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QUALIFICATION WORK FOR THE PRE & IN SERVICE ULTRASONIC EXAMINATION OF AUXILIARY AND SECONDARY PIPING WELDS OF OLKILUOTO 3 EPR™. EXTENSION OF PRE-EXISTING QUALIFICATION ON OLKILUOTO 1&2 NUCLEAR POWER PLANTS.

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Abstract

The EPR™ is being built on the site of Olkiluoto (Finland).

The Finnish regulations impose that the Pre-Service and In-Service Inspections of auxiliary and secondary piping performed with ultrasonic (UT) shall be qualified according to YVL-guide 3.8, which refers to ENIQ Recommended Practices for qualification.

To guide the practical qualification work based on Finnish regulations more detailed guidelines (SP rules) have been produced by Inspecta Certification in collaboration with STUK, Licensees and Inspection Vendors. One of them defines general principles for the extension of pre-existing qualifications.

This paper aims at presenting the results of qualification work performed on UT inspection of auxiliary and secondary piping where these principles of extension have been applied by reference to the qualification pre-existing and applicable to the nuclear power plants of Olkiluoto 1 & 2.

Inspecta Oy, acting as a NDT services company, is in charge of this work, in collaboration with the "NDT sub division" of the "Supply Chain Quality Management" department of AREVA NP. Inspecta Certification, as Qualification Body, has supervised all the qualification steps and finally issued the qualification certificate.

UT acquisition and analysis tools based on phased arrays technology are used.

Keywords: EPR™, ENIQ, PSI Qualification, Piping Welds, UT phased arrays.

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1. Introduction

For the pre-service and the in-service inspections at Olkiluoto 3, the Finnish regulatory guide YVL 3.8 describes the requirements to be fulfilled in order to qualify inspection systems and personnel.

The qualification process aims at demonstrating that the equipment and inspection procedure are qualified to fulfil the inspection objectives according to the related safety requirements.

To guide the practical qualification work based on Finnish regulations more detailed guidelines (SP rules) have been produced by Inspecta Certification in collaboration with STUK, Licensees and Inspection Vendors. One of them defines general principles for the extension of pre-existing qualifications.

This paper aims at presenting the results of qualification work performed on UT inspection of auxiliary and secondary piping where these principles of extension have been applied by reference to the qualification pre-existing and applicable to the nuclear power plants of Olkiluoto 1 & 2.

2. Components description

The piping lines subject to PSI are identified as per ASME XI articles IWB 2500-1 and IWC 2500-1 in term of diameter and thickness.

The range of the austenitic stainless steel piping lines is 60,3 mm to 355,6 mm for the diameter and 5,54 mm to 37,33 mm for the thickness.

The range of the carbon steel piping lines is 168,3 mm to 800 mm for the diameter and 18,26 mm to 60 mm for the thickness.

2.1 Material and manufacture technique

For the piping, the base metal is either forged austenitic stainless steel with grades Z2 CND 18.12 cn and Z2 CN 18.10 or forged ferritic carbon steel with grade P 355 NH.

The concerned components have extended ends allowing UT scanning and from the cast side (valves, check valves) also.

The welds subject to PSI / ISI are butt welds, welded from the outer side.

For the welding procedures, the root run is carried out with manual TIG welding process. Depending on the thickness, the welds are then filled by TIG welding, manual arc welding or submerged arc welding.

For the welding of the carbon steels piping, C-Mn filler materials are used and for stainless steels, 316L filler materials.

2.2 Surface conditions

For all the welds the outer circumferential weld bead is made flush with the adjacent base material. If accessible, the inner surface of weld bead is made flush with the base material too. But for the qualification purpose the inner weld surface is left as welded to cover the “worst case”.

The roughness of the weld bead when grinded does not exceed 6,3 µm. The roughness of scanning surface as well as the reflecting area at the opposite surface does not exceed 12,5 µm.

This shall prevent any scanning problem and sound perturbation due to the surface during the examination.

3. Inspection objectives, qualification blocks and flaw populations

3.1 Inspection objectives & inspection targets

The process of determination of the inspection objectives in terms of flaw dimensions and sizing accuracies is based on ASME XI standard (with the detection of defects in the main stress directions).

