1. Basic information

1.1 CRIS Number: 632.02.02
1.2 Title: VVER Cladded Reactor Pressure Vessel Integrity Evaluation (with respect to PTS Events)
1.3 Sector: 23064
1.4 Location: Czech Republic

2. Objectives:

2.1 Overall objective:

The general objective is to increase standard level of nuclear safety of Czech NPPs (Temelin and Dukovany). The improvement will be based in precisioning, justification and validation of procedures used for reactor pressure vessel (RPV) integrity and lifetime evaluation.

2.2 Project purpose:

To prepare and validate procedures for integrity evaluation of reactor pressure vessels with the presence of austenitic cladding with/without defects found during in-service inspections.

These procedures will include a realistic behaviour of austenitic cladding of reactor pressure vessels especially during Pressurised Thermal Shock events (PTS). These regimes represent the most severe ones in reactors operation and thus they are leading ones in vessel integrity and lifetime assessment.

This procedure should be based on design procedures used for VVER type reactors but would be also harmonised with procedures and approaches applied for PWR type reactors like RSE-M or ASME. It will be validated by a real experimental data from testing large scale specimens with cladding and defects. The process includes design and manufacturing test specimens, their testing and results evaluation and analysis to be applied in the vessel integrity procedure. Specific target will be given to underclad type defects that are realistic in vessels and serves as examples of typical postulated defects in harmonised calculating procedures.

2.3 Accession Partnership and NPAA priority:

In the AP, agreed with the Czech Republic, a continuation of high level of nuclear safety provision at Temelin and Dukovany NPPs and the further strengthening of state regulatory structures for nuclear safety (SUJB) have been signalled.

The Council Report on Nuclear Safety in the Context of Enlargement of June 2001 concluded in general and country specific recommendations, that, with regard to full safety analysis reports and related safety improvement measures, there should become available complete, plant-specific, in-depth safety analysis reports to EU MSs standards, including regulatory reviews and approval.

The above provision of high level of nuclear safety of Czech NPPs (at Dukovany and Temelin) and the further strengthening of state regulatory structures for nuclear safety and radiation protection (SUJB) is regarded by SUJB as a permanent task. This task is in line with the Accession Partnership that makes reference to the implementation of the recommendations contained in the above Council Report. In particular, the project can be connected with the first general recommendations - type I (“all candidate states with nuclear power plants should complete their plant-specific safety improvement programmes according to the presented plans”) and to the second general recommendation – type I (“regarding the full safety analysis report and related safety measures”) and “regarding the resources
of the regulator”). The Czech Nuclear Safety Authority (SUJB) can benefit from the process and results of the project.

Taking into account the above documents, SUJB assumes improvement and validation of procedures for reactor pressure vessel integrity evaluation as an important and integral part of increase of nuclear safety.

3. Description of the Project:

3.1 Background and Justification

VVER reactor pressure vessels of NPPs in Czech Republic (as well as in other VVER operating countries) are covered by austenitic stainless steel cladding on their inner surface to protect them against corrosion. In the same time, austenitic cladding plays an important role in the evaluation of “pressurised thermal shock” events in VVER type reactor pressure vessels from several reasons:

- Cladding is relatively thick (approx. 8 mm) in comparison with most of PWR reactor pressure vessels (approx. 3-4 mm), which affects heat transfer and thus also temperature and stress field in the vessel wall
- Cladding creates high residual stresses in cladding and also in a sub-clad area
- Cladding has usually lower fracture toughness but this material is not of a part of Standard surveillance programmes and thus knowledge of its properties before and mainly during RPV operation is very limited
- Existence of cladding requires and allows an application of “postulated underclad type defects” in PTS calculation – such calculation needs special procedures and definition of fracture criteria
- These fracture criteria must be based on experimental data on cladding behaviour in unirradiated as well as irradiated conditions and also on large scale specimens tested with underclad type defects

As undeclad type defects exist in some RPVs, thus an application of “underclad postulated defect” in PTS calculations will bring such evaluation closer to the reality and will decrease uncertainty in safety margins assessments used in reactor pressure vessel lifetime evaluation. In the same time, harmonization with approaches from procedures used for PWR type RPVs could be performed.

3.2 Linked Activities

This project will be linked with the following running projects:

- 5FP VERLIFE “Unified Procedure for Lifetime Assessment of Components and Piping in VVER NPPs”
- national project (Ministry of Industry and Trade) “Methodical and Technological Procedures for Evaluation of Safety Aspects in VVER type NPPs”

3.3 Results

Three main tasks will be reached within the project:

- Validation of the procedure with experimental results from large scale specimens with cladding and different type defects. An unique archive material from a decommissioned RPV will be used for these tests
- Incorporation of a method for an assessment of allowability of defects found during in-service inspection, using qualified non-destructive procedures (NDT) and equipments
Close interconnection between postulated defect sizes and location with results from NDT qualification

Such modifications of existing design type procedures also allow to incorporate not only results from planned experiments but also allow to harmonize them with the procedures and approaches used for PWR type RPVs.

