ABSTRACT

The EU policy objectives that have been implemented through the programmes of PHARE, TACIS and its successor, the Instrument for Nuclear Safety Cooperation (INSC), focused on the promotion of an effective nuclear safety culture in line with the principles of the Convention on Nuclear Safety, in particular through continuous support for regulatory bodies and, at the plant level, through on-site assistance, including equipment supplies, where such assistance is most needed. Since 1991 the European Commission has launched, through the external action programmes, a number of projects that aimed at providing know-how and technological support to develop the Beneficiary country's internal capabilities in order to enhance the existing plant programmes for maintenance, In-service inspection (ISI), equipment qualification and ageing management for structures, systems and components important to safety.

These projects were components of the Tacis and PHARE programmes related to the On-Site Assistance and Design Safety of VVER and RBMK Nuclear Power Plants, which addressed many areas of nuclear safety, among which In-Service Inspection of the primary circuit components was an important part. Besides other issues, an in-depth assessment of structural integrity of the vital components of VVER reactors, such as reactor pressure vessel, primary coolant piping, steam generators tubes and primary collectors, was of primary concern.

This paper gives an update of the PHARE, TACIS, and INSC projects dealing with In-Service Inspection of VVER and RBMK NPPs, such as qualification of the In-Service Inspection for Russian designed Nuclear Power Plants and In-Service Inspection upgraded equipment for RBMK fuel channels, VVER reactor pressure vessel, primary circuit loops as well as steam generator tube inspections. It details the main objectives and the results obtained.

INTRODUCTION

Nuclear safety assistance from the European Commission to Nuclear Power Plants of Russian design has been established through the TACIS and PHARE programmes, and has been focused on reactor safety issues, contributing to the improvement in the nuclear safety and providing technology and safety culture transfer. Since 2007, a new financial instrument has emerged – the Instrument for Nuclear Safety Cooperation (INSC), which formally replaced the TACIS nuclear safety programme. This new instrument represented a change from "assistance" to "cooperation" programmes, with closer involvement of Beneficiary country institutions on project planning and implementation.

The TACIS, PHARE, and INSC projects dealing with the In-Service Inspection of VVER and RBMK Nuclear Power Plants deal mainly with the Qualification of In-Service Inspection methods and the improvement of In-Service Inspection tools for primary circuit components.

IN-SERVICE INSPECTION QUALIFICATION

Several PHARE, TACIS and INSC projects had the objective of setting up the basis for the qualification of the In-Service Inspection of Russian designed Power Reactors.

In-service Inspection Qualification in PHARE Nuclear Safety
An important effort was carried out to implement In-Service Inspection qualification through the PHARE nuclear safety programme in Central European Countries, concerning the In-service Inspection of the reactor pressure vessel and other primary circuit main welds.

The achievement of a level of quality and effectiveness of In-Service Inspection of VVER 440-213 primary circuit components equivalent to the level of European Union practice has been carried out in applying the ENIQ (European Network for Inspection Qualification) methodology. The ENIQ methodology was applied to VVER 1000 primary components later on.

The efficiency of Non Destructive Testing (NDT) procedures able to be used for In-Service Inspection of Reactor Pressure Vessel (RPV) components was evaluated based on an improved In-Service Inspection programme. This included identification and selection of the procedures to be evaluated and identification of the essential variables of those procedures. Samples representative of RPV areas subject to In-Service Inspection were defined as well as the rules to evaluate and later qualify NDT methods, materials and operators. The size and shape of the samples for each selected area were determined as well as the number, type, location, size and orientation of the flaws to be implanted. Finally the test samples were procured after qualification of the suppliers of the sample material and flaws. The personnel required for evaluation of the results underwent a qualification process, which consisted of the establishment the data for qualification exercises (type of flaws, blind test and / or technical justification), method of evaluation (ratio of detection, false calls), and evaluation of the samples in determining the actual flaws by destructive tests or through partial investigation and non destructive testing.

