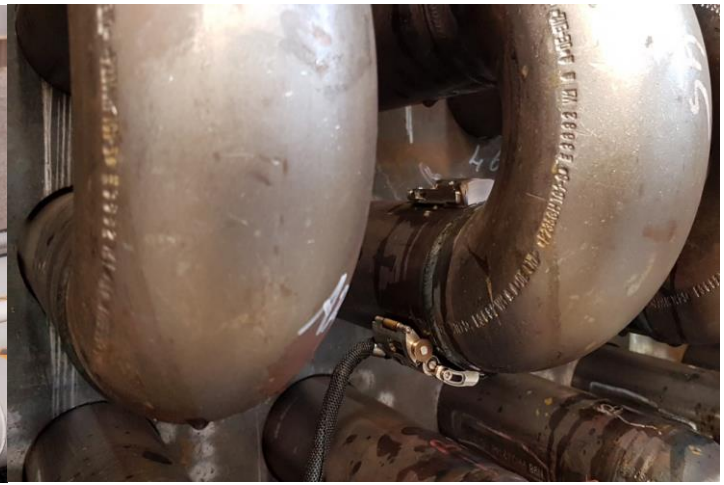


Ultrasonic Phased Array Testing in Lieu of Radiography Testing for Thin-Walled Heat Exchanger Welds: An In-the-Field User Case

Olympus Scientific Solutions Americas | Andre LAMARRE and Stéphan COUTURE

KINT Symposium—October 30 and 31, 2019—Amsterdam, Netherlands

Introduction

Case-Study Participants

- German inspection company
  - Testing personnel and equipment
  - Procedures, etc.

DREIFELD

- Manufacturer of conventional and advanced NDT equipment
  - Phased array instrumentation and probes
  - Scanners and accessories

OLYMPUS

- Software solution provider
  - Assisted analysis software: Automated Detection Technology™
  - CAPA: computer-aided phased array

VERIPHASE®

Original Client Request: Radiography

- Over 1500 boiler tubes
- 76.1 mm OD (3 in. OD)
- Circumferential welds
- 4.5 mm (0.177 in.) wall thickness
- Single 30° V-bevel

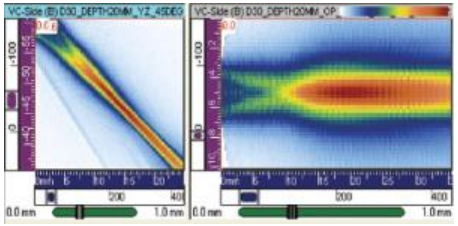
- Dreifeld's evaluation for RT requirements:
  - ❑ Minimum of 2 operators
  - ❑ Must be performed at night
  - ❑ An estimated 50 days to complete

Considerations for UT/Phased Array

- Thin wall
  - Geometry
  - Coverage
- One-sided access only
  - Detection on opposite side
- Difficult access
  - Scan straight
  - Coupling
- TIG (tungsten inert gas) weld
  - Cap almost flush
- Time to analyze files

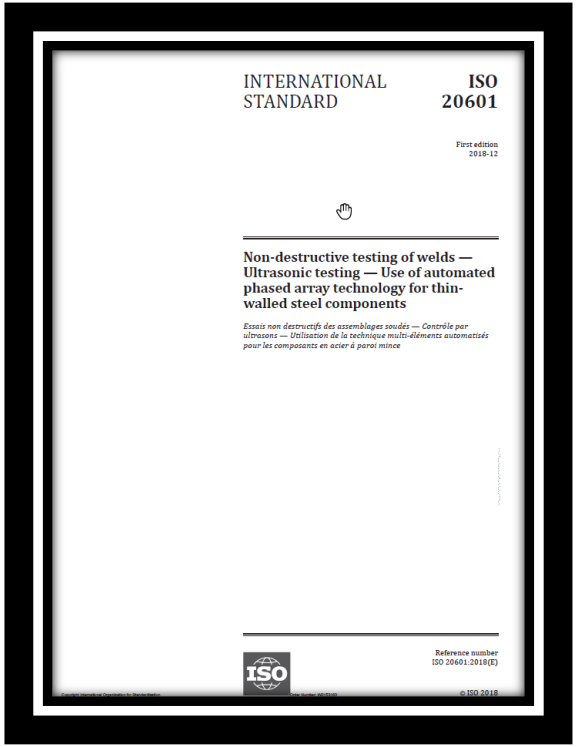
Phased Array Inspection Advantages

- ISO 20601: Use of automated phased array technology for thin-walled steel components
  3.2 mm–8 mm (0.125 in.–0.315 in.)
- 1 operator for acquisition and analysis
- Portable phased array unit
- Small-diameter scanner
- Concave curvature in elevation (CCEV) probes focused in the passive axis
- Post-analysis software
- Assisted analysis software



Decision Factors for Using Phased Array

- With the customer, the decision was made to use phased array instead of radiography
- Key decision factors:
  - Existence of the code ISO-20601
  - Planned completion in less than 2 weeks
  - Time and cost savings
  - Off-the-shelf equipment available
  - Assisted analysis software
  - Dreifeld's experience with phased array