Finally, experimentally validated procedure for RPV integrity evaluation will be submitted to the SUJB for approval and to NPPs for the use within Periodic Safety Review. This procedure will be also applicable for all other RPVs of VVER type in other countries.

3.4 Activities

Project activities should have to be divided into several tasks:

Task 1: Creation of a database of all available fracture toughness data of austenitic cladding of WWER reactor pressure vessels tested in unirradiated as well as irradiated conditions. Analysis of the data and proposal of their generic properties to be used in PTS calculations

Task 2: Determination of real physical properties of cladding necessary for calculations – Young modulus, E, thermal expansion coefficient, α, as a function of test/operation temperature and proposal for their generic properties to be used in PTS calculations

Task 3: Testing sub-large scale specimens (with section of approx. 70x100 mm) with surface (through cladding) as well as with underclad type defects in initial as well as aged/embrittled conditions to determine fracture toughness of the cladding and failure behaviour from underclad type defects

Task 4: Application of non-destructive test methods (acoustic emission, electrical potential etc.) and destructive methods (fractography) for determination of the behaviour of tested defects and their propagation direction and mode

Task 5: Determination of residual stresses in components with cladding and proposal of their generic values to be used in PTS calculations

Task 6: Experimental verification and calibration of “Automated Ball Indentation Method – ABIT” for measurement of tensile properties in operating reactor pressure vessels of WWER-440 and WWER-1000 types as well as on surveillance specimens - determination of properties (stress-strain diagrams) for cladding after different neutron fluences and/or ageing

Task 7: Analysis of sub-large scale specimen test results using elastic-plastic stress analysis and elastic-plastic fracture mechanics approaches

Task 8: Definition/choice of failure criteria for PTS calculations of reactor pressure vessels with underclad type postulated defects based on experimental data and sub-large scale specimen test results

Task 9: Elaboration of a procedure for PTS evaluation of WWER reactor pressure vessels with underclad type postulated defects and its verification by large- scale specimen test results

Task 10: Evaluation of the quantitative cladding role in reactor pressure vessel lifetime evaluation with respect to PTS events and assessment of connected safety margins. Final Report of the project

4. Institutional framework:

The result of the project would contribute to increasing the capabilities of the nuclear sector in the Czech Republic, the State Office for Nuclear Safety as well as TSO can benefit from the implementation and the results of the project. In order to ensure an effective transfer of know how the participation of EU TSOs in the project would be positive.
In light of the recommendations of the Council Report on Nuclear Safety in the Context of Enlargement, this project is of high importance to the Czech Republic. A number of activities foreseen are of industrial nature, with a clear connection to the Dukovany and Temelin NPPs. Nonetheless, SUJB will act as the Beneficiary of this project, as SUJB has the task to co-ordinate, at a national level, the implementation of the said recommendations. SUJB will establish and chair a steering committee to this end.

5. Detailed budget (in M €)

<table>
<thead>
<tr>
<th>Project Components</th>
<th>Investment Support</th>
<th>Institution Building</th>
<th>Total Phare (= IS + IB)</th>
<th>National Co-financing</th>
<th>IFI</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Technical assistance</td>
<td>0.960</td>
<td>0.960</td>
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<td>(2) Preparatory work</td>
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<td>TOTAL</td>
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<td>0.960</td>
<td>0.240</td>
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<td>1.200</td>
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Level of a possible national financing (both from private funds and national budget) and therefore the total Phare cost is under negotiation. It is expected that national funds will cover material handling – archive material costs, specimens machining and waste management.

6. Implementation arrangements

The decentralised implementation scheme (DIS) with ex-ante Commission control will be followed for the project. The CFCU will be the Agency responsible for implementing the Project:

6.1 Implementation Agency: CFCU Mr. Jan Slaviček, Letenská 15 CZ - 118 10 PRAHA 1 phone: +420-2-57044551 Fax: +420-2-57044550 E-mail: jan.slavicek@mfcz.cz

6.2 Beneficiary: The State Office for Nuclear Safety Contact person: Mr. Milos Tichy phone: +420-2-21624740, E-mail: milos.tichy@sujb.cz

6.2 Twinning: N/A

6.3 Non-standard aspects: None.

6.4 Contract:

(1) Contract – Technical Assistance – 0.960 M €

7. Implementation schedule

7.1 Start of project implementation: 2 Q. 2003

7.2 Project completion: 4 Q. 2004

CZ 02-632.02.02
8. Conditionality and sequencing

The Terms of Reference (TOR) will be prepared by SUJB, with final approval together with the Commission.