The completion of the In-Service Inspection qualification programme for primary circuit components other than the reactor pressure vessel consisted in the improvement of In-Service Inspection for the following selected inspection areas: pressurizer pipe to main circulation pipe, safety cooling pipe to main circulation pipe, steam generator transition weld, steam generator: feed water nozzle transition weld, main circulation pump inlet circumferential weld, main circulation pump shell to elbow weld, longitudinal weld of the main circulation pump elbow, pressurizer nozzle to transition nozzle dissimilar weld. This included the following phases: comparison and evaluation of In-Service Inspection effectiveness, supply of test blocks, of inspection equipment and of inspection procedures, definition of training requirements, definition and performance of inspection qualification, evaluation of the improved In-Service Inspection.

The improvement of the In-Service Inspection programme of the steam generator collector has been based on a Round Robin Test (RRT) and the preparation of NDT qualification for this type of inspection. Corrosion cracks damage of VVER steam generator collectors occurs in the shell and especially threaded flange region. The scope of the concerned In-Service Inspections was limited to the area of threaded flange and collector shell. The assessment of the methodology used to inspect the threaded flange and collector flange included the selection of available steam generator collector with real cracks, the performance of RRT with international participation, the assessment of RRT results and the elaboration of procedures for the In-Service Inspection qualification process for steam generator collector.

In-service Inspection Qualification in TACIS and INSC Nuclear Safety

Several TACIS projects were implemented to assess the In-Service Inspection of Russian, Ukrainian and Armenian Nuclear Power Plants (NPPs), to provide NDT training and to provide guidelines for In-Service Inspection qualification.

An important project has been carried out to strengthen the Russian Regulator and its Technical Support Organization in the field of In-Service Inspection of NPPs and its qualification. It included the following activities: assessment of Russian In-Service Inspection concept for meeting structural integrity requirements for VVER and RBMK NPPs, identification and familiarisation with Western NDT equipment using digital flaw detection technology, and assistance to the Russian Regulatory Body in evaluating current inspection qualification systems by applying suitable features of the ENIQ (European Network for Inspection Qualification) approach.

Another important project was carried out in Ukraine for the implementation of a specialised Centre for training, qualification and certification of all personnel in charge of the In-Service Inspection of Nuclear Power Plants. This Centre has been organised in order to perform any activity related to training, qualification and certification, concerning all types of NDT methods applied in the Nuclear Power
Industry. This concerns not only basic theoretical and practical training, qualification and certification of personnel in NDT, but also qualifications related to the application at the NPPs of specific NDT procedures. This project defined the structure of the Centre and provided it with programmes, necessary documentation and basic equipment related to the most commonly applied NDT: Ultrasonic Testing, Eddy Current Testing, Radiography, Penetrant Testing, Magnetic Testing and Visual inspection. The training and qualification have focused on the In-Service Inspection of primary circuit equipment and piping.

In the last several years the European Commission supported non-destructive examination for in-service inspection of primary circuit welds (main circulation piping and pressuriser piping) at Armenia nuclear power plant (ANPP). Two Tacis projects, A1.01/03B and A1.01/04A have been recently implemented with the aim of addressing the applicability of Leak Before Break (LBB). The project results showed that a comprehensive in-service inspection programme (ISI) has to be implemented and maintained to support the LBB concept for the Armenian NPP. Therefore, a new INSC project A1.01/07A1 was launched to perform a complete scope ISI programme for the primary pipework as it was required for qualification of the LBB concept for the primary circuit. During the 2008 and 2009 outages, the ISI programme was conducted, which involved the inspection of 126 welds of the primary coolant pipework (ID500 mm) and pressurizer surge line (ID 200 mm). In addition, the ISI programme considered re-inspection, in the 2009 and 2010 outages, of any welds identified as requiring recurrent inspection following analysis of initial inspection results from the 2008 and 2009 outages. Automated and, in areas with limited access, manual examination, were used. The procedures, equipment and personnel were qualified according to the ENIQ methodology. Although there is no Qualification Body in Armenia, the qualification performed in the country of the suppliers of the services was considered acceptable.

As the last steam generator tube inspection at ANPP Unit 2 was performed in 1994-1995, the entire scope of In-service inspection activities at all six steam generators was performed during the extended annual outage from 25 September until 27 October 2008.