INTERNATIONAL STANDARD

ISO 20601

First edition
2018-12

Non-destructive testing of welds — Ultrasonic testing — Use of automated phased array technology for thin-walled steel components

Essais non destructifs des assemblages soudés — Contrôle par ultrasons — Utilisation de la technique multi-éléments automatisés pour les composants en acier à paroi mince

Reference number
ISO 20601:2018(E)

© ISO 2018

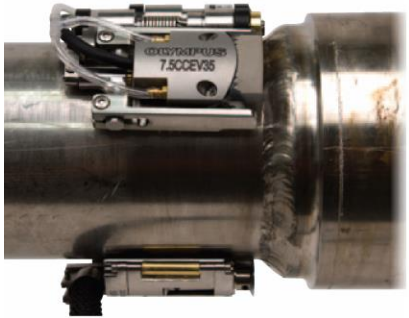
Equipment Description

Ultrasonic Phased Array Equipment: OmniScan™ MX2 Flaw Detector

- 16:128 configuration
- Multiple groups (up to 8)
- Two groups are used:
  - One SW sector scan for weld coverage (50 to 72 SW)
  - One 0 LW for couple check
- Portable, battery operated

Low-Profile Scanner: COBRA™ Pipe Weld Scanner

- Pipe diameter range 21.3 mm to 114.3 mm OD (0.84 in. to 4.5 in. OD)
- Requires only 12 mm (0.5 in.) clearance
- Spring-loaded system that can be installed on any material
- Can be configured for pipe-to-component inspection
- Can be configured for one-sided inspection



CCEV A15 Phased Array Probe

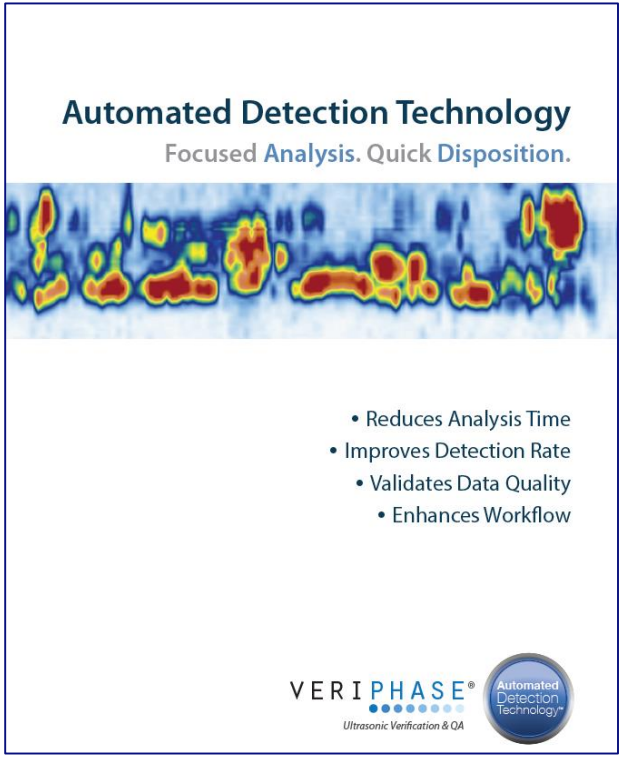
- 16 elements
- 7.5 MHz frequency
- CCEV curved arrays for improved focusing, resolution, and length sizing
- Low-profile custom housing enables 12 mm (0.5 in.) clearance
- Curved shoes to fit the pipe (diameter: 75 mm (3 in.), radius 38 mm (1.5 in.))

Assisted Analysis Software

Main Goals in Using the Assisted Analysis Software

- Reduce analysis time
- Improve detection and reliability
- Ensure quality and compliance

Number of Files	Groups	MB	Length	Time to Process	Notes
1	2	8	15 in. (381 mm)	3 seconds	Boiler Tube
200	2	1600	15 in. (381 mm)	1.25 minutes	Batch Processing
1600	2	12,800	15 in. (381 mm)	10–15 Min	Batch Processing Boiler Tubes



Assisted Analysis Software—Description

- Uses sophisticated algorithms
  - Not simply amplitude flagging
- Program software to see data like an experienced Level II or III sees data
- Consider data points in the scan both individually and collectively
- Algorithms consider everything learned in UT analysis
  - Echo dynamics
  - Amplitude
  - Locations
  - Geometry

