Validation
(orthotropic deck project)

Resulting data

The 4 indications are clear along the C-Scan. S-Scan and A-Scan are used for a complete characterization.



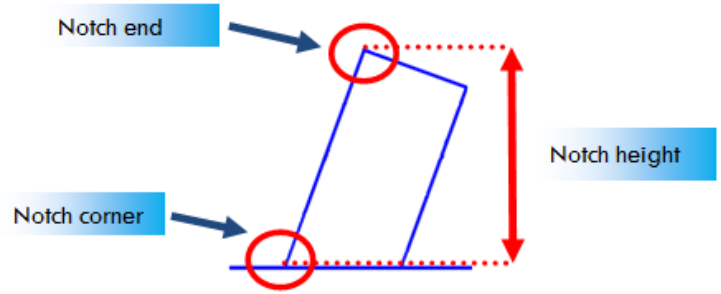
Validation
(orthotropic deck project)

Detailed results

- Accuracy of ±0,1mm for notch height measurements
  - ➡ (approximately ±1% for weld penetration for a 9,5mm thick plate)

NOTCH SIZING

Notch	Notch corner (PA) (mm)	Notch end (PA) (mm)	Notch height (PA) (mm)	Simulation for percentage of penetration (%)	Height measured by metrology (mm)
1mm	9.5	8.6	0.9	91	0.8
2mm	9.5	8.0	1.5	84	1.5
3mm	9.5	7.4	2.1	78	2.2
4mm	9.5	6.4	3.1	67	3.0



SKETCH FOR NOTCH SIZING

Validation
(orthotropic deck project)

Validation with Macro Etch tests

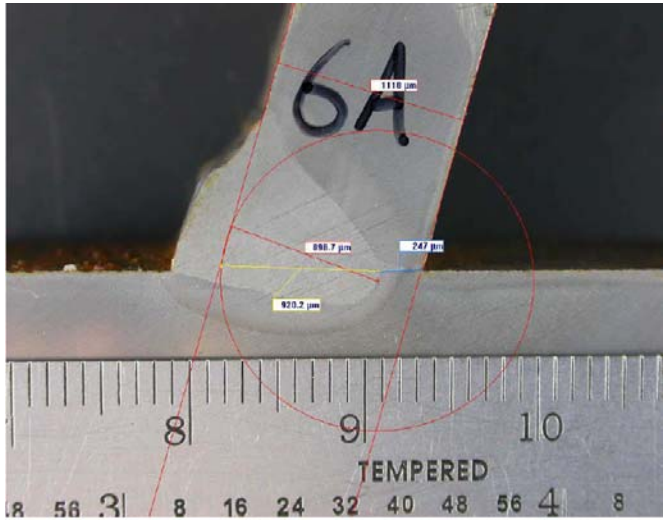
Validation sample with 5 selected position

Validation
(orthotropic deck project)

Measurements validation

Results show a maximum difference of 0.3 mm then ± 3% in accuracy.

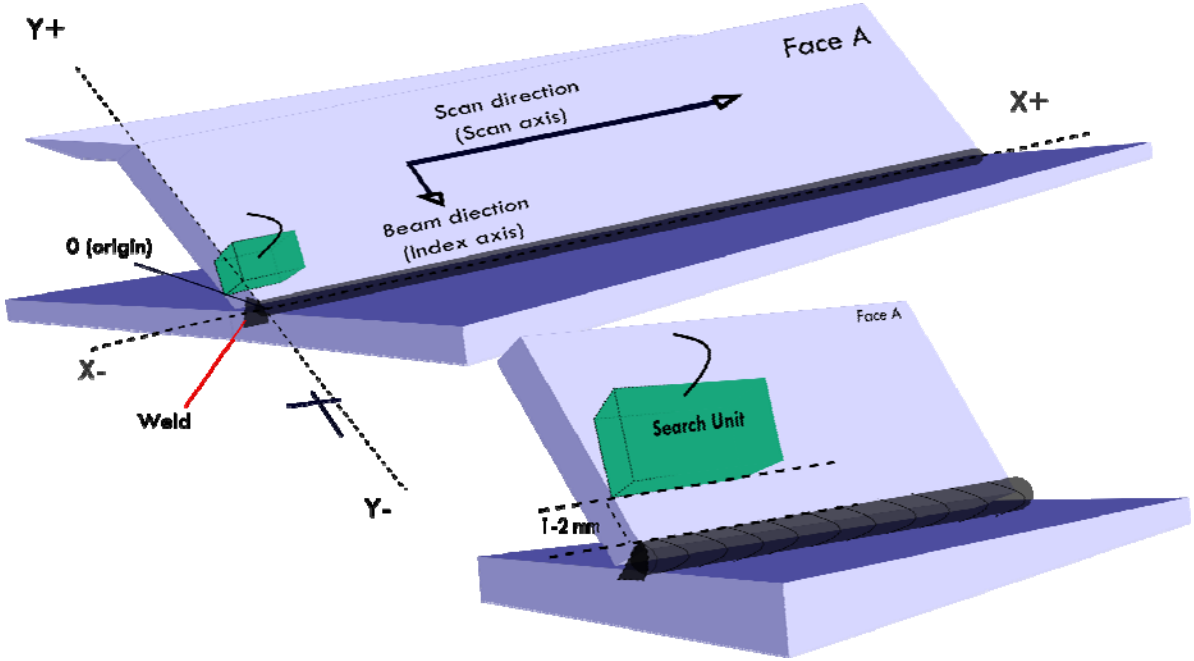
Section #	Scan position (mm)	PAUT Measurement		Macro Etch testing	
		Non fused area mm	% of penetration	Non fused area mm	% of penetration
1	102	1,1	88	1,2	87
2	402	2,6	72	2,6	72
3	574	2,7	71	3	68
4	810	2,8	70	2,9	69
5	1043	2,3	75	2,3	75



