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PHARE NUCLEAR SAFETY

PROJECT PH8.01/99
Dissemination of the PHARE project descriptions and results
Technical assistance to the management of PHARE funded projects

PHARE PH1.02/94Project
In-Service Inspection of Primary Circuits Components
EXTENDED PROJECT SUMMARY

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SUMMARY

PROJECT PH1.02/94

In-Service Inspection of Primary Circuits Components

Main Beneficiary: Dukovany NPP (Czech Republic).
Two co-Beneficiaries: Bohunice NPP (Slovak Republic) and Paks NPP (Hungary).

OVERALL OBJECTIVE

The PHARE 1.02/94 project "In-service inspections of primary circuit components" was launched to improve the effectiveness of in-service inspections of WER 440 type NPPs in the Beneficiary countries towards the level of European practices

PARTNERS

The PHARE 1.02/94 project was awarded to a western consortium, composed as follow:

CONSORTIUM MEMBERS	TECNATOM	SPAIN - LEADER ORGANIZATION
	VTT	FINLAND
WESTERN SUB-CONTRACTORS:	IVO	FINLAND
	JRC	PETTEN, HOLLAND
EASTERN SUB-CONTRACTORS:	NRI	CZECH REPUBLIC

TECHNICAL OBJECTIVES

To optimise and develop mechanized inspection procedures for the most complex austenitic and dissimilar material welds and geometries and to perform qualification as per the ENIQ methodology.

TECHNICAL SCOPE

- Comparison and evaluation of ISI effectiveness,
- Provide a development program and planning,
- Supply of test blocks (open practical demonstrations) supply of inspection equipments,
- Supply of inspection procedures define training requirements,
- Define and perform inspection qualification evaluation of the improved ISI effectiveness,
- Revision by ENIQ and local safety authorities,

INSPECTION AREAS SCOPE:

- Pressurizer pipe to main circulation pipe weld.
- Safety cooling pipe to main circulation pipe weld.
- Steam generator transition weld.
- Transition nozzle to pump elbow weld.
- Transition nozzle to main circulation pipe weld

DELIVERABLES

- Report on ISI effectiveness
- Specifications for the procurement of test blocks
- Specifications for the procurement of NDE equipment
- Specifications for the procurement of calibration blocks
- Specifications for data processing and analysis system

- Inspection procedures and related work instructions
- Training requirements
- Specific qualification procedures
- Evaluation report: evaluation of the improved ISI effectiveness
- Test blocks and calibration blocks
- NDE equipment

IMPLEMENTATION PLANNING

TIME SCHEDULED:	24 MONTHS
TIME PERFORMED:	30 MONTHS
STARTING DATE:	JUNE 96
FINISHING DATE:	DECEMBER 98

OVERALL CONCLUSIONS

The qualification part of this project has met in general the objectives, which were set out at the beginning of the project.

The local sub-contractors and the beneficiaries have acquired a lot of practical experience on how to implement the ENIQ methodology for inspection qualification.

The 5 inspection systems (procedure/equipments) developed for the 5 inspection areas selected for this project were submitted to a qualification simulation exercise. This qualification exercise can be considered a success as it has allowed optimising considerably the inspection procedures.

A large part of this qualification exercise can be transferred directly to a national qualification scheme, if wished so.

FOREWORD

The safety of nuclear power plants is a primary concern of the European Union (EU) and its Member States. In the early 1990s, the European Union decided to take a prominent role in international efforts to help the New Independent States (NIS) and countries of Central Europe to ensure the safety of their nuclear reactors. The Commission's approach to nuclear safety in Central and Eastern Europe and the NIS is based on two main objectives, which are fully in line with the policy of the international community as decided by the G7 in 1992:

(i) In the short term, to improve operational safety; to make near term technical improvements to plants based on safety assessments and to enhance regulatory regimes;

(ii) In the longer term, to examine the scope for replacing less safe plants by the development of alternative energy sources and more efficient use of energy and to examine the potential for upgrading plants of more recent design.