The scope of work involved Eddy current inspection of 5536 tubes in each of six steam generators over the full length from hot or cold collector (or on both half-lengths from hot or cold collector to the U-bend). The total number of tubes inspected was 33216. In addition, the following were also performed: 100% ultrasonic inspection from the inside of the welds of two circumferential collectors ID 886 mm and ID 800 mm in both hot and cold collectors of six steam generators (24 welds); 100% ultrasonic inspection from the outside of collector to pipe circumferential weld Dn500mm in both hot and cold collectors of six steam generators (12 welds); eddy current inspection of 20 threaded openings on both hot and cold collector flanges of six steam generators (total of 240 threaded openings).

All NDT examinations were performed by qualified personnel, in accordance with approved procedures and equipment that have been used during the inspection activities. The plugging criterion (≥ 40% tube wall loss) applied for a Steam Generator tube was conservative; it has been approved by the plant and regulatory body, and provides for acceptable safety margin.

Results of Steam Generator tube eddy current inspection showed that a total of 472 tubes were plugged in according with formal plugging criteria accepted by the Armenian regulatory authority (ANRA). The inspection of the steam generator main flange threaded holes showed that there were no reportable indications found. The ultrasonic examination of steam generator collector welds showed some indications which were still within the acceptable limit but further monitoring is recommended for all reported indications during the next scheduled outages in order to determine possible flaw growth.

SUPPLY OF NDT AND IN SERVICE INSPECTION EQUIPMENT IN TACIS NUCLEAR SAFETY

Several TACIS on-site assistance projects enabled Russian and Ukrainian NPPs to receive modern NDT and In-Service Inspection equipment to improve nuclear safety of operating VVER and RBMK NPPs.

Two TACIS projects dedicated to the In-Service Inspection of RBMK fuel channels and primary circuit (steam drum separators, collectors and piping) for Smolensk NPP in Russia involved the development of dedicated NDT automated methods and equipment based on ultrasonic and eddy current techniques. A feasibility study was made and technical specifications were prepared for equipment,
calibration blocks, test specimens and assessment manual to be applied to indications exceeding acceptable limits. Equipment fabrication and acceptance tests were carried out and the NDT procedures to be applied were developed. This was followed by validation of the NDT procedures and training and qualification of NDT operating personnel with the objective to undertake the In-Service Inspection at Smolensk NPP using the equipment acquired and the procedures developed.

The SK-187 equipment used in Ukraine to perform the automatic ultrasonic In Service Inspection of the reactor pressure vessel from external surfaces had serious limitations in terms of access to areas subject to inspection, reproducibility, accuracy and sensitivity. The SK-187 system has been developed in the seventies on the basis of components which existed at that time. Upgrading measures for this system were required because of deficiencies in the design options and other serious drawbacks. The main SK-187 system improvement measures concerned upgraded ultrasonic transducers for inspection of reactor vessel bottom, shell ring and nozzle-supporting shell ring, the upgrading of scanning devices for ultrasonic inspection, up-to-date ultrasonic flaw detector, control, display and inspection data processing equipment, video inspection, overall testing and metrological qualification of the system, operator training, and better sensitivity and reliability of ultrasonic inspection, especially for flaw detection in the welding area of the reactor vessel cladding and base metal.

The eddy-current equipment and technique are used in Ukraine for the inspection of threaded holes in the main flanges of reactor vessel, main coolant pumps and steam generator headers in order to detect cracks in thread and adjacent base metal. The inspection has been improved by adding a special device for thread preparation, an automatic computerized processing of inspection results and personnel training for the use of the inspection system.

In addition to ISI equipment, the On-site assistance programme involved training and seminars where nuclear power plant personnel learned the NDT techniques used in the European Union (EU). A number of on-the-job training sessions for nuclear power plant specialists were held in partner EU nuclear power plants with the objective of transferring know-how and the best EU practices in performing mechanized as well as manual ultrasonic inspections of the reactor coolant system components.

CONCLUSIONS

The TACIS, PHARE and INSC programmes in Nuclear Safety have devoted important funding to support Non Destructive Testing and In-Service Inspection for VVER and RBMK NPPs, and the main achievements have been detailed in this paper.

There is still a need to improve in-service inspection in VVER and RBMK reactors in relation to the monitoring of ageing phenomena. The main generic issue remains for further consideration of the Qualification of the In-Service Inspection programmes.