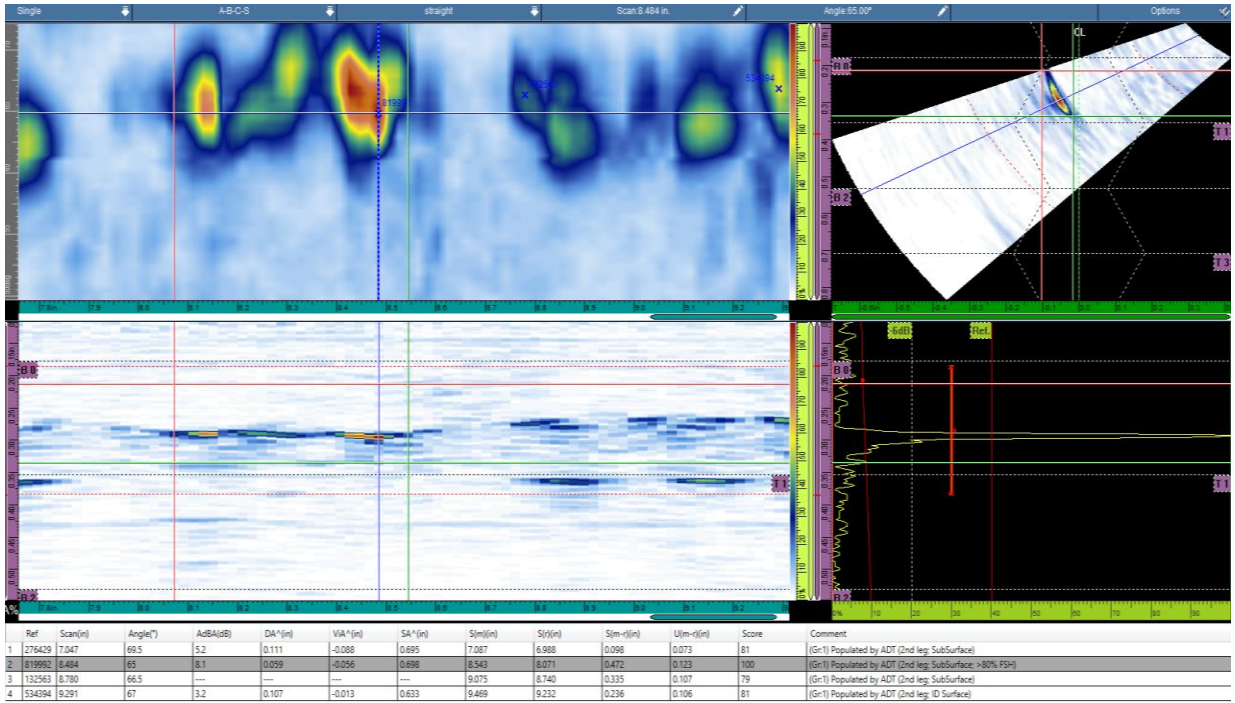
Basic Process

- Load file(s)
  - All info extracted from file
- Consistency checks
- Process
- Make data copy with indication table for each file
- Create analysis planning report
- Generate indication table

N443_2709.opd	3/21/2019 8:15 AM	OmniPC Document	7,983 KB
N443_2709-ADT.opd	3/21/2019 11:07 AM	OmniPC Document	7,984 KB
N444_2709.opd	3/21/2019 8:15 AM	OmniPC Document	7,983 KB
N444_2709-ADT.opd	3/21/2019 11:06 AM	OmniPC Document	7,991 KB
N445_2709.opd	3/21/2019 8:15 AM	OmniPC Document	7,983 KB
N445_2709-ADT.opd	3/21/2019 11:06 AM	OmniPC Document	7,991 KB
N446_2709.opd	3/21/2019 8:15 AM	OmniPC Document	7,983 KB
N446_2709-ADT.opd	3/21/2019 11:07 AM	OmniPC Document	7,984 KB
N447_2709.opd	3/21/2019 8:15 AM	OmniPC Document	7,983 KB
N447_2709-ADT.opd	3/21/2019 11:06 AM	OmniPC Document	8,000 KB
N448_2709.opd	3/21/2019 8:15 AM	OmniPC Document	7,983 KB
N448_2709-ADT.opd	3/21/2019 11:07 AM	OmniPC Document	7,987 KB

Analysis Software Interface

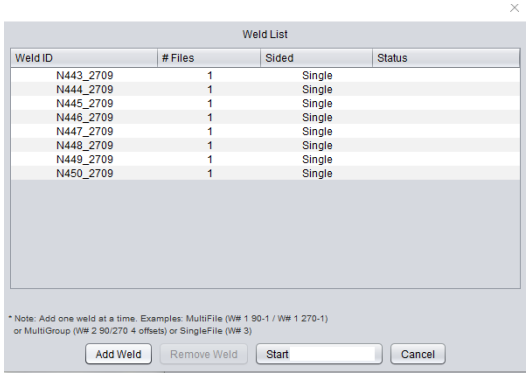
- Open file copy
- Review table and comments
- Sort by criteria
- Automatic cursor positioning (“click and fly”)
  - Groups change
  - Autosizing (cursors)
    - Length
    - Height



	Ref	Scan(in)	Angle(°)	AdBA(dB)	DA^(in)	ViA^(in)	SA^(in)	Si(m)(in)	Si(r)(in)	Si(m-r)(in)	Ui(m-r)(in)	Score	Comment
1	276429	7.047	69.5	5.2	0.111	-0.088	0.695	7.087	6.988	0.098	0.073	81	(Gr:1) Populated by ADT (2nd leg: SubSurface)
2	819992	8.484	65	8.1	0.059	-0.056	0.698	8.543	8.071	0.472	0.123	100	(Gr:1) Populated by ADT (2nd leg: SubSurface: >80% FSH)
3	132563	8.780	66.5	---	---	---	---	9.075	8.740	0.335	0.107	79	(Gr:1) Populated by ADT (2nd leg: SubSurface)
4	534394	9.291	67	3.2	0.107	-0.013	0.633	9.469	9.232	0.236	0.106	81	(Gr:1) Populated by ADT (2nd leg: ID Surface)