Encoding

Scanning pattern

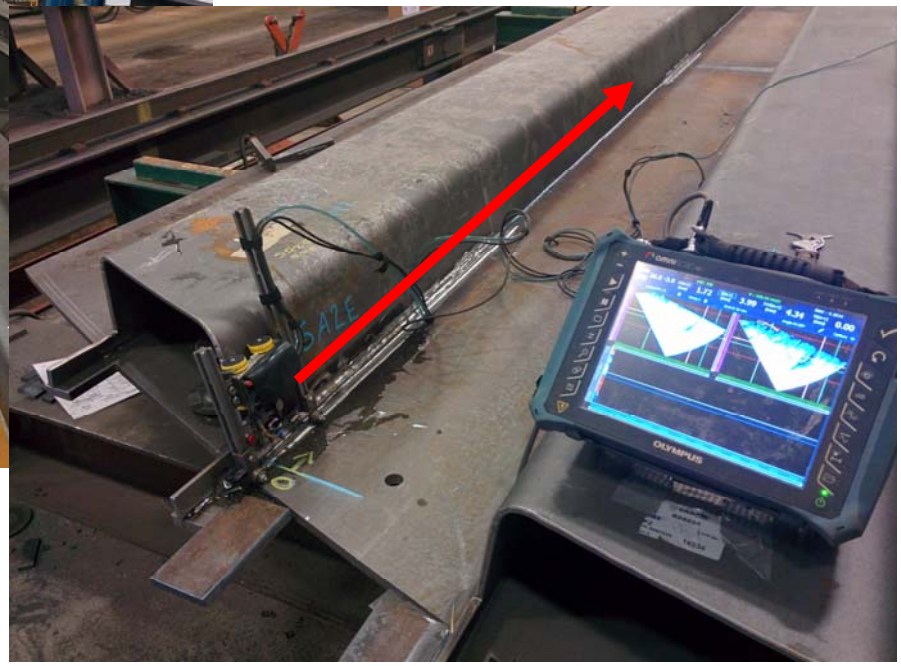
- Probe is moved with an encoded scanner
- PAUT data is saved every 1 millimeter (0,040in)
  - Percentage of weld penetration is available for each position on the weld



