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Progress and effectiveness improvement of ISI for VVER type primary circuit components

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ABSTRACT In-service inspection (ISI) qualification programme in the Czech Republic is based on the Czech Round Robin Test and two Phare projects focused on ISI qualification of WWER 440-213 type components: reactor pressure vessel (RPV) and main primary piping components other than RPV. The manufacture of three test assemblies for RPV and five test blocks for other primary components with implanted defects is in progress. Performance of ISI qualificiation is intended for them.

INTRODUCTION

The importance of ultrasonic in-service inspections providing input data for WWER type Nuclear Power Plant (NPP) integrity assessment in conjunction with results and conclusions of the first phase of Czech Round Robin Test (RRT) consisting of blind trials on ultrasonic test assemblies focused on personnel performance conducted at Nuclear Research Institute Řež, plc (Division of Integrity and Materials) in 1993-1994 led to the need for in-service inspection qualification of critical primary circuit components. The ISI qualification programme has been started to be considered and prepared in the Czech Republic since 1995.

A REVIEW OF THE CZECH ROUND ROBIN TEST

A short review of the first phase of the Round Robin Test

The first phase of the Czech Round Robin Test (RRT), consisted of blind trials on ultrasonic test assemblies, focused on personnel performance. It was conducted at Nuclear Research Institute Řež, plc (Division of Integrity and Materials) in 1993-1994. The RRT consisted of blind test block trials and was performed on five test blocks simulating critical primary circuit components of WWER 440 (V-213) and WWER 1000 (V-320) type NPPs. The mock-ups, described in detail in [1], manufactured in Russia with implanted flaws simulating reactor pressure vessel (RPV) circumferential welds, clad/base interface and primary circuit pipes were inspected with manual and automated ultrasonic testing (UT) techniques. These blind test trials were conducted by seven teams from four countries (U.K., Hungary, Slovak Republic and Czech Republic). The details are presented in [1]. Automated inspections were performed by two teams only - by ŠKODA and Ois (G.B). The results showed that the possibility of occurence of low performance of UT team cannot be neglected. The test assemblies and implanted flaw specifications including the results of UT inspection teams were also assessed and comprised with the ASME Code Section XI Appendix VIII requirements. At the end of the first phase of RRT the results were partially verified by radiographic examinations of the specimens.

A brief review of the second phase of the Round Robin Test

The last two years approximately the Czech RRT continued in the second phase with automated inspections performed by two teams from Western Europe (Intercontrole and Siemens) under the EU contract. The test assemblies were the same as in the first phase conducted in the Czech Republic. The specifications of the test blocks are given as mentioned above in [1] in conjunction with some preliminary partial results from the first phase of the RRT. At present the second phase of the Czech RRT is finished at Siemens.

The third phase of the Round Robin Test

As the regional inspection vendors (ŠKODA Nuclear Machinery, Ltd resp. the inspection teams of Paks and Bohunice NPP) improved their ISI equipment and bought new advanced UT systems from AEA Technology resp. Siemens (SAPHIR) within the last year, it seems to be reasonable to finish the Czech RRT with automated inspections performed with these advanced UT systems. Final results of the RRT will be assessed, verified and published after destructive examinations of the test assemblies. The destructive examinations and especially the assessments of UT test trials results are expected to be conducted in cooperation with JRC IAM Petten. By this way it is possible to use the experience of JRC Petten as the reference laboratory of the PISC programme and to assess all the results according to the same rules and criteria.

PRESENT PROGRAMME OF ISI QUALIFICATION

Non-destructive testing procedures and techniques, and ultrasonic procedures and techniques in particular, used for in-service inspections of main components of WWER type NPP primary circuits have to be qualified for what concerns the minimum performance to be achieved.

Qualification schemes and qualification procedures will be elaborated within national and international projects which will be based on ENIQ Recommended Practices and focused on the inspection qualification of ISI and simultaneously will be elaborated under the support of PHARE projects, mentioned below, in accordance with the recommendations of the ENIQ methodology and with the trend of European attitudes to harmonization of codes and standards especially in the nuclear industry.

These qualification schemes relate to all the major aspects of tests: procedures, equipment and personnel. However, the majority of effort in the Czech Republic will be devoted to ISI qualification of inspection procedures and equipment. The part of ISI qualification devoted to practical examinations will be conducted within "open" test trials and the rest of work will be covered by technical justification.

The present phase of the inspection qualification programme is focused on performance demonstration capabilities of both ultrasonic testing equipment, ultrasonic techniques and in-service inspection procedures used or intended for inspections of both the WWER 440 and WWER 1000 critical primary circuit components. The background of this phase is based on the information gathered on current inspection rules and evaluation of results relating to manufacture, pre-service and in-service inspections and applicable procedures used for inspection of critical primary circuit components.

