

**SAFETY IMPROVEMENT AND RESULTS OF COMMISSIONING OF  
MOCHOVCE NPP WWER 440/213**

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**Abstract**

Mochovce NPP is the last one of this kind and compared to its predecessors, it is characterized by several modifications which contribute to the improvement of the safety level. In addition based on Nuclear Regulatory Authority requirements and based on documents:

- IAEA – Safety Issues and their ranking for NPP WWER 440/213
  - IAEA – Safety Improvement of Mochovce NPP Project Review Mission
  - Riskaudit – Evaluation of the Mochovce NPP Safety Improvements
- Additional safety measures have been implemented before commissioning.

The consortium EUCOM (FRAMATOME – SIEMENS), SKODA Praha, ENERGOPROJEKT Praha, Russian organizations and VUJE Trnava Nuclear Power Plants research institute were selected for design and implementation of the safety measures.

The papers summarized, safety requirements, safety measures implemented, results of commissioning and results of safety analysis report evaluation.

**1. INTRODUCTION**

Construction of 4 WWER 440/V213 units at Mochovce site commenced in 1984. In 1990, due to lack of financial resources and also due to political and economical transition in the country, the construction was interrupted. Apart from necessary conservation work, only the replacement of the original Russian-Czechoslovak instrumentation and control systems by SIEMENS systems on units 1 and 2 had been performed till 1995.

The Mochovce NPP project is the last one of WWER 440/213 type and, compared to its predecessors, it is characterized by several modifications which substantially contribute to the improvement of the safety level. Among the most important are the implementation of the seismic requirements, the implementation of the Siemens control system and other modifications in primary and secondary circuit systems issued from the operational experience of the same type of NPPs in Jaslovské Bohunice and Dukovany. The most important modifications from operational experience included in the original design of Mochovce NPP are the following: heating of ECCS storage-water tanks and hydro-accumulators, installation of pressurizer relief valves, primary circuit venting under accident conditions, installation of RHR system via ECCS cooler, replacement of aluminium insulation material of the primary circuit by stainless steel, installation of steam dump stations to atmosphere per steam generator, emergency feed-water system outside the turbine hall, up-graded SG-feed water control system, up-graded fire fighting water system, use of innovated semiconductor technology for processing unit of reactor protection system, and others.

Completion of first two units of Mochovce NPP restarted based on Resolution of the Slovak Government in September 1995. An essential safety enhancement program was required to assure such safety levels, which are comparable with current international practice.

Safety improvement of the Mochovce nuclear power plant is a basic requirement of Nuclear Regulatory Authority (UJD). "The nuclear safety improvement program of Mochovce NPP" elaborated in 1995 is based on the following documents, being the results of national and international safety review activities:

- IAEA safety review mission to Mochovce NPP (SIRM), 5 to 13 May 1994 (IAEA - Report VVER-SC-102),
- Evaluation of Safety Improvements 1994 (Riskaudit - Report No. 16),
- Safety Issues and their Ranking for VVER 440/213 NPPs (IAEA-EBP-VVER-03/1996).

It consists of 87 safety issues elaborated in the framework of 10 design areas as well as 11 issues oriented to operational area. Safety categories of individual safety issues are defined and ranked according to the approach used in IAEA documents.

Implementation of the Mochovce Safety Enhancement Project was divided into three principal phases:

- studies and analyses,
- design preparation phase, coordinated by general designer (Energoprojekt Praha); when necessary the engineering services of Russian designers are ensured,
- implementation of modifications of system or civil engineering structures are performed by prime contractors of equipment parts and civil engineering parts and their subcontractors.

## 2. ORGANIZATION OF THE COMPLETION WORKS OF MOCHOVCE NPP-UNITS 1 AND 2

The position of the General Designer (Energoprojekt Praha) as well as the prime contractors for the Civil Engineering works (Hydrostav Bratislava) and for the Equipment part (Škoda Praha) has been kept in the framework of the new organization in order to maintain the original warranties for the engineering and the realization of the construction. In addition, new structures have been integrated to the project in charge of the following tasks:

- EUCOM (Framatome and Siemens Consortium) in charge of the main safety measures part,
- Russian organizations under Atomenergoexport in charge of the solution of a part of the safety measures and providing services in the field of engineering and commissioning of Russian special systems (reactor protection systems, in-core instrumentation),
- EDF as consultant for engineering activities related to the project management and the preparation of the future operation,
- VUJE as technical assistant for the realization of safety measures.