The PHARE program, especially design safety projects aim at analysing major safety concerns regarding soviet-designed reactors, formulating appropriate solutions, and supporting their implementation. The effectiveness of in-service inspections of WER 440 type NPPs issue has been identified and was addressed in the PHARE 1.02/94 project "In-service inspections of primary circuit components" project. Five weld joints of primary circuit (other than reactor pressure vessel that was concerned in PHARE 93 project 4.1.2.) were defined as target areas for the project.

The main Beneficiary was Dukovany NPP (Czech Republic) and the co-Beneficiaries Bohunice NPP (Slovak Republic) and Paks NPP (Hungary).

The PHARE 1.02/94 project was awarded to a western consortium, composed as follow:

CONSORTIUM MEMBERS	TECNATOM	SPAIN - LEADER ORGANIZATION
	VTT	FINLAND
WESTERN SUB-CONTRACTORS:	IVO	FINLAND
	JRC	PETTEN, HOLLAND
EASTERN SUB-CONTRACTORS:	NRI	CZECH REPUBLIC

Tecnatom assumed the leadership of the project tasks and subtasks.

Local subcontractors were actively involved in carrying out specified project tasks and subtasks as established in the Work Plan.

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1 INTRODUCTION

The PHARE 1.02/94 project "In-service inspections of primary circuit components" was launched to improve the effectiveness of in-service inspections of WER 440 type NPPs in the Beneficiary countries towards the level of European practices.

Five weld joints of primary circuit (other than reactor pressure vessel that was concerned in PHARE 93 project 4.1.2.) were defined in the ToR as target areas for the project.

The main Beneficiary was Dukovany NPP (Czech Republic) and the co-Beneficiaries Bohunice NPP (Slovak Republic) and Paks NPP (Hungary).

Tecnatom as leader of the consortium and VTT Manufacturing Technology as a consortium member formed the project consortium. Tecnatom subcontracted Joint Research Centre of EU (JRC Petten) as a key organization on developing the European qualification of NDT methods. Nuclear Research Institute in Czech Republic (NRI Rez) was subcontracted as a local organization and it subcontracted further local experienced nuclear industry companies, which provided workshops for manufacturing of test and calibration blocks. VTT subcontracted IVO Power Engineering and IVO Technology Centre that are parts of the IVO Group operating two VVER units in Finland.

2 OBJECTIVES

The overall project objectives was to optimise and develop mechanized inspection procedures for the most complex austenitic and dissimilar material welds and geometries and to perform qualification as per the ENIQ methodology.

The project objectives set, within the framework of In-service Inspection /Non-destructive Examination (ISI/NDE), was summarized as follows:

- Assessment of effectiveness of NDE procedures able to be used for In-Service Inspection (ISI) of primary circuit components (other than RPV), based on an improved ISI programme;
- Definition and supply of test assemblies and calibration blocks representative of five selected inspection areas;
- Define qualification procedures and perform the qualification exercises for five selected inspection areas;
- Presentation of the ISI efficiency improvement and NDE qualification results to safety authorities and to the reviewers.

These objectives concern 5 inspection areas, which have been selected according to the Safety relevance. Considering that the use of realistic test blocks is of vital importance for the project and reviewing the available sound material suitable for manufacturing these blocks, the inspection areas included in the scope of the project have been finally defined as:

1) Pressurizer pipe to main circulation pipe weld: austenitic weld between Ø 245 mm nozzle and Ø 500 mm pipe.

2) Safety cooling pipe to main circulation pipe weld: austenitic weld between Ø 108 mm nozzle and Ø 500 mm pipe.

3) Steam generator transition weld No 4.3.1: dissimilar butt weld between austenitic and ferritic steel pipes Ø 1245 mm with wall thickness 74 mm collector sections.

4) Transition nozzle to pump elbow weld: austenitic weld between elbow and transition nozzle both having nominal Ø 646 mm and wall thickness 71 mm.

5) Transition nozzle to main circulation pipe weld: austenitic weld between pipe and transition nozzle both having nominal Ø 566 mm and wall thickness 35 mm.

3 IMPLEMENTATION

3.1 Assessment of the improved ISI system effectiveness

The project activities and the main results were presented in the project final report [1].