PAUT data acquisition

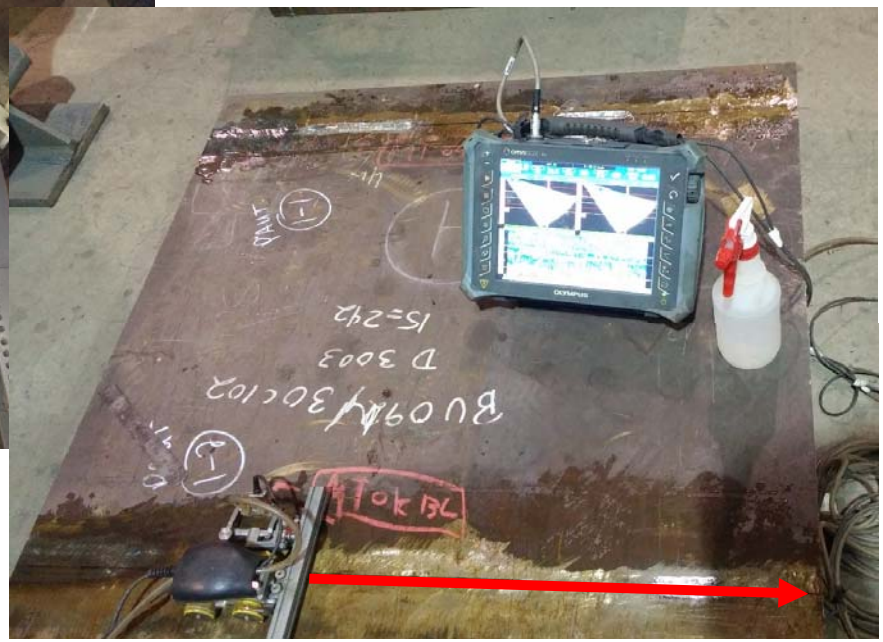
Important parameters to set

- Scan Resolution
- Scan Speed
- Data Size



Encoding

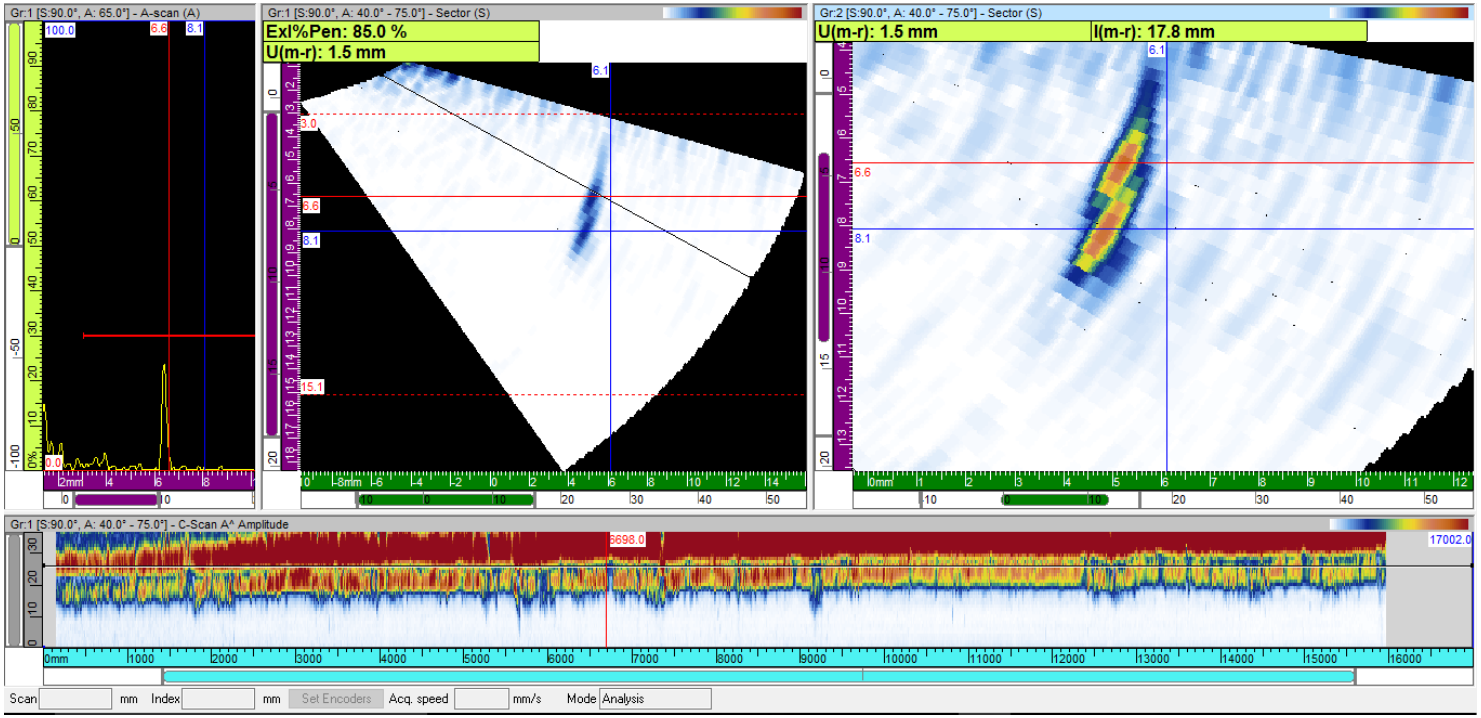
Scanning pattern



PAUT data acquisition

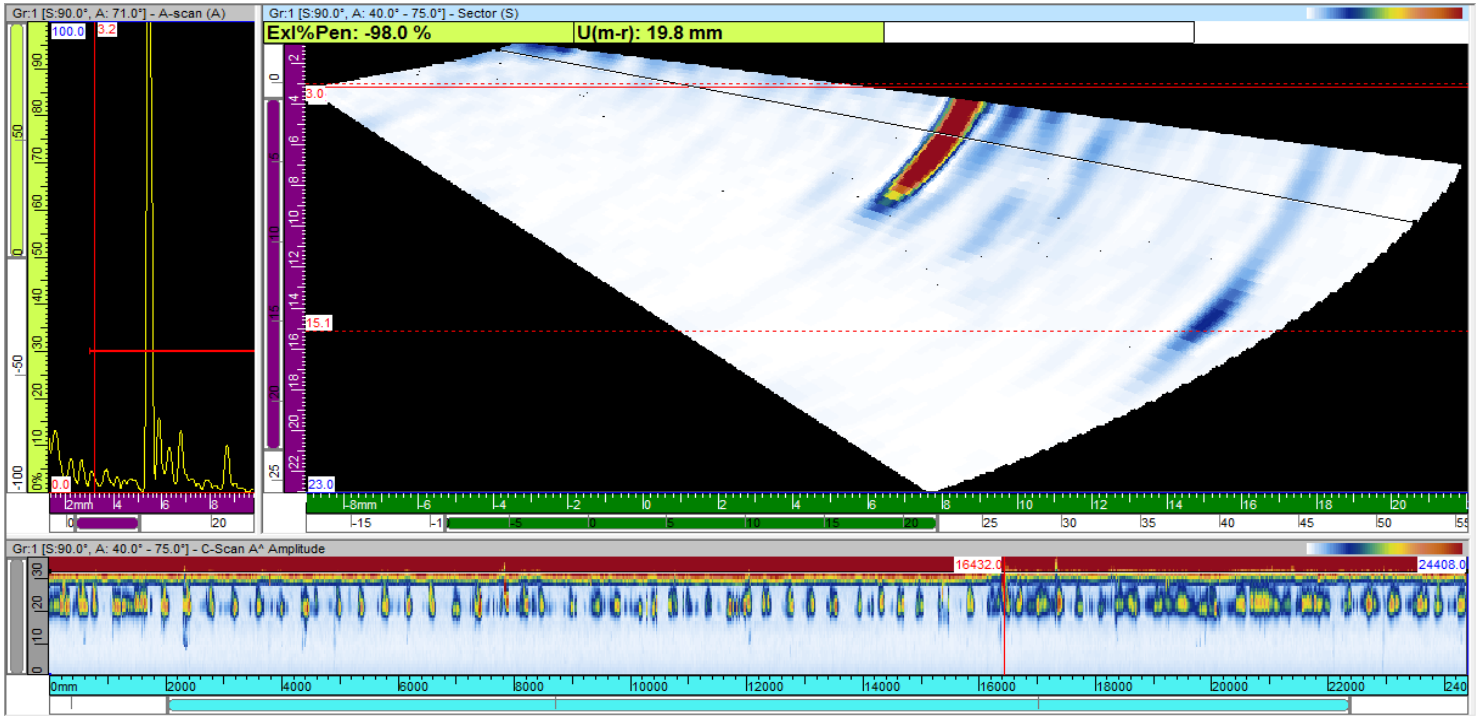