Planned Analysis Process: Data Funnel

- Extract (“data dump”) files
  - 200 to 320 per day
- Process all files simultaneously
- Sort by specific criteria
  - Code specific
  - User specific
- Find data quality issues quickly
- Communicate major issues quickly



MultiWeld Analysis File Detail Report								
Severity List	Data File	Hotlist Size	Total Hotlist Size	Hits exceeding 80% FSH and ≥.250"/6.35mm	Hits exceeding 50% FSH and ≥.250"/6.35mm	Average Hits per 1" / 25.4mm	User Defined Criteria N/A	Data Quality
#1	N450_2709.opd	6	6	1	1	0.23		Severe
#2	N447_2709.opd	4	4	0	2	0.42		None
#3	N444_2709.opd	2	2	1	1	0.21		None
#4	N445_2709.opd	2	2	0	1	0.21		None
#5	N446_2709.opd	0	0	0	0	0.00		None
#6	N449_2709.opd	0	0	0	0	0.00		None

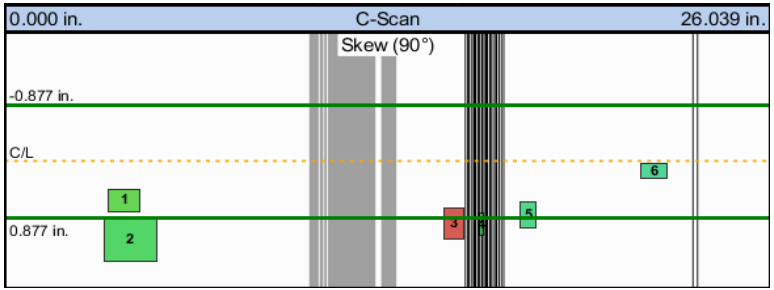
Data Quality (Data Drop Out & Couplant Loss)	
None	0%
Moderate	Between 0% and 1%
Severe	≥ 1% / 2 in an Inch or Adjacent

Data Quality

- Data drop out and loss of couplant
  - % in scan
  - 2 per in./adjacent
- Code issues flagged
- Individual reports
- Ensures quality is checked

Data Quality Overview								
File Processed	Group	Data Drop Out	Data Drop Out %	2 Drop Out Per Inch	Adjacent Drop Out	Loss of Couplant	Loss of Couplant %	Average Hits per 1"/25.4mm
Data Quality Issues.opd	Gr:1	Yes	3.63%	Yes	Yes	Yes	10.14%	0.23

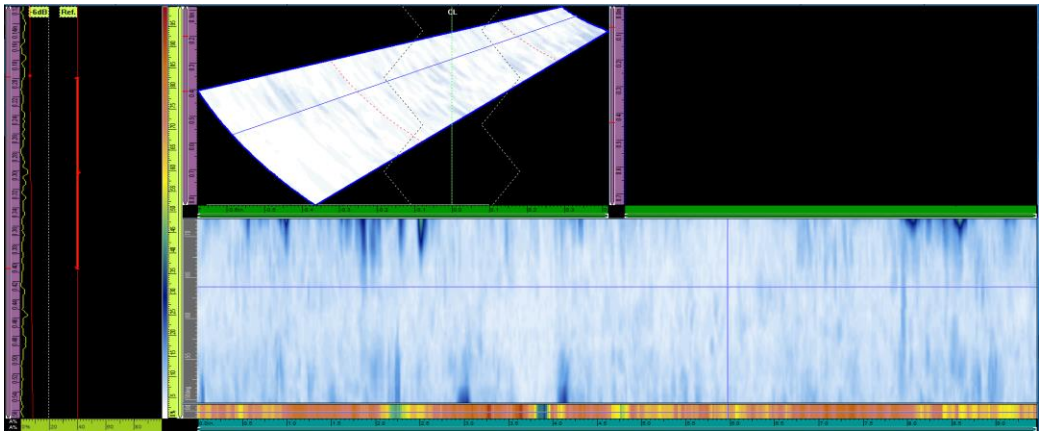
Data Quality Detail					
File Processed	Group	Scan Start	Scan Stop	Length	Issue
Data Quality Issues.opd	Gr:1	10.361 in.	10.676 in.	0.315 in.	Loss of couplant
Data Quality Issues.opd	Gr:1	10.715 in.	10.833 in.	0.118 in.	Loss of couplant
Data Quality Issues.opd	Gr:1	10.873 in.	10.952 in.	0.079 in.	Loss of couplant
Data Quality Issues.opd	Gr:1	10.991 in.	12.606 in.	1.615 in.	Loss of couplant
Data Quality Issues.opd	Gr:1	12.803 in.	13.315 in.	0.512 in.	Loss of couplant
Data Quality Issues.opd	Gr:1	15.639 in.	15.679 in.	0.039 in.	Data drop-out
Data Quality Issues.opd	Gr:1	15.718 in.	15.797 in.	**0.079 in.**	Adjacent data drop-out
Data Quality Issues.opd	Gr:1	15.718 in.	16.979 in.	**1.261 in.**	Two or more data drop-outs within one inch
Data Quality Issues.opd	Gr:1	15.836 in.	15.876 in.	0.039 in.	Data drop-out
Data Quality Issues.opd	Gr:1	15.915 in.	16.033 in.	**0.118 in.**	Adjacent data drop-out



