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Qualification works for the mechanized Pre-service Inspection (PSI) for the Primary Circuit of the new European Pressurized Water Reactor (EPR)

Jürgen LAUBE [1], Frederic LASSERRE [2], Guenter GUSE [3], Jean Michel TCHILIAN [4]

[1]« intelligeNDT Systems & Services» an AREVA and SIEMENS Company; Erlangen, Germany ;
Phone : +49 (0) 9131 1893046; e-mail : juergen.laube@intelligendt.de

[2] « Mines & surveillance » department, Plant sector, AREVA Nuclear Power ; Paris, France ;
Phone : +33 (0)1 34 96 87 91 ; e-mail : frederic.lasserre@areva.com

[3]« intelligeNDT Systems & Services» an AREVA and SIEMENS Company; Erlangen, Germany ;
Phone : +49 (0) 9131 1892309; e-mail : guenter.guse@intelligendt.de

[4] « Mines & surveillance » department, Plant sector, AREVA Nuclear Power ; Paris, France ;
Phone : +33 (0)1 34 96 87 93 ; e-mail : jeanmichel.tchilian@areva.com

Abstract

The first European Pressurised Reactor (EPR) is being built on the site of Olkiluoto (Finland).

The Finnish regulations of application impose that the Pre-Service and In-Service Inspections of the main primary components shall be performed with ultrasonic (UT) and Eddy current (ET) systems qualified according to ENIQ (European Network for Inspection Qualification) methodology. The scope of inspection is defined on the bases of ASME XI standard. Therefore the scope of qualifications will cover nearly 50 different inspection configurations in view of geometry, material and inspection targets.

This paper aims at presenting the qualification process followed and at giving information and results on one of its applications: the qualification of UT system devoted to the examination of the surge line circumferential welds.

IntelligeNDT System and Service GmbH, an AREVA and Siemens Company, is in charge of this work, in collaboration with the “NDT sub division” of the “Mines & Surveillances” department of AREVA NP.

Enhanced UT acquisition and analysis tools based on phased arrays technology and SAPHIR^{Plus} - UT platform are used.

Keywords: EPR, ENIQ, PSI Qualification

1. Introduction

The Finnish regulatory guide Y.V.L 3.8 describes the requirements which need to be fulfilled in order to qualify inspection systems and personnel for the pre-service inspection in Olkiluoto.

For the main primary components, the scope of inspection areas shall be selected according to ASME XI code clause IWB/ IWC and the qualification of the inspection systems shall be performed according to ENIQ recommendation guides.

The qualification process consists in several steps which aim at demonstrating that the equipment and personnel involved in are suitable qualified to fulfil the inspection objectives according to the related safety requirements.

The surge line circumferential austenitic welds are one type among nearly 50 safety class 1 areas of the main primary components to examine.

For these welds, the operation of the input and output data at each stage of the qualification follows the general qualification process; it is summarised in the present paper together with the practical results obtained.

The basis data are the input information established for each area to examine (which areas are presented in a PSI/ISI programme) according to regulatory guide lines. This information states on the inspection objectives, the characteristics of the component, the NDE means foreseen and all the lay-out data needed (accessibility, radiation level, …).

Among the inspection objectives the inspection target size, type and the examination volume are defined from ASME recommendations or domestic justification and feed back from experience.

The qualification process can be launched once the input information document released.

2. PSI / ISI Qualification

The main steps of the qualification process which is followed in the frame of OL3 is summarized[1] in figure 1.

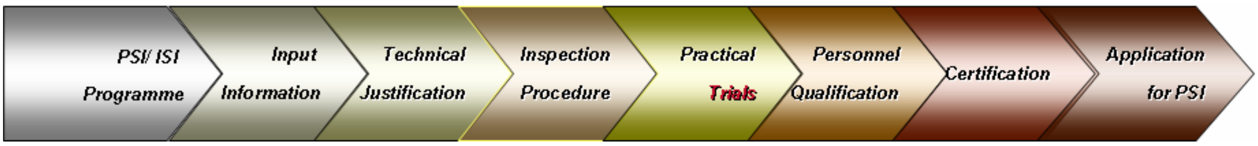

Figure 1. Qualification process

Concerning the surge line component, the PSI / ISI programme specifies a volumetric examination of all the austenitic circumferential butt welds located between the main coolant line and the pressurizer (see further). UT is retained as the volumetric examination technique.