Their dimensions depend on the base material type and its thickness. They are represented in tables 1 and 2 by their depth (a) and length. A "a/l" ratio of 0,15 is retained as the most appropriate regarding the feed back experience except for ferritic steel pipes with larger dimensions (note 1).

These postulated defects are the inspection targets.

Pipe size Φ x t mm	60 5,54	114 8,56	168,3 10,97	219 12,7	273,1 12,7	114 13,49	168 14,27	355 15,09
Depth (a) Length	0,5 3,3	0,8 5,3	1,0 6,7	1,1 7,3	1,1 7,3	1,2 8,0	1,3 8,7	1,3 8,7
Pipe size Φ x t mm	168 18,26	219 20,62	273 25,4	323 28,58	210 37,33			
Depth (a) Length	1,6 10,7	1,8 12	2,1 14	2,4 16	3,1 20,7			

Table 1: Detection target of the inspection in austenitic steel material

Pipe size Φ x t mm	168x18,26	273x21,44	246x24,0	356x26,0	355x27,79
Depth (a) Length	1,6 10,7	1,9 12,7	2,1 14,0	1,9 12,7	2,1 14,0
Pipe size Φ x t mm	508x32,54	508x38,1	760x40,0	880x60,0	
Depth (a) Length	2,0 (1) 20,0	2,0 (1) 20	2,0 (1) 20,0	2,0 (1) 20	

Table 2: Detection target of the inspection in ferritic steel material

3.2 Qualification blocks. Detection requirements and inspections objectives

The demonstration of the capability of the inspection system to meet the requirement is principally based on open trials on dedicated qualification blocks.

When comparing the OL1&2 and OL3 pipe sizes and inspection targets, it appears that all dimensions or materials (castings) are not included in so-called “old qualification”. Therefore, new test blocks have been manufactured to complement the coverage of the “old qualification”.

These additional qualifications blocks are fully representative of the parts to be inspected; where different geometries or material grade are met, the “worst case” from the inspection point of view are retained.

According to the aforementioned principles, one additional block is representative of the smallest outside diameter met; another one is representative of the larger thickness met for austenitic pipe. Two additional blocks have been prepared to be representative of austenitic Pipe/cast assemblies.

Tests pieces have been made from austenitic material to be more difficult to inspect.

Complementary test pieces and detection requirements are gathered in table 3.

Block n°	Pipe Size (Φ x t mm)	Detection target (mm)	Materials
Block n°1	60x5,56	0,5x3,3	Pipe /pipe
Block n°2	355x15,09	1,3x8,7	Pipe/cast
Block n°3	210x37,3	3,1x2,07	Pipe/pipe
Block n°4	219x12,7	1,1x7,3	Pipe/cast

Inspections objectives:

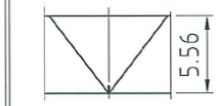
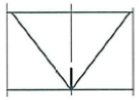
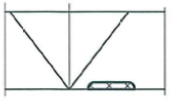
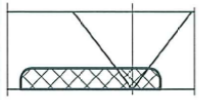
- Maximum Height sizing and depth positioning error (mm): 3,0
- Maximum Length sizing error (mm): 10 mm
- Maximum Circumferential Location error (mm): 25 mm
- Characterization: Planar recognition

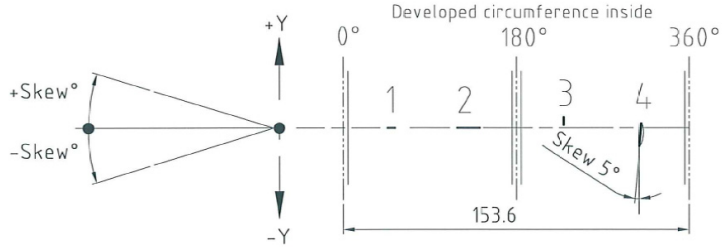
Table 3: Detection requirements and inspection objectives