The evaluation of the improved ISI effectiveness was performed through the following subtasks:

- Definition of applicable Codes and Standards
- Identification of usual and probable defects
- Define acceptance criteria based on applicable Codes and Standards
- Define flaw detection and sizing acceptance criteria with Western requirements
- Produce Calibration and test blocks
- Specify and produce the inspection equipment
- Specify Inspection techniques and prepare Inspection procedures

3.1.1 Definition of applicable Codes and Standards

The main NDE methods applied at in-service inspections of Beneficiary NPPs were liquid penetrant and visual testing. Ultrasonic testing had been applied to some extent according to ASME XI code at Bohunice NPP only.

As the intention of the project was to implement volumetric UT method to the target inspection areas, no local codes could be identified as relevant.

After a short review to the ASME code and to the European codes (German KTA 3201.4 and French RSEM) it was agreed that ASME XI would be used as a guideline to specify the inspections. It was also agreed that qualification would not be performed according to ASME XI Appendix VIII but European Methodology (ENIQ) would be used as a guideline.

3.1.2 Identification of usual and probable defects

The Beneficiary NPPs compiled known defect information and also their opinions about the probable defects in each inspection area.

IVO Loviisa NPP delivered defect information about the comparable inspection areas. Finally no service-induced defects were reported by the NPPs in the target areas.

The table bellow summarizes the findings concerning postulated and specific defects according to ENIQ Methodology (specific, postulated and unspecified defects).

Area N°	Postulated defects	Specific defects
1	• radial fatigue crack in nozzle inner radius [1)] • circumferential fatigue crack in weld root	• lack of fusion in groove faces
2	• radial fatigue crack in nozzle inner radius • circumferential fatigue crack in weld root	• lack of fusion in groove faces
3 [3)]	• circumferential fatigue crack in root area in base metal (nearby the. lack of fusion in groove buttering boundary) [2)] • circumferential fatigue crack in root area in buttering boundary	• lack of fusion in buttering boundary • lack of fusion in groove faces
4	• circumferential fatigue. lack of fusion in groove crack in weld root faces	• lack of fusion in groove faces
5	• circumferential fatigue. lack of fusion in groove crack in weld root faces	• lack of fusion in groove faces

Notes:

1) radial crack can grow towards the weld and finally be an axial crack of weld

2) galvanic corrosion of base metal nearby the buttering can be simulated by local grinding of base metal in test block (not considered in qualification)

3) inspection volume should cover that volume which is possible to inspect

3.1.3 Definition of acceptance criteria

The calculation of acceptable defect sizes for the five inspection areas was performed by IVO based on available limited input data.

The final acceptable defect sizes (calculated according to ASME XI) that have been achieved are (Circumferential/Axial):

1. Pressurizer Pipe to Main Circulation pipe weld - 20mm/17mm
2. Safety Cooling Pipe to Main Circulation pipe weld - 12mm/13 mm
3. Steam Generator Transition weld - 25mm/n.a.
4. Transition Nozzle to Pump Elbow weld - 26mm/22mm
5. Transition Nozzle to Main Circulation pipe weld – 11mm/15mm

3.1.4 Definition of flaw detection and sizing criteria

The defect sizes to be detected with 100% confidence have been calculated from the critical crack sizes by subtracting the maximum allowable depth sizing error.

Using this approach the basic detection and sizing acceptance criteria were defined.

3.1.5 Calibration and test blocks produced

The objective of the project was to produce calibration and test blocks for each inspection area using materials with the same properties and the same dimensions as the real components in the main Beneficiary NPP (Dukovany NPP).

This objective has been met nearly completely. Only exception was made in the inspection area 3 (Steam generator dissimilar weld) where the used rings had slightly smaller diameter than the real component and also, only a part of the welded ring was available to produce combined calibration and test block of inspection area 3. This limitation decreased number of defects to be fabricated in this block.

The dimensions of the calibration reflectors were chosen according to Section XI and Section V of ASME Code, 1995 Edition.

3.1.6 Test equipment specified and delivered by the project

The inspection approach developed in the project was based on a volumetric inspection by mechanized ultrasonic inspection of each target area. Therefore three specific scanners were specified, developed and delivered during the project.