Starting with the specification of the component and environment in the input information, a technical justification and first practical trials (so called “open tests”) are scheduled to demonstrate that the inspection procedure planed to be used with the given equipment (preliminary described in the input information document as well) is appropriate enough to fulfil the inspection objectives.

A second set of practical trials (the “blind tests”) are done for the personnel qualification (by using the already qualified procedure).

Finally, certification is requested to the Qualification Body before to be allowed to apply the equipment and the personnel to PSI (and later on ISI).

The procedure demonstration is performed considering qualification targets which shall be representative and in coherency with the inspection targets.

For the main primary components, mostly, no degradation mechanism can be postulated because of the new enhanced EPR design. This statement does lead to “conventional” type (neither specific nor postulated defect) qualification to handle with artificial qualification targets.

However, in order to demonstrate the capabilities of the equipments on real configurations, a physical process of degradation (in most cases fatigue cracking) has been considered for both the technical justification and the practical trials (see here after).

3. Input information

According to the related Finnish guide line, the data mentioned in the input information documents (generally one document per same type of zone to be inspected) are devided in the following parts :

- Qualification level,
- component description,
- inspection system to be used (preliminary data),
- inspections objectives,
- defect analysis,
- personnel qualification.

3.1 Qualification level

For all the main primary components, including the surge line welds, the zones to be examined are of level 3 (the highest) regarding the safety classification.

3.2 Component description

The component and area to be examined is described in the input information document in terms of geometry (dimensions and shape), material, manufacturing, surface state, inspection conditions (lay-out, accessibility, radiation and temperature environment).

The EPR surge line spool connecting the pressurizer to the main coolant line comprises 7 circumferential austenitic welds (see schematised for example the location of the "SL_20" pipe to pipe weld in figure 2).

All the seams are of automatic narrow groove TIG welding type. The parts of 316L and 304L grade materials are forged.

For the set of surge line welds, the outside surface geometry may vary but allows nevertheless in all cases (according to one of the specific basis requirements for the design) the performance of the control.

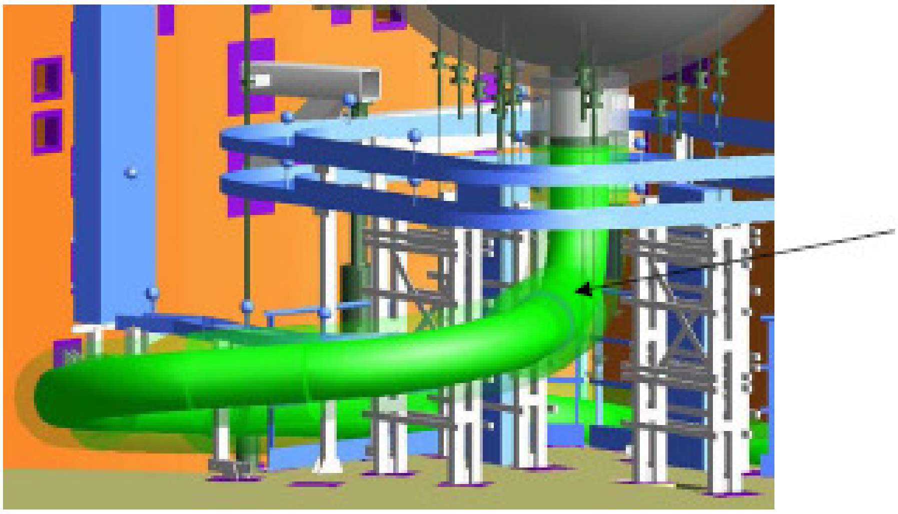

Figure 2. Location of one of the circumferential welds ("SL_20") on the surge line upper part

3.3 Inspection system

The system which is planed to be used is briefly described in the input information document in terms of manipulator features, probes characteristics, acquisition and analysis devices.

This information is useful either to anticipate the further qualification tasks (technical justifications, accessibility lay-out, …) and to give a first information of the delivery tool.

For surge line examination, the common iNDT's pipe manipulator "BH70" is used.

A guide rail system (adapted to the radius of the pipes as shown on the figure 3) enables the mechanized examination from the outside of the circumferential welds of the surge line.