Inspection

Inspection Scenario

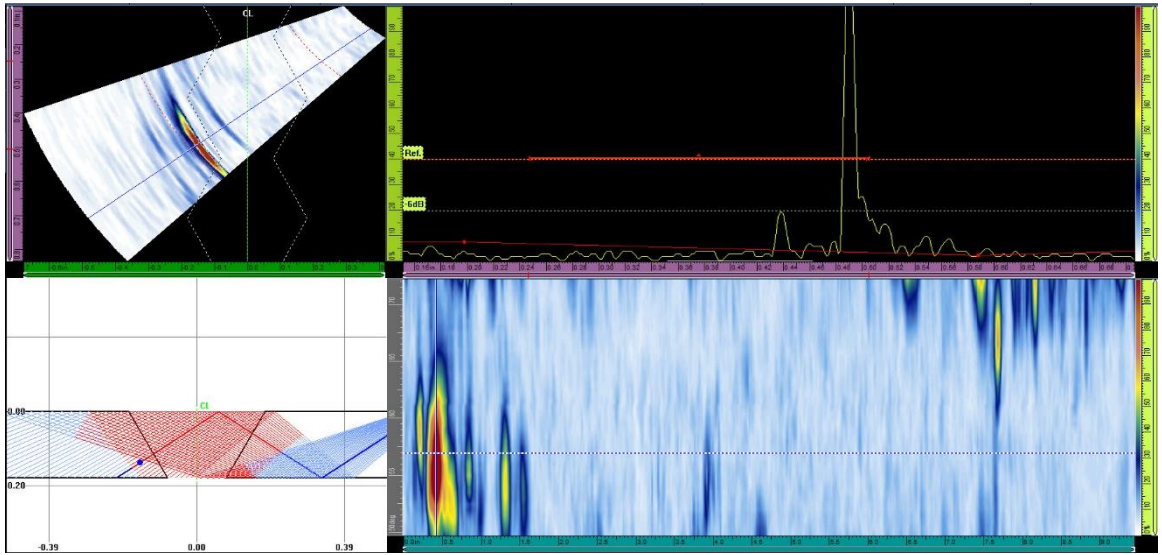
- S-scan at fixed probe position
- 50 to 72 SW with 0.5-degree resolution
- 0 LW coupling check
- Scan resolution: 0.5 mm
- Beam generated with 16-element aperture
- 7.5 MHz A15 phased array probe



Multigroup A-C-R-S view of a weld without defects with the couplant check group at the bottom

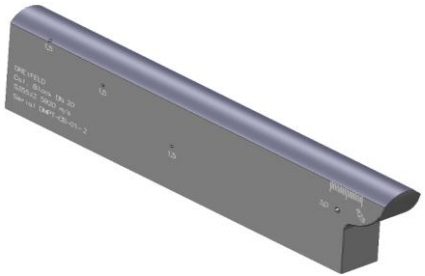
Inspection Scenario

- Full weld coverage
- C-scan, S-scan, A-scan
- 1st, 2nd, 3rd leg
- The 3rd leg of the inspection was validated with rebound on the weld crown on a validation block



Calibration

- A reference block was used to set the sensitivity and TCG of each phased array beam
- A block similar to the one suggested by the code but with a radius of 25 mm (1 in.) at the end of the block
- The top of the block was manufactured with a 38 mm (1.5 in.) radius—same as the pipes to be inspected



A.1 Typical reference block

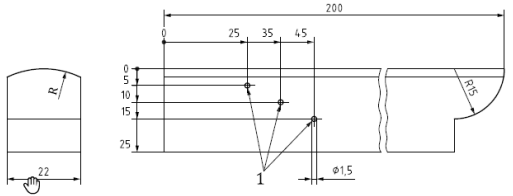
The block shown in Figure A.1 is used to:

a) perform DAC/TCG;

b) check time delays (related to the probe shoe wear) and index point.

For sensitivity setting, a block, as for example shown in Figure A.2, is recommended.

Dimensions in millimetres



Key

1 side-drilled hole (SDH)

R is the curvature of the block close to the curvature of the test object (for component of diameter $D > 600$ mm the top of the block may be flat)

Figure A.1 — Typical reference block with side drilled-holes

A given reference block may cover a range of component curvature from 100 % to 70 % of its own curvature, provided appropriate correction in ultrasonic path and sensitivity are taken into account.

The end of the block may have a radius ($r = 15$ mm).

In all cases, with regard to the diameter or curvature, the requirements mentioned in 6.2.3 shall apply. The maximum allowed gap between probe shoe and reference block is 0,5 mm.

The length and width of the reference block should be chosen such that all the artificial reflectors can be properly scanned.

9.3.4 Reference reflectors

The reference block as shown in Figure A.1 shall at least contain two side-drilled holes (SDH).