Interpretation

PAUT data analysis
Orthotropic Deck



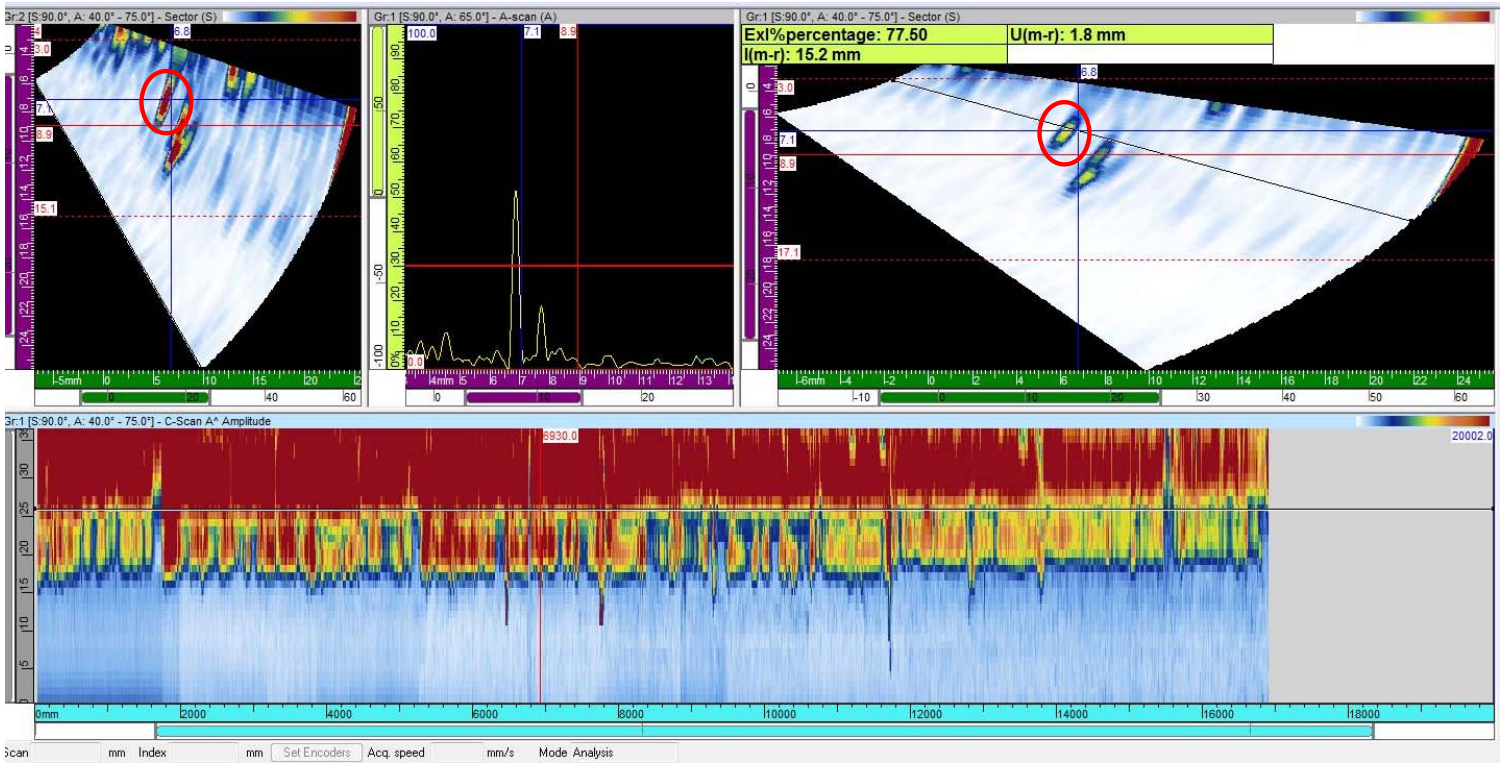
Interpretation

PAUT data analysis
Orthotropic Deck



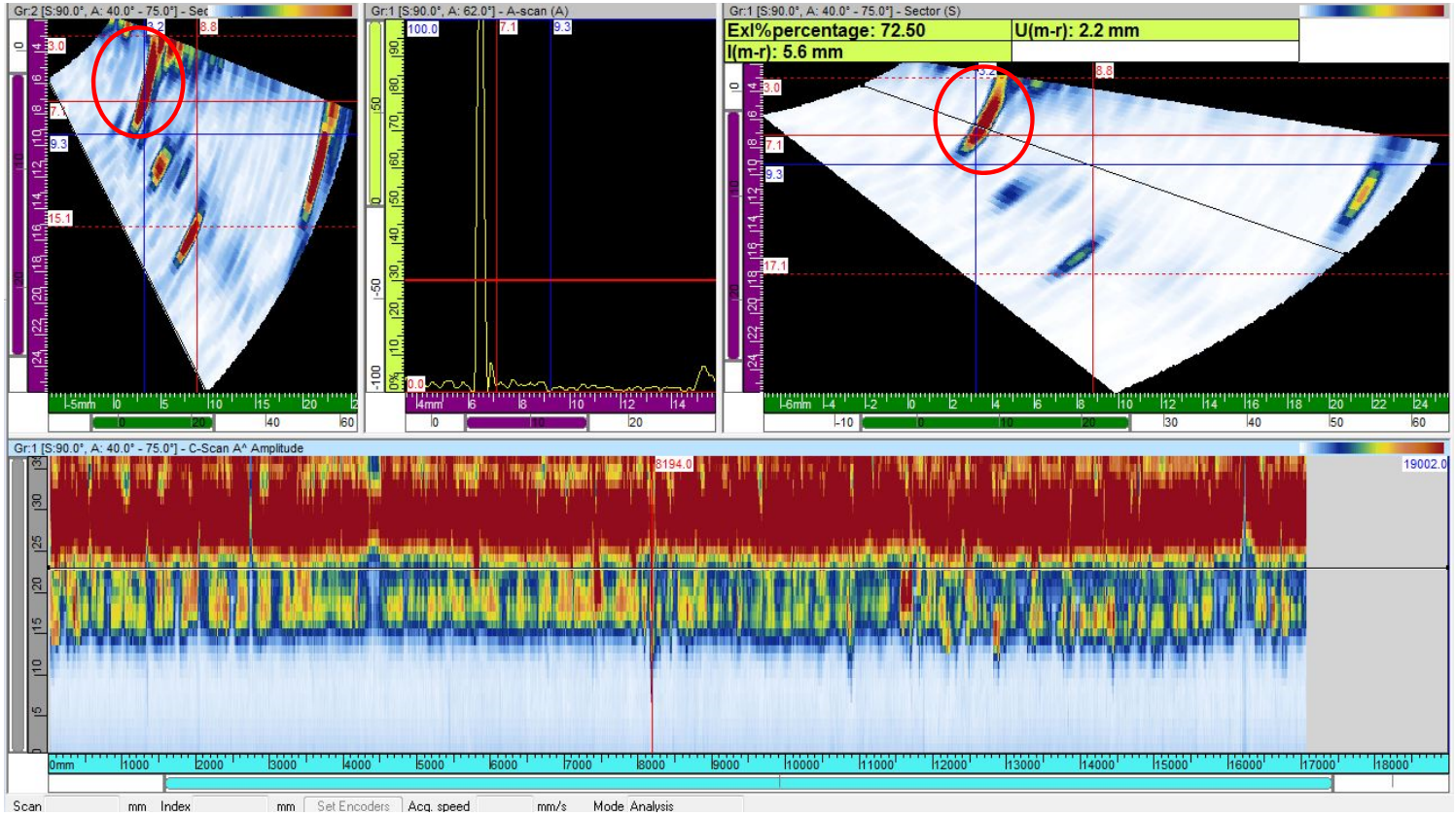
Interpretation

PAUT data analysis
Orthotropic Deck