Remote controlled operation of the movements will allow scanning of the inspection area and acquisition and storage of the inspection data for analysis.

The outer scanning path positions and the increment can be pre-selected, the scanning procedure will run automatically within preset limits. The speeds of the 2 coordinate movements are continuously variable.

UT data are acquired through Phased Arrays probe assemblies and processed with the "SAPHIR^{Plus}" UT system.

For the surge line welds examination, the four(4) Phased Arrays transducers (both direction of propagation for longitudinal defect detection and for transversal defect detection) are "2x8" elements probes, SEL 2 MHz type, which enable "customization" of the UT beams (e.g. refraction angles from 35° to 70°) in relation to the detection objectives.

The "SAPHIR^{Plus}" work station[2] provides several ways of displaying the processed UT data.

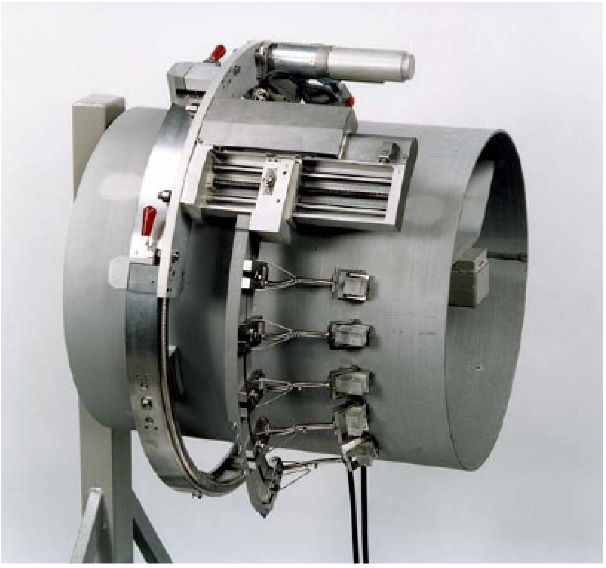

Figure 3. Surge line UT manipulator

3.4 Inspection objectives

The input information documents also list the objectives of the pre-service and the in-service inspections, which will be taken back for the qualification process as well. The main inspection objectives specified are, still according to the guide lines :

- the defect properties,
- the volume to be inspected,
- the detection target (size to be detected and characterised),
- the inspection tolerances,
- the other objectives.

For the surge line welds examination, the inspection objectives are illustrated with the table 1 and the figure 4 (for the inspection volume).

In most cases, the inspection target size is based on the ASME XI IWB-3500 tables which define the acceptance criteria. An appropriate height/length ratio (“a/l”) is set as well.

For the surge line, the ASME XI table IWB 3514-2 is of application and a value “a/l” = 0,3 is retained as appropriate due to feed back from experience and engineering judgement.

Only surface breaking planar type flaws are considered. The related inspection target size calculated from ASME acceptance criteria tables is equal to 3x17 mm.

In the present case of surge line inspection, the detection target is the inspection target (as the inspection target dimensions come from the ASME XI acceptance flaw sizes, it is assumed that the suitable margins are already taken into account).

The inspection objectives in terms of sizing and positioning accuracies are defined from the ASME XI appendix VIII recommendations.

3.5 Defect analysis

The defect properties are illustrated in table 1 when applied to the surge line inspection.

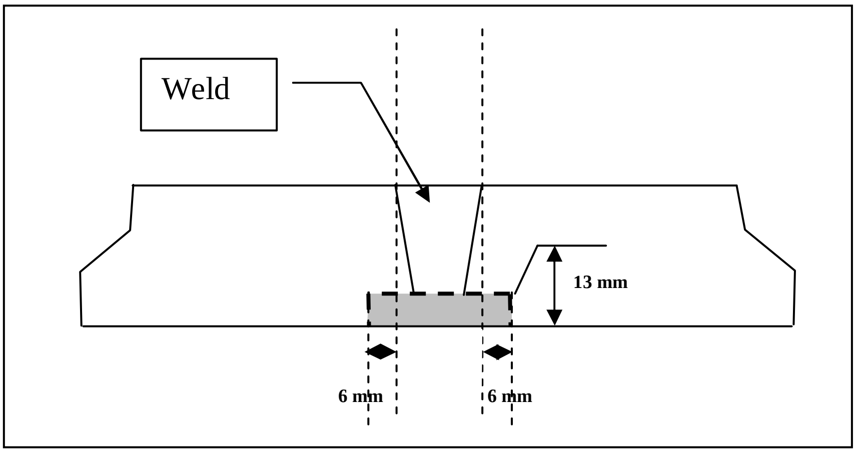

Figure 4. Surge line volume of examination

The tilt angle ranges values for example are determined to cover a possible disorientation when the defect is likely to grow up in the direction of the weld bevel orientation, namely in the heat affected zone (HAZ).