The reference block shall at least contain one side-drilled hole (SDH) and two notches (Figure A.2) or alternatively two flat-bottomed holes (FBH) or two round-bottomed holes (RBH). The length of the side-

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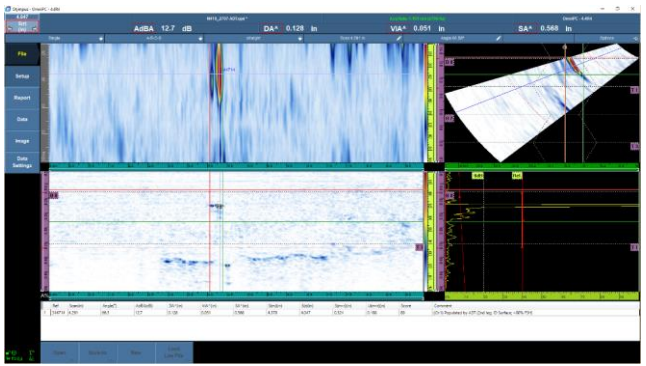
Workflow

- Ultrasonic settings
- Calibration
- Acquisition
- File verification
- Transfer a batch of files to a PC
- Analysis using:
  - OmniPC™
  - ADT software
- Reporting

Summary of Project Results

- 1608 tubes completed
- Average of >200 welds a day
- 320 welds done in a single day (2.5 GB of data)
- >12 GB of data project total
- Software helped ensure all data was complete and compliant



Metric	CAPA	RT (estimated)	Difference
Days to Complete	8	50	-42
Number of Technicians	*1	2	-1

* PAUT could be performed during the day

New Developments

Ultrasonic Phased Array Equipment: OmniScan™ X3 Flaw Detector

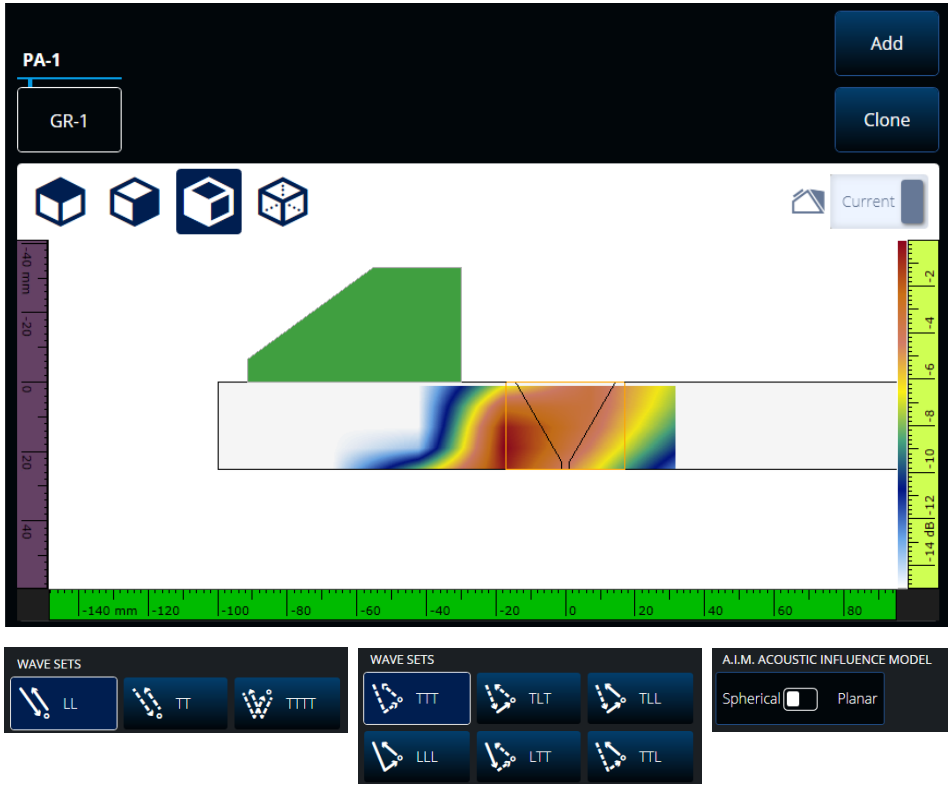
- Innovative TFM imaging
- Improved phased array
- Inspection speed doubled compared to the MX2 model
- Connect wirelessly to the Olympus Scientific Cloud™ to download the latest software