A PART OF ISI QUALIFICATION PROGRAMME BASED ON PHARE PROJECTS

A substantial progress in the implementation of ISI qualification methodology is in Czech Republic caused by the direct participation of Czech companies in internationally oriented activities like Phare regional projects. Nuclear Research Institute Řež, plc, ŠKODA Nuclear Machinery, Ltd. and other companies from the central Europe region participate in the 4.1.2/93 and 1.02/94 Phare projects focused on ISI improvement and NDT qualification at present.

Phare project 4.1.2/93

The project started in the autumn 1995. A brief description of the Phare 4.1.2/93 project is given in Table 1. Three test assemblies are manufactured in the project scope. All the test assemblies are provided with implanted flaws of two types. Majority of the defects are simulated by PISC type A defects. The rest of flaws consist of EDM notches. No practical examinations are planed in this project. A preparation for the ISI qualification will be finished with the elaboration of the appropriate qualification procedure. The test assemblies designed and/or manufactured in the project can be discribed as follows:

(a) WWER 440 nozzle to safe-end weld mock-up with two inspection areas: dissimilar weld and nozzle inner radius (see Table 2 and Table 3 for details)
material: 15Kh2MFA low alloy steel

(b) WWER 1000 type primary nozzle with austenitic cladding (primary nozzle of internal diameter of 850 mm, see Table 4)
one inspection area: nozzle inner radius
material: 15Kh2NMFA low alloy steel

(c) WWER 1000 simulated primary nozzle with homogenous weld (primary nozzle to primary piping with I.D. of 850 mm weld, see Table 4)
one inspection area: predominantly homogenous weld
material: 15Kh2NMFA low alloy steel

(d) WWER 440 type RPV test block with circumferential weld and clad/base interface
base metal: 15Kh2MFA low alloy steel

(e) WWER 1000 type RPV test block with circumferential weld and clad/base interface;
base metal: 15Kh2NMFA low alloy steel

A part of these test assemblies are to be provided with supplementary "weld repair" defects in the future. All the implanted defects (PISC type A defects and EDM notches) involved in this project are manufactured by JRC Petten/Ispra.

Table 1 - Description of the international project - Phare 4.1.2/93

Project characteristics	Description
Designation	WWER 440-213 IN-SERVICE INSPECTION
Selected component	WWER 440-213 Type RPV
Project type	PHARE 93
Project designation	Phare Regional Project 4.1.2/93
Main Beneficiary	Dukovany NPP (Czech Republic)
Co-Benefiaciaries	Bohunice NPP (Slovak Republic) Paks NPP (Hungary)
Contractor Consortium	Belgatom, S.A. leader
Consortium members	EdF, Siemens, Intercontrole
Western Subcontractor	JRC IAM Petten
Local Subcontractor	consortium NRI Řež, plc & ŠKODA Nuclear Machinery, Ltd (ŠKODA Jaderné strojírenství s.r.o.)
Consortium leader	NRI Řež, plc

Table 2 - WWER 440-213 type RPV test assembly with nozzle inner radius inspection area and implanted PISC type A defects

Inspection area: WWER 440-213 nozzle inner radius						
Defect type	Location	Notation	Defect orientation	Number of defects [1]	Defect length [mm]	Defect depth [mm]
underclad crack	interface base metal/cladding	A	radial	4	18-120	6-40
fatigue crack	cladding close to inner surface	B	radial	2	12-24	4-8
Total				6	12-120	4-40

Table 3 - Description of WWER 440-213 Type RPV test assembly with implanted defects

<table>
<tr><td colspan="5">Phare Regional Project 4.1.2/93
"WWER 440-213 IN-SERVICE INSPECTION"
Selected Component : WWER Type RPVs</td></tr>
<tr><td>Inspection area</td><td>Flaw type</td><td>Simulation type of real defect</td><td>Test assembly
-
Type of trials</td><td>Number of implanted defects</td></tr>
<tr><td rowspan="2">WWER 440 type 500 mm I.D. nozzle to safe-end dissimilar weld</td><td>fatigue cracks</td><td>PISC type A defect</td><td rowspan="2">for open trials intended and manufactured</td><td>9</td></tr>
<tr><td>lack of fusion type defects</td><td>EDM notch</td><td>11</td></tr>
<tr><td rowspan="2">WWER 440 type 500 mm I.D. nozzle inner radius</td><td>underclad (sub-clad) cracks</td><td>PISC type A defect</td><td rowspan="2">for open trials intended and manufactured</td><td>4</td></tr>
<tr><td>through-clad cracks</td><td>PISC type A defect</td><td>2</td></tr>
<tr><td rowspan="3">WWER 440 type circumferential butt weld</td><td>underclad (sub-clad) cracks</td><td>PISC type A defect</td><td rowspan="3">for open trials intended and designed</td><td>designed not yet manufactured</td></tr>
<tr><td>fatigue cracks in the weld root</td><td>PISC type A defect</td><td>designed not yet manufactured</td></tr>
<tr><td>lack of fusion type defects</td><td>EDM notch</td><td>designed not yet manufactured</td></tr>
</table>