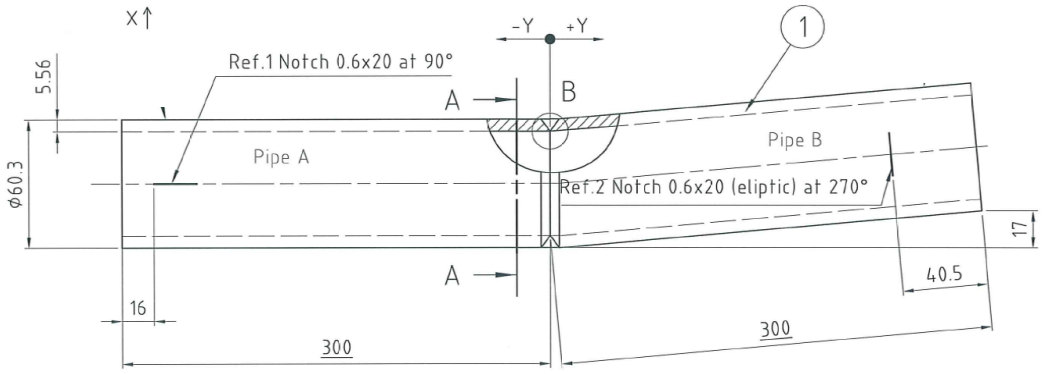
The flaw populations are a mix of real cracks and artificial reflectors (mainly EDM notches). The repartition of defects on the blocks takes into account the volume to be examined. The defects are oriented perpendicular to the inner surface (surface breaking on inner surface).

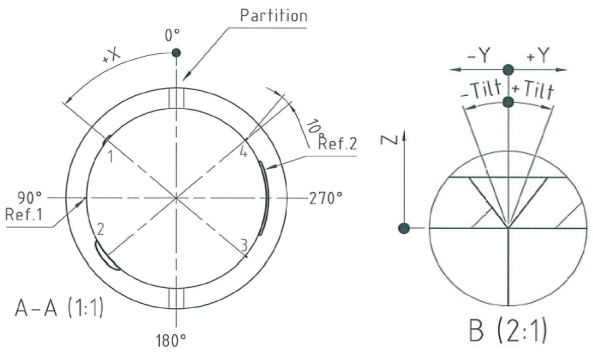
These flaws are in longitudinal or transverse respect to the welds; some of them are skewed and/or tilted ($0° \pm 10°$).

It shall be emphasized that real cracks are included in all UT test blocks, even if, in most cases, no degradation mechanism is identified. The main goal of the qualification is the demonstration of the NDT system capability to detect and size defects, and eventually define the capability restrictions and the limits of validity.

Defect No.	1	2	3	4
Det. B Scale 5:1	 Pipe A Pipe B			
Height	0.5	1.5	0.5	1.5
Length	5	9	3.2	10
X°/mm inside	50°/ 22.8 mm	130°/ 61.5 mm	230°/ 102 mm	310°/ 133 mm
Y	0	0	2.5	-2.5
Z	0	0	0	0
Skew	0°	0°	0°	5°
Tilt	0°	0°	0°	10°
Type of defect	Crack	Crack	EDM	EDM
Orientation	Longitudinal	Longitudinal	Transverse	Transverse
Ground depth	0.6	1.8	0.5	1.5