OmniScan X3 Flaw Detector—Inspection Scenario

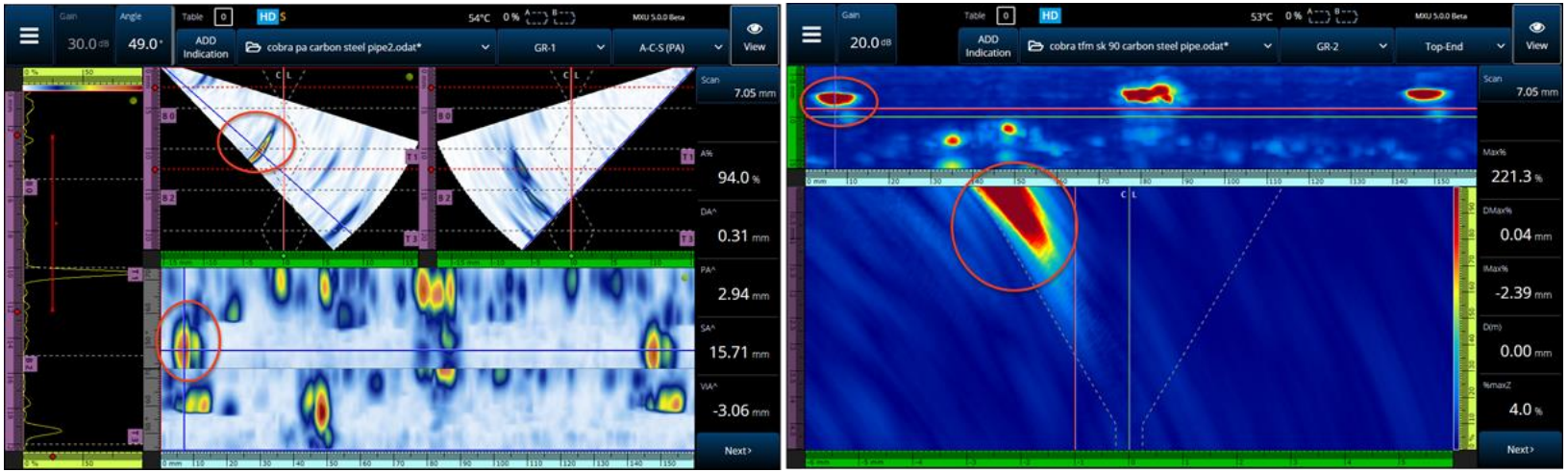
- Tests comparing phased array and TFM on a small-diameter pipe
  - Carbon steel
  - 45 mm (1.75 in.) pipe diameter
  - 5 mm (0.2 in.) thick
  - 5 MHz CCEV probes with 60 SW wedge
  - COBRA scanner

OmniScan X3 Flaw Detector—Simulation and Setup Tools

- AIM (Acoustic Influence Mapping) simulation tool
  - Displays the distribution of the ultrasound energy for an optimized inspection
  - The representation is updated with:
    - The probe and wedge
    - The TFM mode: TT, TTT, TTTT, LL, etc.
    - The type of reflector: spherical or planar

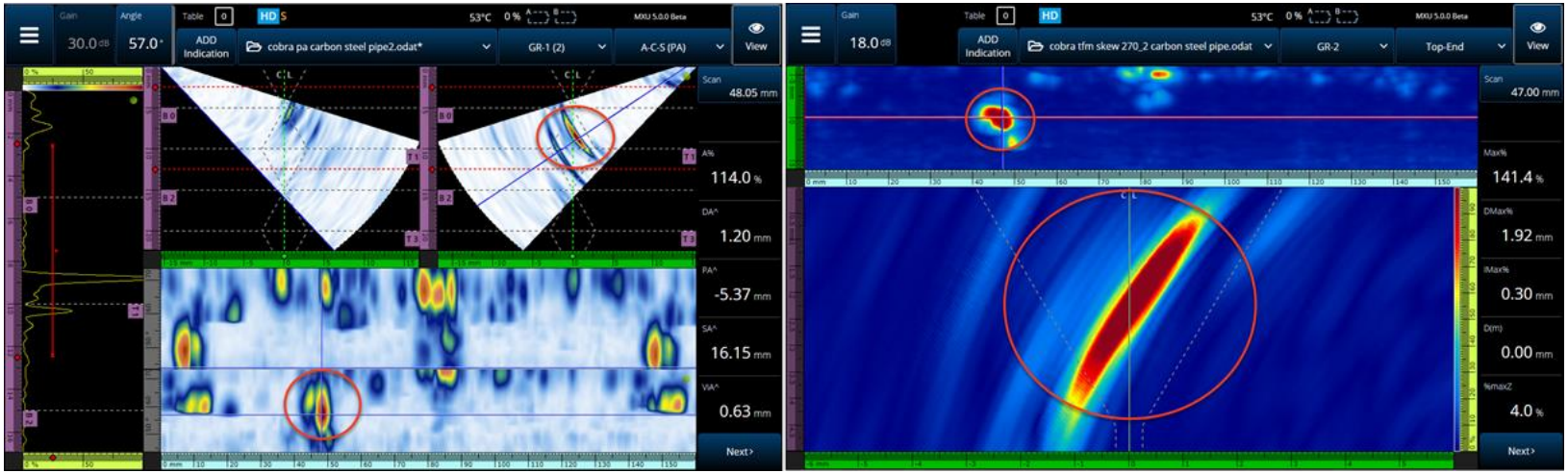


OmniScan X3 Flaw Detector—Comparison of PA and TFM Data (TTTT Mode)