The project will be sequenced as follows:

2 Q. 2003: contract signature and project work plan is precised
3 Q. 2004: draft final report with the final report to be submitted in the last quarter of 2004.

Annexes to project Fiche

1. Logical framework matrix
2. Detailed implementation chart
3. Contracting and disbursement schedule
### Log frame Matrix

**Project:** VVER Cladded Reactor Pressure Vessel Integrity Evaluation (with respect to PTS events)

**Programme:** 6232.02.02  
**Contracting period expires:** 30.11.2004  
**Disbursement period expires:** 30.11.2005  
**Total Budget:** 1.200 MEUR  
**Phare contribution:** 0.960 MEUR

<table>
<thead>
<tr>
<th>Overall objective</th>
<th>Objectively verifiable indicators</th>
<th>Sources of verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Ability to take on the obligations of membership in EU , including adherence to the aims of political, economic and monetary union</td>
<td>- Acknowledgement by the European Commission</td>
<td>- European Commission Regular Report</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Project purpose</th>
<th>Objectively verifiable indicators</th>
<th>Sources of verification</th>
<th>Assumptions</th>
</tr>
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<tr>
<td>- To implement second general recommendation of type I of the Council Report on Nuclear Safety in the Context of the Enlargement, ensuring the implementation of good safety practices within EU. - More specifically to harmonise RPV integrity evaluation with requirements of PWR and IAEA codes and rules taking into account specifics of VVER cladded RPVs</td>
<td>- Enhancement of capabilities to perform detailed safety assessments of Temelin and Dukovany in the areas covered by the project</td>
<td>- Available reports evaluating safety of both NPPs</td>
<td>- Other recommendations within the Council Report on Nuclear Safety in the Context of the Enlargement implemented as well</td>
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</table>

<table>
<thead>
<tr>
<th>Results</th>
<th>Objectively verifiable indicators</th>
<th>Sources of verification</th>
<th>Assumptions</th>
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</thead>
<tbody>
<tr>
<td>- Elaboration of VVER RPV integrity procedure with realistic type postulated defects and realistic material properties harmonized with PWR type codes and rules - Definition of safety margins in RPV integrity evaluation</td>
<td>- Definition of failure criteria for PTS calculations of RPVs with underclad type postulated defects - Assessment of safety margins using the new procedure in comparison with a Standard one based on surface type postulated</td>
<td>- Report on analysis of failure conditions of specimens/components with cladding and defects - Report on residual stresses measurements with recommendations for generic values to be used in calculations</td>
<td>- Available experience with design, and manufacturing large scale specimens with any type of the defects - Available inspection methods for determination and sizing defects in large scale specimens</td>
</tr>
<tr>
<td>Activities</td>
<td>Means</td>
<td>Assumptions</td>
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<tr>
<td>---------------------------------------------------------------------------</td>
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<tr>
<td>- See activities in the PF</td>
<td>Technical Assistance 0.96 M €</td>
<td>- Co-financing from the state budget ensured</td>
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<tr>
<td>- Workshops on standard procedure for cladded RPV integrity evaluation</td>
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<td>- Available base metal, welding wire, etc for manufacturing of large scale</td>
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<tr>
<td>including PTS regimes and lifetime assessment</td>
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<td>and standard specimens</td>
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<tr>
<td>focus on users of the procedure - regulatory bodies, operators,</td>
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<td>- Available computer programs for stress analysis and fracture mechanics</td>
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<td>technical support organisation from VVER operating countries</td>
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<td>calculations</td>
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<td>- Experience with standard RPV integrity assessment with surface type</td>
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<td>postulated defects</td>
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<td></td>
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<td>- Experience with large scale specimen testing and their evaluation</td>
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**Preconditions**

- Approved Terms of Reference.
- Budget allocated from state funds
ANNEX 2

Detailed Implementation Chart for the Project

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<tr>
<th>Year</th>
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<th>2004</th>
<th>2005</th>
<th>2006</th>
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<td>ASOND</td>
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<td>Start of procurement procedures</td>
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<td>Start of project implementation</td>
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<tr>
<td>Project completion</td>
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ANNEX 3

CONTRACTING AND DISBURSEMENT SCHEDULE BY QUARTER FOR FULL DURATION OF THE PROJECT

Cumulative Quarterly Contracting Schedule (M€)

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<tr>
<th>Quarter / Year</th>
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<th>1Q/03</th>
<th>2Q/03</th>
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<tr>
<td>VVER Cladded Reactor Pressure Vessel Integrity Evaluation with respect to PTS events</td>
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Cumulative Quarterly Disbursement Schedule (M€)

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<th>Quarter / Year</th>
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