The scanner PET-1 was delivered to be used for the inspection areas 1 and 2.
It can be mounted on the smaller diameter pipes of these inspection areas and move around this pipe. The scanning arm is designed to be able to move the UT probe in perpendicular direction to the weld on the main circulation pipe.

The PISA scanner was delivered to be used in the inspection area 3.
Due to the design of the collector lower end, there is no space on the collector for the scanner and an auxiliary guide ring has been necessary. Scanner is able to move on the auxiliary guide ring round the collector on magnetic wheels and to perform scans perpendicular to the weld.

The scanner PET-2 was delivered to be used in the inspection areas 4 and 5.
In this inspection area an auxiliary guide ring was manufactured to be mounted on the transition nozzle. Moving on this ring around the inspection area scanning on both sides of the nozzle part is possible and both inspection areas can thus be covered.
In later phases of the project it was seen necessary to scan also on the conical part of the nozzle and an additional support ring was manufactured to be mounted on the main circulation pipe.

SIROCO is the remote control system delivered for all the scanners.
The control provides a capability for performing trajectories implying sequential and (or) simultaneous movements on any of the axes, up to the maximum number of six.
Tecnatom S.A produced the scanners PET-1 and PET-2 and SIROCO controller as a part of the project.
IVO Technology Centre manufactured the PISA scanner.

The delivered equipment includes also six ultrasonic probes.

3.1.7 <u>Inspection techniques and procedures</u>

The development of the inspection techniques and compilation of procedure for each inspection area was performed in several stages:

- The procedures have been written with procedures of ENIQ Pilot Study as a model.
- After the mock-ups of the inspection areas were finished the inspection techniques and procedures were optimised.
- The scanners and inspection technique have been tested, using the mock-ups and the necessary changes made.
- Using optimised procedures a full data acquisition was made and inspection results analysed. This data was included in the Technical Justification to show the capability of the developed inspection techniques.
- At the end of the optimisation process the staff of NRI was trained on the application of each inspection procedure.
- Finally a simulated qualification of the procedures and their application on the test blocks was made. For such action, the role of the qualification body was taken by the personnel of JRC and Beneficiary NPP and the staff of NRI was playing the role of the Inspection vendor performing the data acquisition and analysis.
- The final versions of the inspection procedures were issued after qualification simulation and the remarks made at the qualification simulation were taken into account.

3.2 Application of Qualification Approach

A qualification procedure, based upon the general principles as given in the second issue of the European Methodology for Qualification of Non-Destructive Tests (ENIQ), has been written specifically for this project.

The inspection qualification approach consisted of assessing the technical justification that was written in support of the inspection procedure and equipment, and conducting open test piece trials

3.2.1 <u>Assessment of the Technical Justification</u>

The technical justification identified correctly the 5 inspection areas and there is a thorough review of the essential parameters in agreement with the ENIQ European methodology and the ENIQ recommended practices 2 and 3 on technical justification.

It is important to stress that some essential parameters related to the component have not been verified on site. There is, for example, no evidence on the macrostructure of the qualification test pieces. The evidence given in support to the capability of the inspection procedures is almost mainly based upon laboratory trials performed on open trials test pieces. The technical justification was concluded with a section in which different limit cases for defects were identified and the evidence given is related only to surface-breaking fatigue defects.

3.2.2 Open test piece trials

The qualification trials were extensively conducted for the 5 inspection areas.

3.2.3 Conclusions on the application of the Qualification approach

1.) It is important to note that the inspection areas, which were selected for this project, do not belong to easy inspection cases due to both the material characteristics and the geometry.

2.) The inspection qualification results obtained are only valid for surface-breaking fatigue cracks. In view of the difficulties encountered with the implantation technique used for fatigue cracks the results obtained for these implanted cracks (only a limited number) were not considered[1].

3.) Concerning the evidence on the capability of the different inspection procedures to meet the different ISI objectives the following conclusions can be drawn:

Detection and length sizing

- For inspection areas 1, 2, 3 and 5 sufficient evidence was provided for detection and length sizing that the submitted inspection procedures allow to reach the ISI objectives.
- For inspection area 4, which has a particular difficult geometry and considering the related limitations, the submitted inspection procedure can be used for detection[2].