Block n°1 pipe/pipe qualification block – Defects data & block design

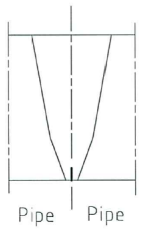
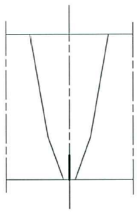
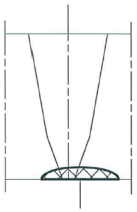
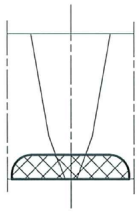
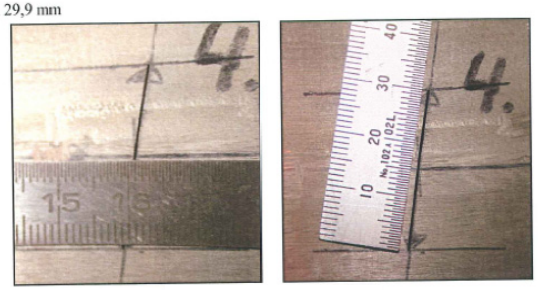
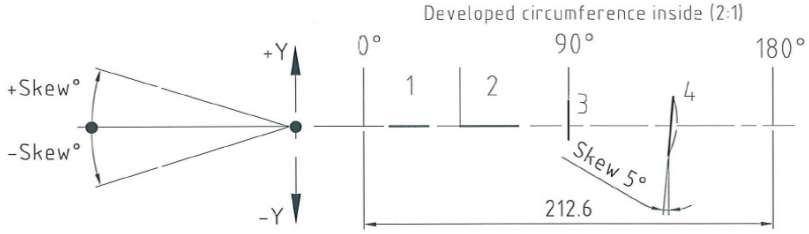
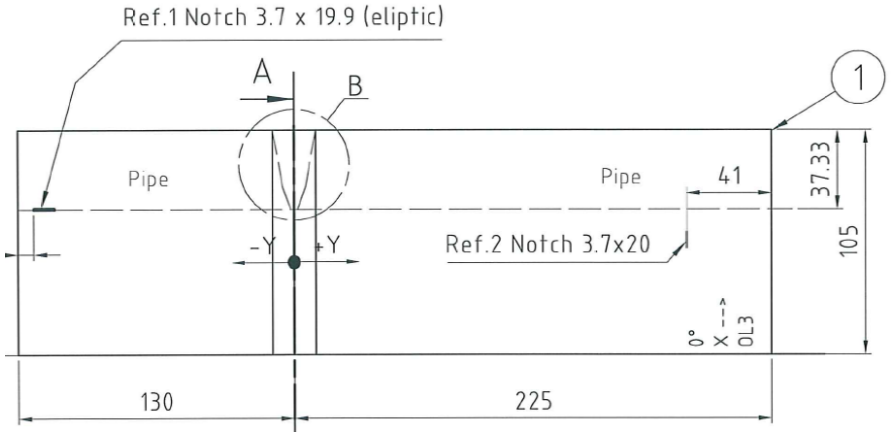
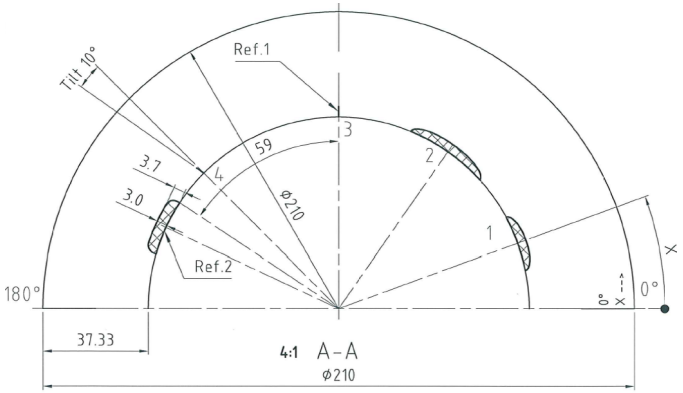
Defect No.	1	2	3	4
Det. B Scale 4:1				
Height	3.1	6.2	3.1	6.1
Length	20	27.5	19.9	29.9
X°/mm inside	20°/ 23 mm	55°/ 66 mm	90°/ 108 mm	135°/ 161 mm
Y	0	0	3	0
Z	0	0	0	0
Skew	0°	0°	0°	5°
Tilt	0°	0°	0°	10°
Type of defect	Crack	Crack	EDM	EDM
Orientation	Longitudinal	Longitudinal	Transverse	Transverse
Ground depth	3.2	6.4	3.1	6.1

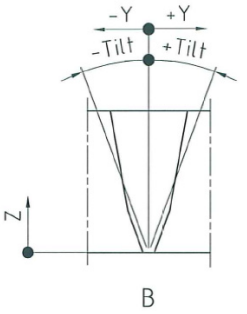
Photo of Defect 4
Defect length 29,9 mm



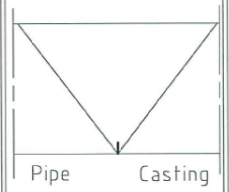
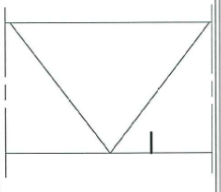
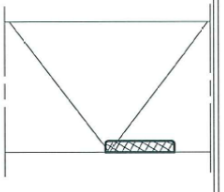
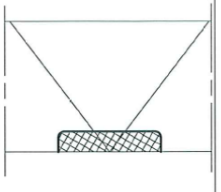