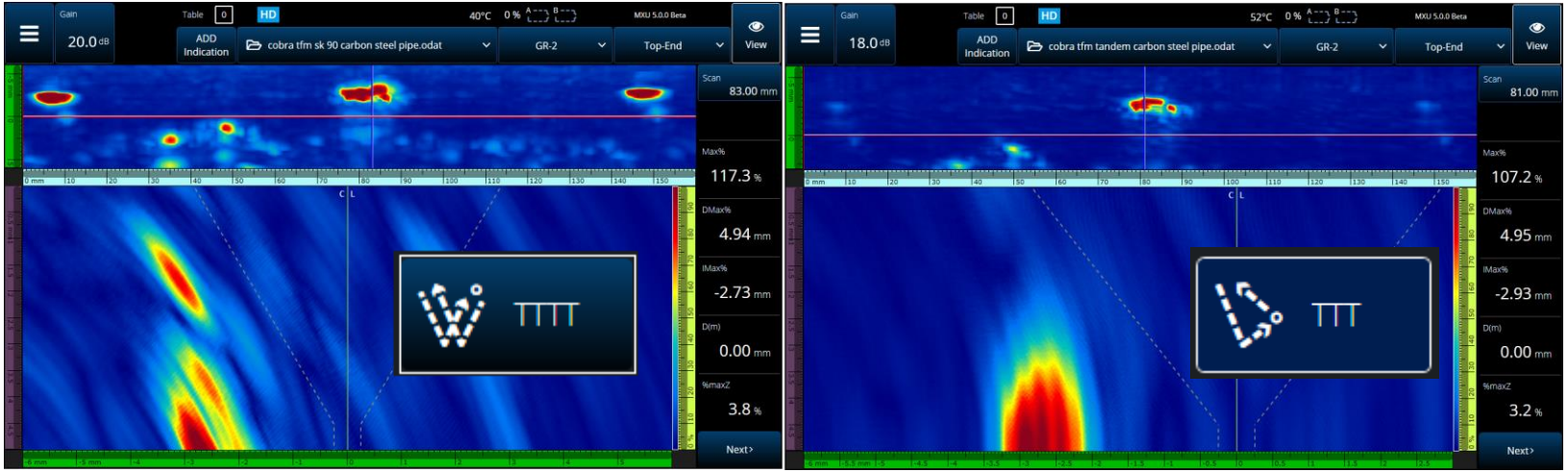
- Indication is at the same location on the weld representation for both techniques
- Traditional C-scan compared to a top view

OmniScan X3 Flaw Detector—Comparison of PA and TFM Data (TTTT Mode)



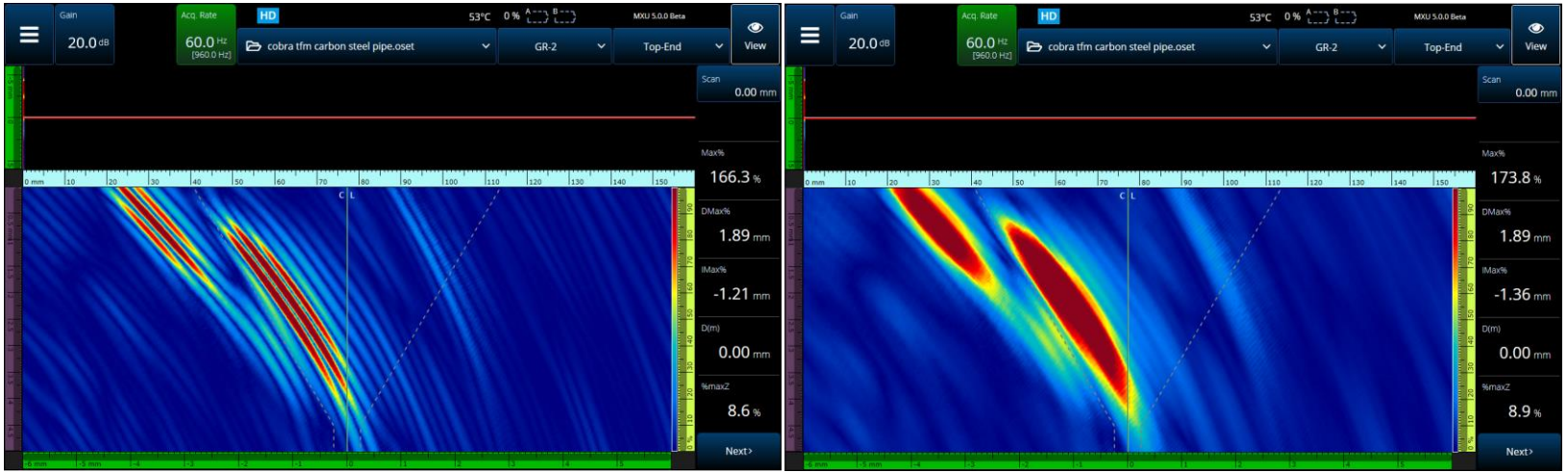
- Indication is at the same location on the weld representation for both techniques
- Traditional C-scan compared to a top view

OmniScan X3 Flaw Detector—Comparison of TTTT Mode (Pulse-Echo) and TTT Mode (Tandem) for Root Crack Detection



- With TFM, selecting the right mode is crucial for proper detection and sizing

OmniScan X3 Flaw Detector—TFM Computed Envelope



- Signal processing—it is not image smoothing
- Removes artifacts, the oscillatory behavior from the raw wave

Acknowledgements

- Mr. Dreifeld for sharing his field experience

- Nick Bublitz from VeriPhase for providing expertise and documentation

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