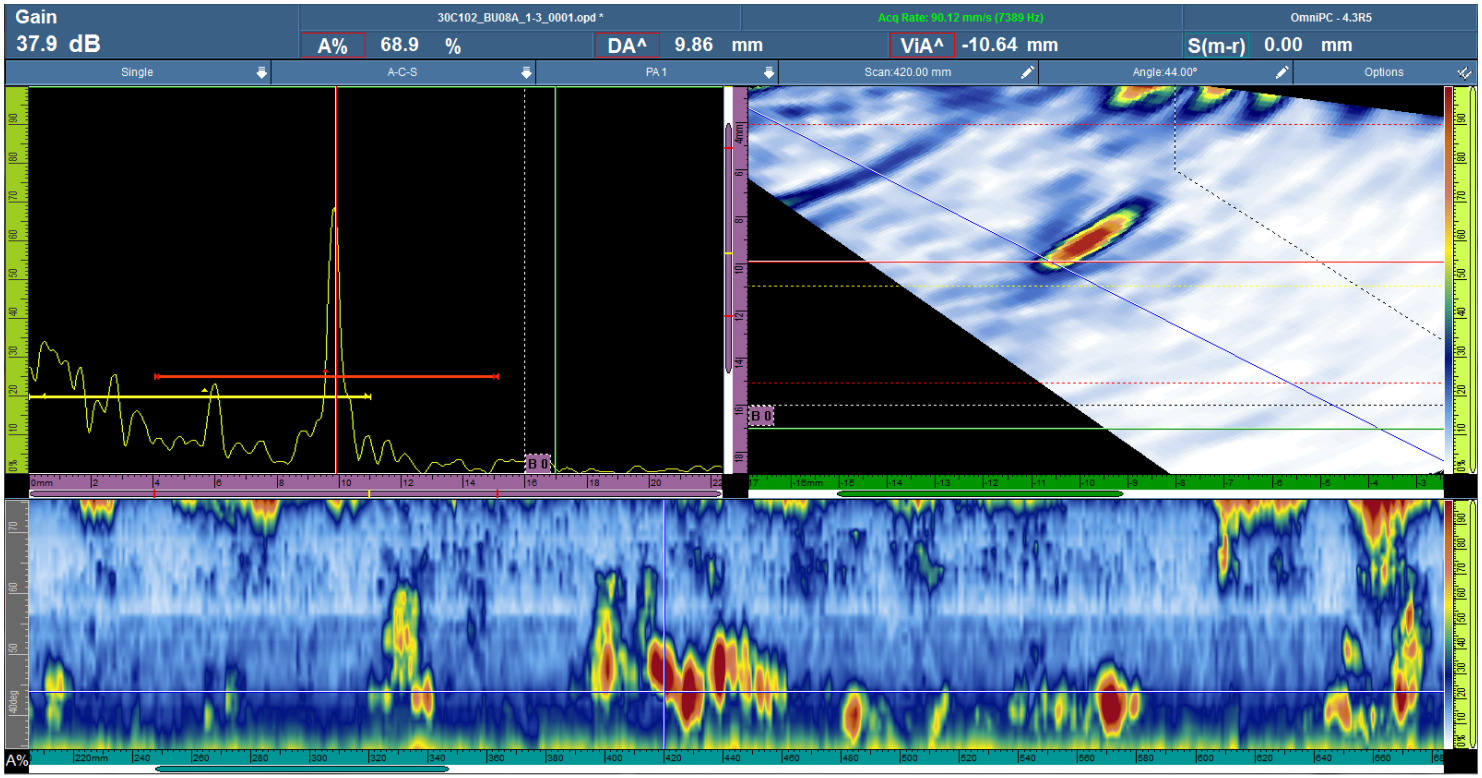
Interpretation

PAUT data analysis
Orthotropic Deck



Interpretation

PAUT data analysis
Structural Boxes



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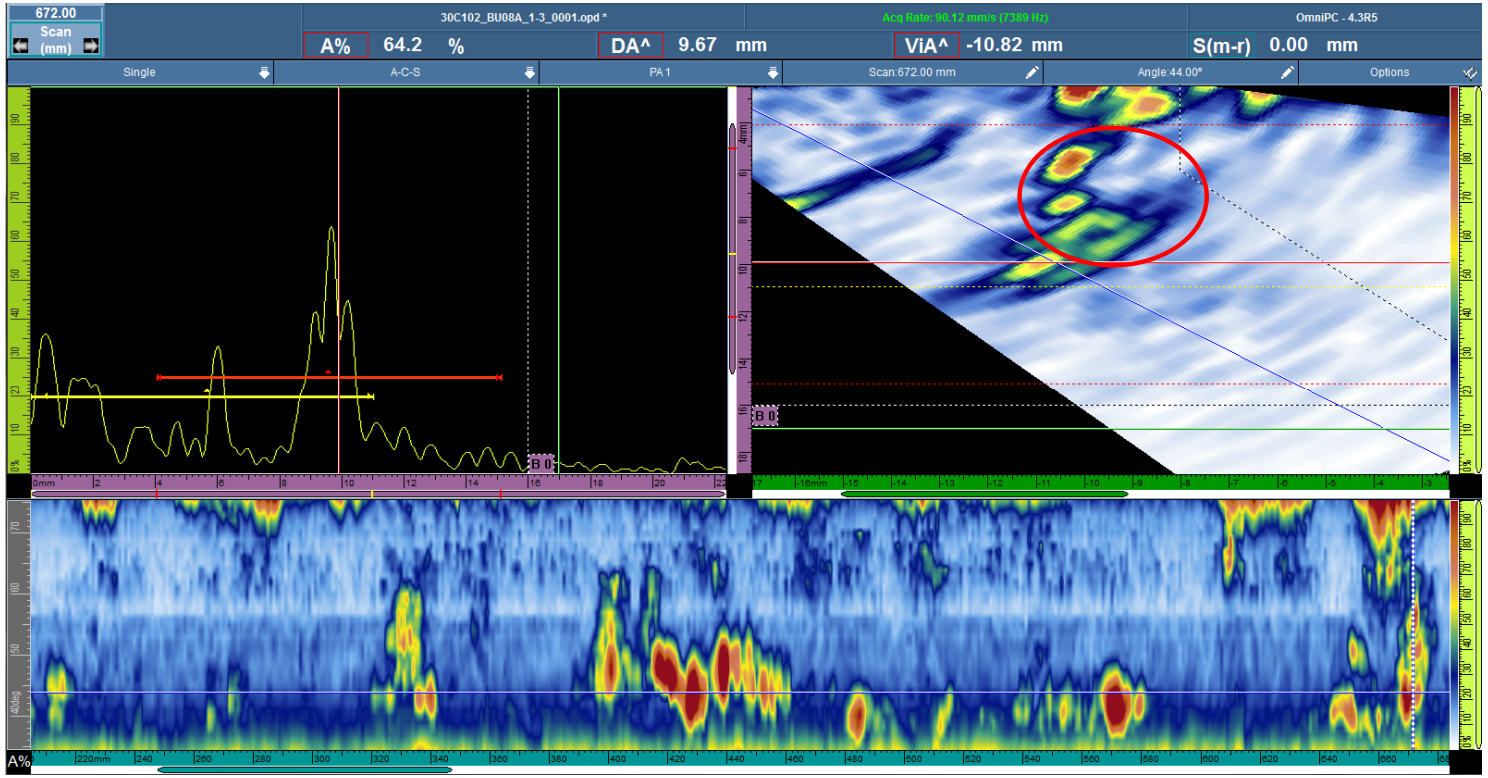
Structural Boxes