Depth sizing

- Sufficient evidence has been provided for inspection areas 1,2 and 5 that the ISI objectives can be reached[3].
- Despite the fact that the ISI objectives were met for depth sizing for inspection areas 3 and 4, one should pay attention to not put too much confidence in the depth sizing capabilities, due to the intrinsically difficult geometry of these inspection areas.

False call performance

- The false call performance is directly related to the capability of the inspection team to distinguish geometrical indications from indications due to real defects. Although the inspectors have their capability to do so, but it is recommended that the criteria to make that distinction are more clearly given in the inspection procedure.
- It is also very important to have a good fingerprint of the qualification test pieces in order to ensure that unintended defects do not give rise to misinterpretations.

4.) There is the need to define an additional ISI objective for location of the defect along the X-axis of the components.

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[1] The problem of the use of implantation techniques in austenitic welds is a general problem for inspection qualification.

[2] Study might be done to determine more in detail the influence of the geometry.

[3] There is an important limitation for inspection area I due to the fact that the geometry of the test piece does not allow to size defects in through- wall extent larger than 16 mm.

5.) In this project the main emphasis was put upon the verification of the capability of the inspection procedures. For a real in-service inspection it will also be necessary to pay attention to the following quality assurance issues:

- Probe characterization program
- Develop a correct filing system for the data acquisition files
- Personnel qualification / certification[4] along the requirements of the inspection procedure

3.3 Overall conclusions

The qualification part of this project has met in general the objectives, which were set out at the beginning of the project.

The local sub-contractors and the beneficiaries have acquired a lot of practical experience on how to implement the ENIQ methodology for inspection qualification.

The 5 inspection procedure/equipments developed for the 5 inspection areas selected for this project were submitted to a qualification simulation exercise. This qualification exercise can be considered a success as it has allowed optimising considerably the inspection procedures.

A large part of this qualification exercise can be transferred directly to a national qualification scheme, if wished so.

4 PROJECT EQUIPMENT AND SPECIFICATIONS DELIVERIES

4.1 Main NDE equipment

The following scanners and electronic controller were delivered within the scope of this project:
Mechanized scanner: PET I (Pipe Equipment of Tecnatom 1)

- Mechanized scanner: PET 2 (Pipe Equipment of Tecnatom 2)
- Mechanized scanner: PISA (Mechanized Inspections for Pipe and Nozzles)
- SIROCO Electronic Controller and three power interfaces, one for each of the above scanners.

The PET mechanized scanners have been designed and manufactured by Tecnatom, S.A. The PISA mechanized scanner has been designed and manufactured by IVO Technology Centre. The SIROCO Electronic Controller and the three Power Interfaces have been designed and manufactured by Tecnatom, S.A.

[4] There is the need to have a formal personnel qualification / certification system. It is a matter that has to be decided at the level of the individual beneficiary countries.

4.2 Other deliverables

- Time schedule, work plan and QA program
- Report on ISI effectiveness
- Specifications for the procurement of test blocks
- Specifications for the procurement of NDE equipment
- Specifications for the procurement of calibration blocks
- Specifications for data processing and analysis system
- Inspection procedures and related work instructions
- Training requirements
- Specific qualification procedures
- Evaluation report: evaluation of the improved ISI effectiveness
- Test blocks and Calibration blocks
- NDE equipment

5 LIST ABBREVIATIONS

AOV	Air Operated Valve
BRU-A	Steam Dump to the Atmosphere Valve
ENIQ	European Network for Inspection and Qualification
IAEA	International Atomic Energy Agency
ISI	In-service Inspection
JRC	Joint Research Center
NRI	Nuclear Research Institute
NPP	Nuclear Power Plant
NTD	Non Destructive Test
RCS	Reactor Coolant System
QA	Quality Assurance

6 REFERENCES

[1] PHARE 1.02/94 project "In-service inspections of primary circuit components", Project Final Report, TECNATOM & VTT, December 1998