Phare project 1.02/94

This project was started in the summer 1996. A brief description of the Phare 1.02/94 project is given in the Table 5. Five test assemblies are designed and manufactured in the project scope. All the test assemblies are provided with implanted flaws. Majority of the defects will be simulated by PISC type A defects. The test assemblies designed and manufactured in the project cover two T-pieces, steam generator shell to collector dissimilar weld and two circumferential welds (transition nozzle to main circulation pump elbow, primary circulation pipe to transition nozzle) together with appropriate calibration blocks involving base metal with weld, SDH (side drilled holes) and notches (see Fig.1 as an example). A preparation for the ISI qualification will be finished with the elaboration of the appropriate qualification procedure. Practical "open" examinations are intended in this project for all the five inspection areas.

Table 4 - Description of WWER 1000-320 Type RPV test assemblies with implanted defects

<table>
<tr><th colspan="5">Phare Regional Project 4.1.2/93
"WWER 440-213 IN-SERVICE INSPECTION"
Selected Component : WWER Type RPVs</th></tr>
<tr><th>Inspection area</th><th>Flaw type</th><th>Simulation type of real defect</th><th>Test assembly
-
Type of trials</th><th>Number of inserted defects</th></tr>
<tr><td rowspan="2">WWER 1000 type 850 mm I.D. nozzle to primary piping weld</td><td>fatigue cracks</td><td>PISC type A defect</td><td rowspan="2">for open trials intended and manufactured</td><td>8</td></tr>
<tr><td>lack of fusion type defects</td><td>EDM notch</td><td>9</td></tr>
<tr><td rowspan="2">WWER 1000 type 850 mm I.D. nozzle inner radius</td><td>underclad (sub-clad) cracks</td><td>PISC type A defect</td><td rowspan="2">for open trials intended and manufactured</td><td>5</td></tr>
<tr><td>through-clad cracks</td><td>PISC type A defect</td><td>4</td></tr>
<tr><td rowspan="3">WWER 1000 type circumferential butt weld</td><td>underclad (sub-clad) cracks</td><td>PISC type A defect</td><td rowspan="3">for open trials intended and designed</td><td>designed not yet manufactured</td></tr>
<tr><td>fatigue cracks in the weld root</td><td>PISC type A defect</td><td>designed not yet manufactured</td></tr>
<tr><td>lack of fusion</td><td>EDM notch</td><td>designed not yet manufactured</td></tr>
</table>

CONCLUSIONS

The Czech RRT, presented in the paper from the first phase in 1993-1994 to the third part intended to be performed this year, highlighted the need for in-service inspection qualification of critical WWER type primary circuit components in the Czech Republic. The Phare projects above mentioned can be regarded as the substantial contribution to the Czech ISI qualification programme. The reason for that is not only the manufacture of three test assemblies representing RPV inspection areas and five test mock-ups simulating critical inspection regions in the primary circuit components other than RPV, however, the transfer of know-how and technology related to ISI.

Table 5 - Description of the international project - Phare 1.02/94

Project characteristics	Description
Designation	IN-SERVICE INSPECTION OF WWER 440-213 PRIMARY CIRCUIT COMPONENTS
Selected component	main WWER 440-213 Type primary circuit components other than RPV
Project type	PHARE 94
Project designation	Phare Regional Project 1.02/94
Main Beneficiary	Dukovany NPP (Czech Republic)
Co-Benefiaciaries	Bohunice NPP (Slovak Republic) Paks NPP (Hungary)
Contractor Consortium	TECNATOM S.A. leader
Consortium members	VTT (Finland)
Western Subcontractor	JRC IAM Petten, IVO (Finland)
Local Subcontractor	NRI Řež, plc
Cooperation with manufacturers:	
piping	Modřany Piping Plant, plc (Czech Republic)
steam generator	Vítkovice plc POWER MACHINERY (Czech Republic)

Based on the experience received within the RRT and the two mentioned Phare projects the Czech Regulatory Body - SONS, utilities, manufacturers of nuclear equipment and vendors are considering a realistic approach to NDT inspection qualification with all the above mentioned aspects taking into account the difficulty, time and cost of implementation.