Interpretation

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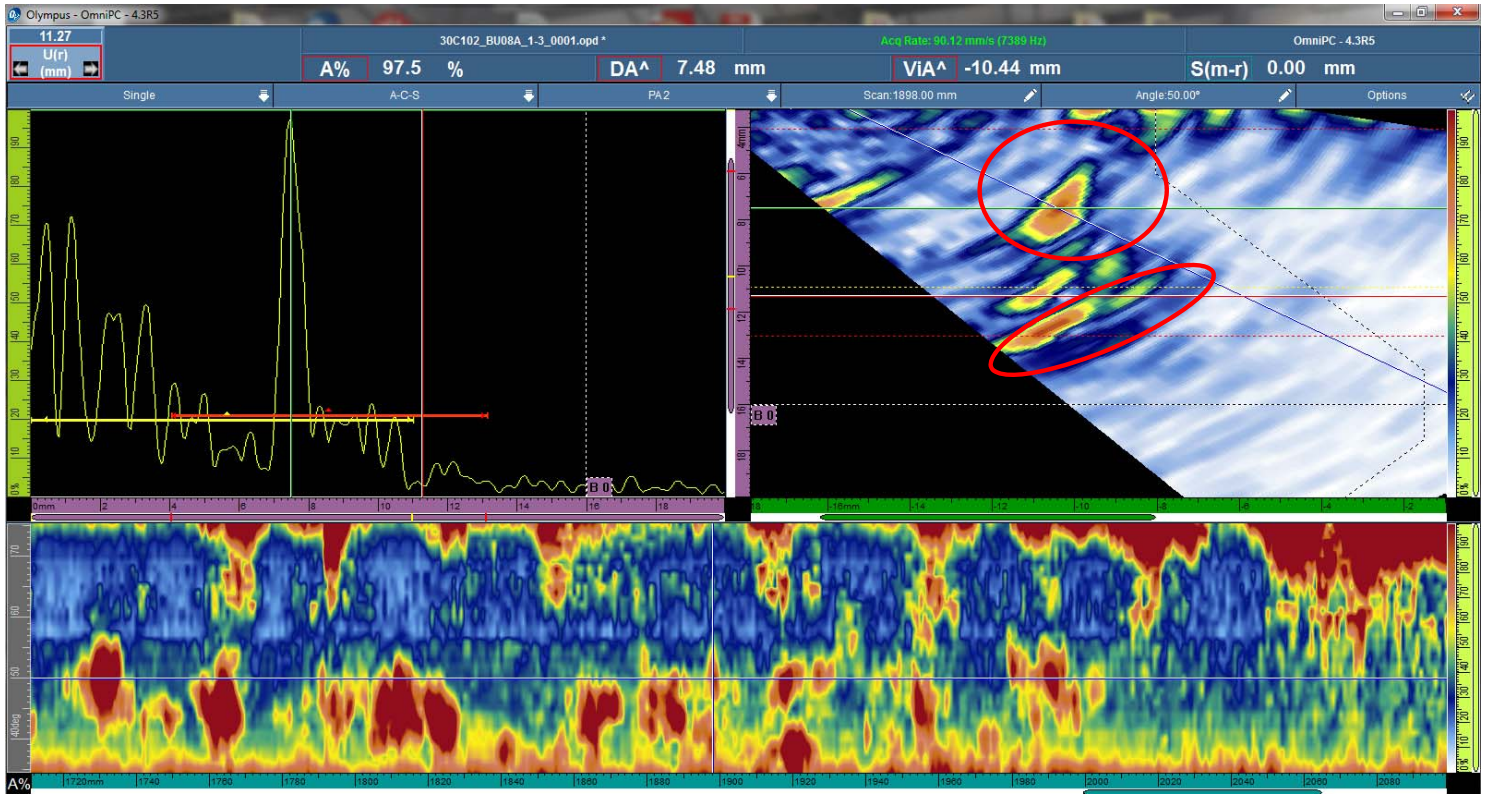
Structural Boxes



Reporting

Inspection report example
Orthotropic Deck

NUCLEOM
INNOVATION • INTEGRATION

PAUT REPORT
RAPPORT No./Report no.: Q14-7138-019 rev0

CLIENT/Customer:	Structol-Ponts inc.	COMMANDE/Order:	
ADRESSE/Address:	1445 rue du Grand Tronc Québec (Québec), G1N 4G1	No. CONTRAT/Job no.:	
		RÉFÉRENCE/Reference:	
RESPONSABLE/Responsible:	Annik Rochefort, Ing.	PROJET/Project:	

PHASED ARRAY ULTRASONIC INSPECTION

DESCRIPTION/Description:

Mesure du pourcentage de pénétration de la soudure entre l'auge et le tablier (pièces constituant le tablier orthotropique) tel que spécifié (voir section résultats).