Here, as for most of the components, no degradation mechanism is postulated (thermal inappropriate event or behaviour for example have been justified and left out).

Nevertheless, in order to demonstrate the capabilities of the equipment to handle real flaws, fatigue cracking is considered in the input data and in the qualification process (some flaws of this kind are integrated in the qualification blocks).

3.6 Personnel qualification

NDT personnel involved are qualified according to EN 473 standard. Namely, for data evaluation, it shall be of at least level 2.

Personnel performing the PSI must also pass the OL3 specific qualification on the blind test blocks.

Supporting personnel should have adequate knowledge and certification (e.g. data collection personnel level 1 certification).

For equipment operator (e. g. manipulator operator), no NDT certification will be necessary, but training is done.

These requirements are applied in each type of qualification, including for instance the Surge line welds inspection.

4. Inspection procedures and Technical justification

The inspection procedures for all the examinations to be performed must be qualified. This is done by demonstrating that these procedures used with the devoted equipments are able to fulfil the requirements of the input information, namely the inspection objectives.

This demonstration is made in the Technical Justification Dossiers ("TJD").

The evidence must be given by means of theoretical and parametric studies, experimental trials or feed back from experience and is afterwards assessed during the open qualification tests; this process qualifies the procedure and establishes in parallel the capabilities of the equipment.

The final checking steps on the "open tests" blocks ends the qualification demonstration (balancing of the capabilities justified with or without practical tests is also part of the TJD's).

In a second step, once the equipment and procedure qualified, the operators for PSI/ISI work (see previously) must pass "blind tests" with the qualified means to validate their NDT skills.

For the surge line qualification, the performances of the UT equipment and procedure which have been demonstrated are summarized in table 2.

The capabilities for the equipment and procedure operated to fulfil the inspection objectives are thus widely demonstrated in the TJD.

The surge line examination procedure describes how to use the different propagation laws of each of the four phased arrays probes in order to detect, size (height and length, by tip diffraction detection analysis) and characterize the indications.

No specific threshold is prior defined; the maximum allowable dynamic down to the noise level is considered, in relation with the performance of detection of the reference defects.

5. NDT systems

The inspection systems used for OL3 inspection are made of manipulators and UT equipments. The "SAPHIR^{Plus}" system (which has already been described worldwide[2]) enables the use of classical or phased arrays probes.

The probe system configuration applied to the surge line examination is shown in figure 5.

6. Qualification blocks

For each group of qualification, several open and blind test blocks are designed and manufactured.

Blocks are representative of the part of interest (geometry, material, welding process…) and contain defects (artificial and realistic).

The surge line open test block is shown as example in the figure 6 (452 mm length, 410 mm OD and 40 mm thick, including an on-site type weld).

It has been design and manufactured from a real surge line pipe and contains EDM notches and mechanical fatigue cracks (longitudinal and transversal) of numerous sizes (see the flaw population of the open block in the table 2).

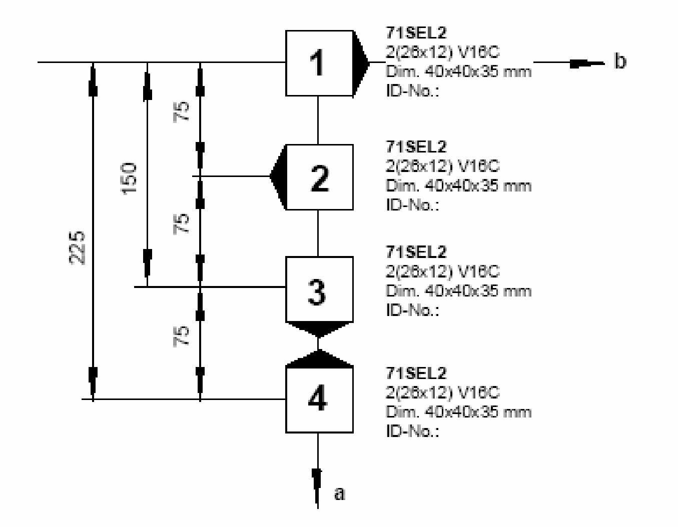

Figure 5. Probe configuration for Surge line examination

7. Analysis and results. Open tests

In the case of the surge line examination, the qualification results on the open test bloc are gathered in the table 3 (blind tests are in progress).