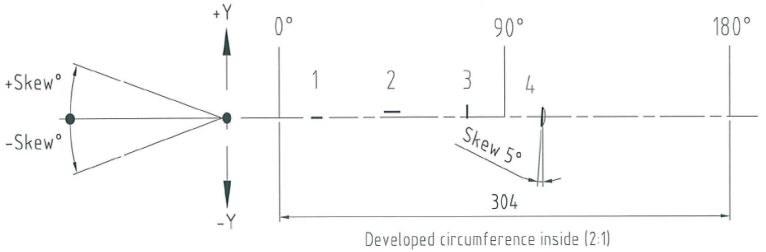


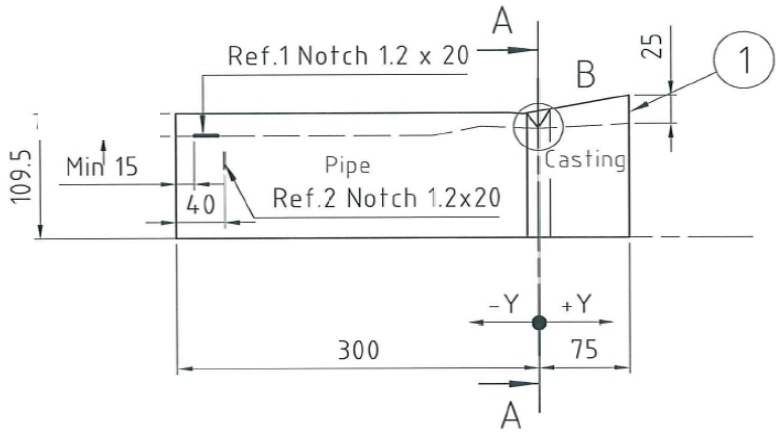


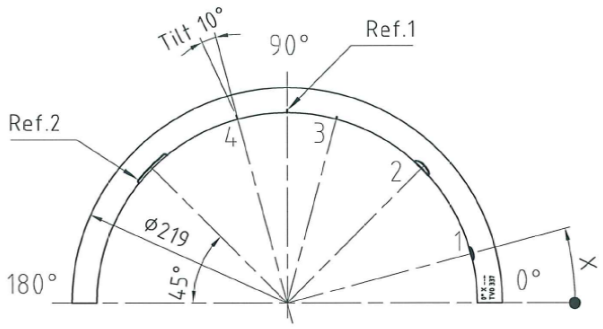


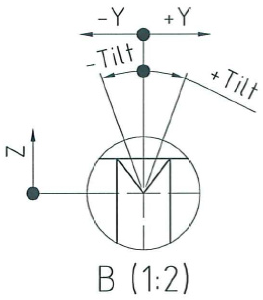
Block n°3 pipe/pipe qualification block – Defects data & block design

Defect No.	1	2	3	4
Det. B Scale 10:1				
Height	1.1	2	1.1	1.8
Length	6.0	9.5	6.8	10
X°/mm inside	15°/ 25 mm	45°/ 77 mm	75°/ 128.5 mm	105°/ 179 mm
Y	0	3.5	3.4	2.5
Z	0	0	0	0
Skew	0°	0°	0°	5°
Tilt	0°	0°	0°	10°
Type of defect	Crack	Crack	EDM	EDM
Orientation	Longitudinal	Longitudinal	Transverse	Transverse
Ground depth	1.4	2.2		









Block n°4 pipe/cast qualification block – Defects data & block design

4. NDT systems

A Zetec's OmniScan Phased Array equipment is used as ultrasonic equipment. The data collection system used is the OmniScan 1.4 version. The UltraVision 1.0 has been used for the data analyzing with standard lap top computer.

Manual MPS2 scanner (Inspecta) is used for the probe movements with one axis encoding for diameter range 60 to 100 mm.
Manual MPS scanner (Zetec) is used for the probe movements with two axis encoding for diameter range 100 mm and above.