REFERENCES

1. Horáček,L., Žďárek, J., 1994. Preliminary Results from the NRI Programme on the NDE Reliability of WWER Materials. *Proc. of the Joint CEC IAEA Specialists Meeting on Non-Destructive Examination Practice and Results. State of the Art and PISC III Results:333-342* (EUR 15906 EN). Brussels-Luxembourg

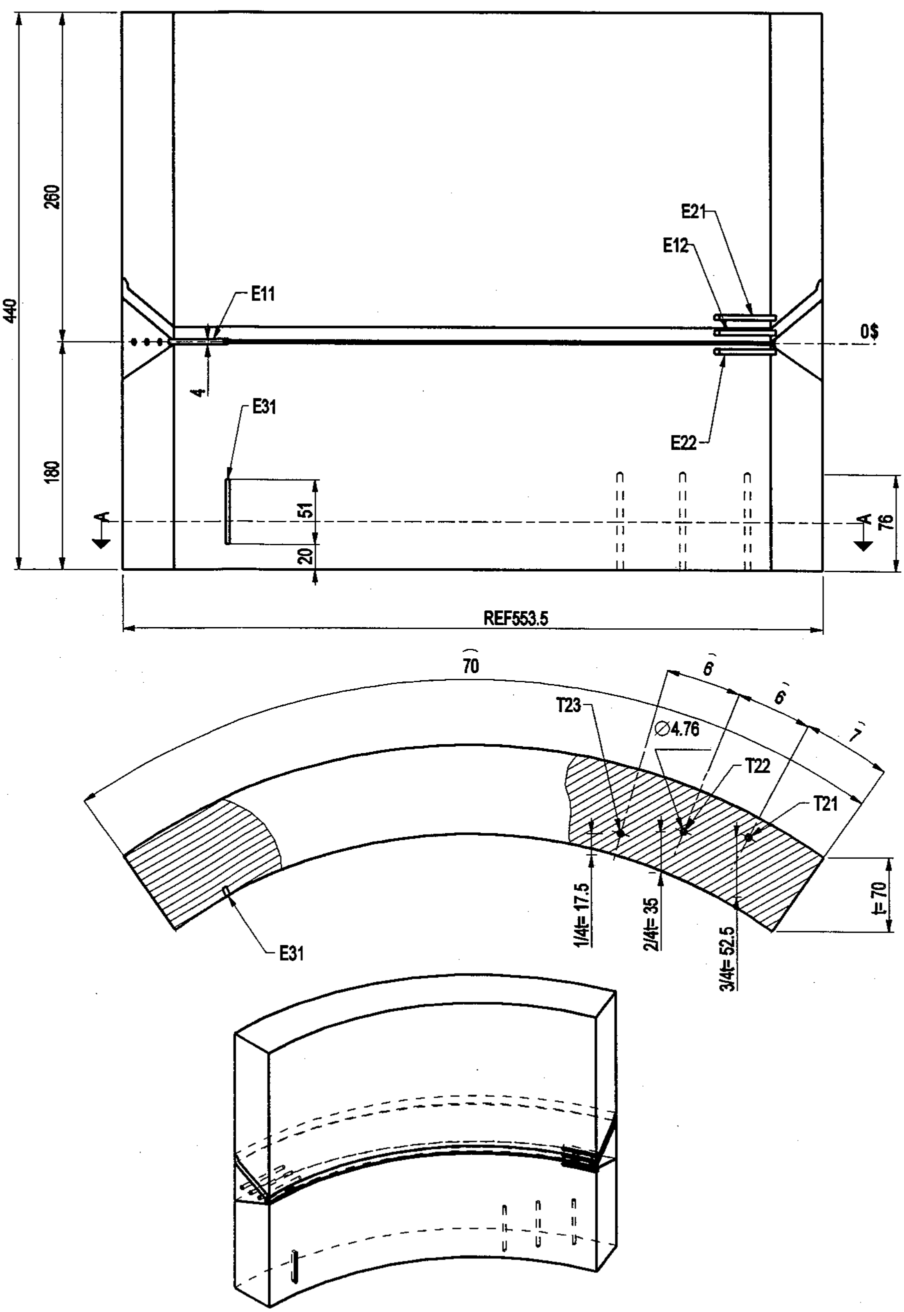

Fig. 1 - Calibration block of steam generator collector dissimilar weld