The results have been obtained and verified by following step by step the process as described within the specific UT inspection procedure for this component developed by our NDT specialists.

Figure 6. Surge line open test block

PARAMETER	VALUE
Defect properties	
Type	Crack
Degradation mechanisms	Mechanical fatigue
Shape	Undefined
Through-wall position	Inner surface
Axial position	Most likely in the HAZ
Tilt angle	0° ± 17° (Longitudinal defects) 0° ± 10° (Transversal defects)
Skew angle	0° or 90° ± 5°
Roughness/branching	Smooth or rough surface, not branched
Orientation	Transversal or longitudinal
Presence of residual stress	Inner surface : tensile stress
Content of the defect	Air or water
Detection target (Height x length) size	3 x 17 mm^2
Inspection accuracies	
Maximum Height sizing and depth positioning error	3,2 mm
Maximum Length sizing error	19 mm
Maximum Location error	3,5° ; 10 mm
Other objectives	
Type of characterization	Planar recognition
False calls	No false call unmanaged

Table 1. Inspection objectives for the surge line welds.

8. Conclusion

In the frame of the OL3/EPR project, the PSI/ISI performance is a challenging mix of reference fields : according to the Finnish YVL regulation guides, both ASME XI (for the scope of inspection) and ENIQ type (for the procedure, equipment and personnel qualifications) requirements must be fulfilled.

When in accordance, these combined rules however lead to strong safety insurance supports and guides, made of a well boarded knowledge of the capabilities of the NDE systems used.

No	Type of defect	Orien.	xPosition [°]	yPosition [mm]	zPosition [mm]	Height [mm]	Length [mm]	Tilt / Skew [°]
1	Crack	L	45	-12	ID	2	15	0/0
3	Crack	L	80	0	ID	3	15	0/0
5	Crack	L	120	0	ID	5	18	0/0
7	Crack	L	160	12	ID	8	26	0/0
9	EDM	L	245	3	ID	10	29	0/0
11	EDM	L	290	2	ID	3	17	10/10
13	EDM	L	334	7	ID	13	40	17/0
2	Crack	T	60	0	ID	2	15	0/0
4	EDM	T	99	1	ID	3	17	10/0
6	Crack	T	140	0	ID	5	15	0/0
8	EDM	T	219	0	ID	10	25	0/0
12	EDM	T	309	3	ID	5	17	10/10
15	Vol.	-	25	0	Root	3	3	-

Table 2: surge line open test block – flaw population

Positioning	Requirement	Test result
Longitudinal flaws	±10 mm	±3 mm ax / ±3 mm circ.
Transversal flaws	±10 mm	±2 mm / ±1 mm

Length	Requirement	Test result
Longitudinal flaws	±19 mm	-7 / +11 mm
Transversal flaws	±19 mm	-7 / +4 mm

Depth	Requirement	Test result
Longitudinal flaws	±3,2 mm	±1 mm
Transversal flaws	±3,2 mm	-1,5 / 0 mm

Table 3. Summary of the surge line equipment and procedure performances.

In the case of the surge line examination, this has led to a qualification successfully passed, the devoted procedures and equipment having fulfilled all the inspection objectives.

These capabilities are due, between others, to the strength of the engineering knowledge of UT specialists, phased arrays technology used, where the probes are operated in order to get the most optimized conditions of examination (UT beams adaptability).

The same qualification process is being applied to the other areas of main primary components.

Despite of the obvious amount of work, such framework finally gives confidence to contribute in the right way to the pre-service inspection of the EPR in Olkiluoto.

9. Bibliography

[1] ECNDT BERLIN 2006. “Getting ready for PSI in OLKILUOTO 3 on the new EPR power plant in FINLAND”

[2] ECNDT BERLIN 2006. “Experience with enhanced analysis tools based on UT-data collected with Saphir-UT system on complex geometries”