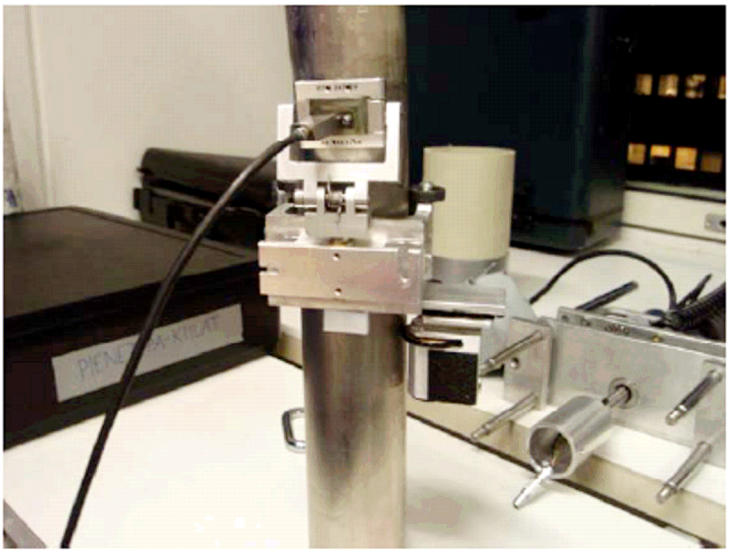


Figure 2: Installation of scanner MPS2

5. Results obtained

Open tests were executed on blocks n°1 to n°4.

On block n°2, with austenitic cast material on one side, no defects have been detected. In fact, the defects have been wrongly implanted only on cast side; consequently, the results given here after are only dealing with blocks n° 1, 3 & 4.

Results on Block n°1

Defect	**Orientation**[3]	**Detection**	**Positioning** Circumf.[1] (mm)		**Sizing**			
			Real	Meas.[2]	Length (mm)		Height (mm)	
					Real	Meas.[2]	Real	Meas.[2]
1	L	Yes	159	155	5	3	0,5	1,2
2	L	Yes	115	121	9	9	1,5	2
3	T	Yes	68	69	3,2	3	0,5	0,4
4	T	Yes	26	26	10	8,3	1,5	1,2

1) Circumferential, 2) Measured, 3) T = Transverse, L = Longitudinal

Results on Block n°3

Defect	Orientation[3]	Detection	Positioning Circumf.[1] (mm)		Sizing			
			Real	Meas.[2]	Length (mm)		Height (mm)	
					Real	Meas.[2]	Real	Meas.[2]
1	L	Yes	20	20	20	17	3,1	3,5
2	L	Yes	81	79	27,5	36	6,2	7
3	T	Yes	167	165	19,9	11,7	3,1	4,1
4	T	Yes	249	255	29,9	35	6,1	7,8

1) Circumferential, 2) Measured, 3) T = Transverse, L = Longitudinal

Results on Block n°4

Defect	Orientation[3]	Detection	Positioning Circumf.[1] (mm)		Sizing			
			Real	Meas.[2]	Length (mm)		Height (mm)	
					Real	Meas.[2]	Real	Meas.[2]
1	L	Yes	25	21	6,7	10	1,1	2,1
2	L	No[4]	-	-	-	-	-	-
3	T	No[4]	-	-	-	-	-	-
4	T	Yes	179	170	10	6	2	2,7

1) Circumferential, 2) Measured, 3) T = Transverse, L = Longitudinal

4) Defects located only on cast side

Achieved status bases on the "open tests" results:

Based on the results of open tests given here above it can be point out that the inspection objectives are generally achieved concerning detection, sizing and positioning.

For blocks n°1 & 3 and whichever the orientation of defects (longitudinal or transverse) all the defects are detected and sized within the range of tolerance.

For blocks for n°4 the defects totally or partially located in pipe side are detected and sized (height) within the range of tolerance. The defects, or part of defects, located in the cast side are not detected.

At this stage, the qualification doesn't cover austenitic pipe to cast weld inspections for the defects part which are located on the cast side.

6. Conclusions

The UT In Service Inspection of auxiliary and secondary piping welds of Olkiluoto EPR™ has been qualified according to the principle of extension of pre-existing ENIQ qualifications.

This approach permits to alleviate the qualification effort but keeps the high level of confidence on the process followed.

The only restriction noted concerns the defects, or part of defects located in cast side, which are not detected. On this point, we are still looking for possible improvement through new technical developpements.

As a part of the qualification, the equipment Zetec Omniscan with data acquisition system Omniscan 1.4 and analyzing software Ultravision 1.0 have been checked and accepted together with the inspection procedure.

These good results are due, notably, to the skill and knowledge of UT specialists. Thanks also to phased arrays technology used, where the probes are operated in order to get optimized conditions of examination (UT beams adaptability).