DONNÉES TECHNIQUES/Technical data:

SOUDURE/Weld		CONFORMÉMENT À/In accordance with		TRANSDUCTEUR/Transducer	
MATÉRIEL/Material:	Acier au carbone	NORME/Code:	n/a	MARQUE/Mark:	Olympus 5L16-A10
TYPE/Type:	pénétration partielle	SECTION/Section:	n/a	MHz:	5 MHz
PRÉPARATION/Prep.:	Demi V			1 DIMENSIONS:	16 ele. (9.6x10)
PROCÉDÉ/Process:	SAW	CRITÈRE/Criteria:	n/a	ANGLE/Angle	SA10-N55S-IHC
ÉPAISSEUR/Thickness:	9,0 mm			No. SÉRIE/Serial no.:	H1937
APPAREIL/Equipment:		**CALIBRATION/Calibration**		MARQUE/Mark:	
MARQUE/Mark:	OmniScan MX2	BLOC/Block:	SDH 2.4 mm	MHz:	
MODÈLE/Model:	32/128 PR	COUPLANT/Couplant:	water	2 DIMENSIONS:	
No. SÉRIE/Serial no.:	OMNI2-100339			ANGLE/Angle	
				No. SÉRIE/Serial no.:	

RÉSULTATS/Results:

PL018-3 **R0**
Plaque de 9mm

La position 0 mm est identifiée en bleu directement sur la pièce.
Un cordon a été détecté le long de la soudure.

Longueur de l'échantillon (mm)
772

	Total Length	%
≥ 80%	160	20,7%
[70% à 80%]	378	49,0%
[60% à 70%]	192	24,9%
< 60%	42	5,4%
No Data		

	NOM/Name	CERTIFICATION/Certification	DATE/Date
INSPECTÉ PAR/Inspected by:	Daly Souissi	CAN/CGSB 48.9712 UT2	2015-09-04
VÉRIFIÉ PAR/Verified by:	Jérôme Boudreault-Leclerc	CAN/CGSB 48.9712 UT3	2015-09-08
APPROUVÉ PAR/Approved by:			

T-Paut Ortho v01 page 1 / 2

FILE: Test_Paut_9mm-PL018-3.rdt

Position (mm)	Length (mm)	Penetration (%)
0	18	[60% à 70%]
18	192	[70% à 80%]
210	98	≥ 80%
308	66	[70% à 80%]
374	62	≥ 80%
436	92	[70% à 80%]
528	14	[60% à 70%]
542	16	< 60%
558	28	[70% à 80%]
586	160	[60% à 70%]
746	26	< 60%
772		

rib lenght	772	
	Total Length	%
≥ 80%	160	20,7%
[70% à 80%]	378	49,0%
[60% à 70%]	192	24,9%
< 60%	42	5,4%
No Data		

≥ 80%
[70% à 80%]
[60% à 70%]
< 60%
No Data

page 2 / 2

Inspection report example
Orthotropic Deck

- Weld penetration is showed by a color code

FILE: Test_Paut_9mm-PL01B-3.rdt

Position (mm)	Length (mm)	Penetration (%)
0	18	[60% à 70%]
18	192	[70% à 80%]
210	98	≥ 80%
308	66	[70% à 80%]
374	62	≥ 80%
436	92	[70% à 80%]
528	14	[60% à 70%]
542	16	≤ 60%
558	28	[70% à 80%]
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772		

rib lenght	*772*	
	Total Length	%
≥ 80%	160	20,7%
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No Data		

≥ 80%
[70% à 80%]
[60% à 70%]
≤ 60%
No Data

Reporting

Inspection report example
Structural Boxes

NUCLEOM
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PAUT REPORT
RAPPORT No./Report no.: Q15-7231-005 rev0

CLIENT/Customer:	CANAM	COMMANDE/Order:	
ADRESSE/Address:	115 Boulevard Canam Nord, Saint-Gédéon-de-Beauce, QC (G0M 1T0)	No. CONTRAT/Job no.:	
		RÉFÉRENCE/Reference:	
RESPONSABLE/Responsible:	Michael Roy	PROJET/Project:	

PHASED ARRAY ULTRASONIC INSPECTION

DESCRIPTION/Description:

Mesure de la pénétration de soudures à pénétration partielle avec préparation d'un seul coté entre deux plaques assemblées en L. La technique utilisée est l'ultrasons multiéléments. Ce rapport couvre la division #30.

DONNÉES TECHNIQUES/Technical data:

SOUDURE/Weld		CONFORMÉMENT À/In accordance with		TRANSDUCTEUR/Transducer	
MATÉRIEL/Material:	Acier au carbone	NORME/Code:	n/a	MARQUE/Mark:	Olympus 5L16-A10
TYPE/Type:	pénétration partielle	SECTION/Section:	n/a	MHz:	5 MHz
PRÉPARATION/Prep.:	Demi V			1 DIMENSIONS:	16 ele. (9.6x10)
PROCÉDÉ/Process:	SAW	CRITÈRE/Criteria:	n/a	ANGLE/Angle	SA10-N55S-IHC
ÉPAISSEUR/Thickness:	16mm			No. SÉRIE/Serial no.:	H1937
APPAREIL/Equipment:		**CALIBRATION/Calibration**		MARQUE/Mark:	
MARQUE/Mark:	OmniScan MX2	BLOC/Block:	SDH 2.4 mm	MHz:	
MODÈLE/Model:	32/128 PR	COUPLANT/Couplant:	water	2 DIMENSIONS:	
No. SÉRIE/Serial no.:	OMNI2-100339			ANGLE/Angle	
				No. SÉRIE/Serial no.:	

RÉSULTATS/Results:

Division	Poutre	Boite	Conformité de la pénétration de la soudure			
30	30C100	BU12	1--1	1--2	1--3	1--4
		BU11A	1--1	1--2	1--3	1--4
		BU8	1--1	1--2	1--3	1--4
		BU4A	1--1	1--2	1--3	1--4
	30C101	BU2A	1--1	1--2	1--3	1--4
		BU4A	1--1	1--2	1--3	1--4
		BU9	1--1	1--2	1--3	1--4
		BU11A	1--1	1--2	1--3	1--4
	30C102	BU8	1--1	1--2	1--3	1--4
		BU2A	1--1	1--2	1--3	1--4
		BU12	1--1	1--2	1--3	1--4
		BU9	1--1	1--2	1--3	1--4
	30C103	BU8	1--1	1--2	1--3	1--4
		BU8	2--1	2--2	2--3	2--4
		BU6	1--1	1--2	1--3	1--4
		BU5A	1--1	1--2	1--3	1--4

	NOM/Name	CERTIFICATION/Certification	DATE/Date
INSPECTÉ PAR/Inspected by:	Daly Souissi	CAN/CGSB 48.9712 UT2	2015-11-02
VÉRIFIÉ PAR/Verified by:			
APPROUVÉ PAR/Approved by:			

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NUCLEOM
INNOVATION • INTEGRATION

PAUT REPORT
RAPPORT No./Report no.: Q15-7231-005 rev0

PHASED ARRAY ULTRASONIC INSPECTION

RÉSULTATS/Results:

Soudure	Fichier .OPD	Résultat					
30C103-BU08 (1-1)	30C103_BU08_1-1_001	0-375	376-839	840-1065	10566-2224	2225-2256	2256-Fin
30C103-BU08 (1-2)	30C103_BU08_1-2_001	0-600	600-840	841-1964	1965-2239	2240-Fin	
30C103-BU08 (1-3)	30C103_BU08_1-3_001	0-550	551-656	657-1164	1165-2134	2135-Fin	
30C103-BU08 (1-4)	30C103_BU08_1-4_001	0-578	579-648	649-1263	1264-1768	1769-Fin	
30C103-BU08 (2-1)	30C103_BU08_2-1_001	Toute la longueur					
30C103-BU08 (2-2)	30C103_BU08_2-2_001	Toute la longueur					
30C103-BU08 (2-3)	30C103_BU08_2-3_001	Toute la longueur					
30C103-BU08 (2-4)	30C103_BU08_2-4_001	Toute la longueur					
30C103-BU06 (1-1)	30C103_BU06_1-1_001	Toute la longueur					
30C103-BU06 (1-2)	30C103_BU06_1-2_001	Toute la longueur					
30C103-BU06 (1-3)	30C103_BU06_1-3_001	Toute la longueur					
30C103-BU06 (1-4)	30C103_BU06_1-4_001	Toute la longueur					
30C103-BU05A (1-1)	30C103_BU05A_1-1_001	0-335	336-375	376-849	850-590	891-Fin	
30C103-BU05A (1-2)	30C103_BU05A_1-2_001	0-314	315-380	381-549	550-790	791-Fin	
30C103-BU05A (1-3)	30C103_BU05A_1-3_001	Toute la longueur					
30C103-BU05A (1-4)	30C103_BU05A_1-4_001	Toute la longueur					

Pénétration inférieure à 7mm
Pénétration égale ou supérieure à 7mm

Advantages and limitations

Advantages

- Penetration percentage is measured at all positions in the weld
- Accuracy on the weld penetration percentage is ±5% (±1% in optimal conditions)
- Repeatability, less subjectivity in acquisition and analysis
- Track record
- Can be adapted for different joint configuration
- Fast acquisition

Advantages and limitations

Limitation

- Weld flaws can affect the data interpretation (undercuts, LOF)
- Weld profile can affect the data acquisition
- Requires expertise in PAUT technology
- Non constant long weld could require many hours of analysis.
- Electronic limitations

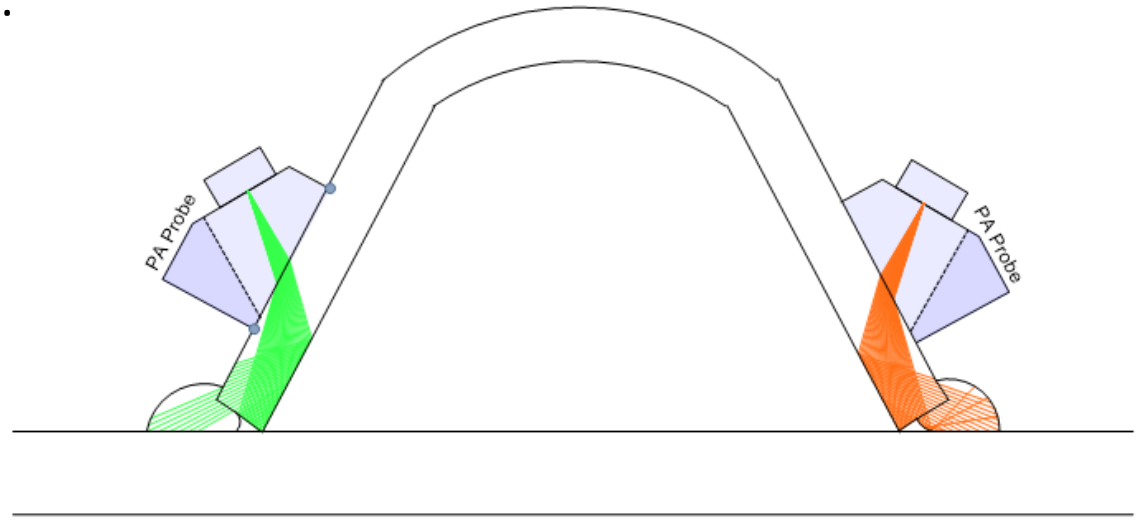
Conclusion

- PAUT (Phased Array Ultrasonic Testing) is an efficient technique to monitor weld penetration for orthotropic bridges over the entire length of the weldment

- The technique has been proven on 5 different projects (bridges and steel structures) in collaboration with CANAM BRIDGES

Conclusion

- The technique can include more than one probe in order to perform 2 or more simultaneous scans.



- It's possible to characterize flaws (Porosities, LOF, etc.) along the scan. A sensitivity calibration is needed in this case.

Special thanks to:

- Francis Boudreault-Leclerc
- Jérôme Boudreault-Leclerc
- Éric Levesque

Thank you, questions are welcome!