Contract negotiations started in October 1995 and the signature of the contracts with the main suppliers took place in April 1996. In May 1996, the Slovak government gave its warranty for the loans and SE signed loan agreements for the financing of the completion of the project. Financing sources are in fig. 2.

In May 1997, VUJE has been added to the chart organization as the leader in charge of the whole commissioning.

A QA program approved by Regulatory body UJD was elaborated for the completion works project of Units 1 and 2.

### 3. TECHNICAL CONDITION OF THE INSTALLATIONS

One of the decisive conditions allowing the completion of Mochovce NPP project was the conservation of the technical condition of the installations during the standstill period from 1993 to 1996. Therefore an exceptional care was dedicated to the conservation and the surveillance of equipment condition and their components.

The first important inspection was performed from September 1993 to April 1994 under EDF supervision. A selected amount of equipment was deeply inspected during these controls targeting the main circulation pipe, including isolating valves, main coolant pumps, SGs, primary circuit make-up system, decontamination and ventilation systems. The results are reported in the final reports and completed by video records of the different systems and components condition of Units 1 and 2.

The conclusions led to the observation that the condition of the majority of equipment was suitable and no irreversible damage was discovered. Deficiencies have been characterized as defects needing a corrective treatment without replacement of the different systems or their main components, but for the completion or erection works, it was necessary to include related costs in order to bring the equipment in accordance with technical conditions and general technical standards.

After the settlement of the chart organization of the completion works project, EMO asked the prime contractor Skoda Praha to proceed with a general inspection of all the erected and supplied equipment of Units 1 and 2. A special project documentation was prepared by the various final subcontractors for the performance of this task. This inspection was performed for both units from January 1996 to June 1997. The control of the existing documentation and the qualification of the staff were also included in this task.

The result of the final report regarding the performance of the inspection concludes to the need of corrective actions, including the replacement of some components within the framework of completion works of Units 1 and 2 and before the equipment transfer for tests. The good technical condition of important equipment was confirmed. Final subcontractors have prepared corrective action procedures on the basis of the inspection conclusions, in order to bring the equipment in accordance with detailed design, technical specifications, QA programs and standards requirements.

All completion works performed in Units 1 and 2 are executed according to QA programs elaborated by the different contractors and supervised by the Regulatory Body UJD.

### 4. SAFETY IMPROVEMENT PROGRAM

Safety improvement of the nuclear plant is a permanent objective of SE management and NPP Mochovce staff. "The nuclear safety improvement program of Mochovce NPP" elaborated in 1995 is the logical continuation of EDF activity in the field of safety assessment

summarized in the “Safety improvement Report” (SIR) which was submitted to the public review. This program is conceived as long term and aims reaching at the moment of the NPP start-up the safety level corresponding to the international standards included in IAEA Safety Standards accepted by the Regulatory body UJD; it will also create good conditions for a continuous safety improvement in the future. Such an approach is in accordance with the world tendency for safety improvement, life extension, modernization and power upgrading of already constructed NPPs, and it is issued from the permanent follow-up of the world progress in the field of nuclear safety.

Since the beginning of 1990's, Mochovce NP was submitted to several international audits with around 2000 experts assessing the safety level and their conclusions were in short that there were no safety problems which could not be solved and which could prevent the start-up of Mochovce NPP. The main tasks related to Mochovce NPP safety level assessment are summarized in table 1.

The safety improvement program of Mochovce NPP is based on the “Defence in Depth” principles and its aim is to verify and to prove the fulfillment of the “general principles of nuclear safety” defined in INSAG-3. This approach is deterministic, but also combined with the probabilistic approach, in accordance with the technical safety target defined in INSAG-3.

Table 1

Main international missions related to Mochovce NPP safety level assessment		
Pre-OSART Mission (IAEA)	Review of Pre-Operational Safety at Mochovce Nuclear Power Plant	9 - 29 January 1993
Mochovce NPP Safety Improvement Review Mission (IAEA)	Review of safety improvements proposed for Mochovce NPP	5 - 13 May 1994
WATRP Mission IAEA	Review of Pre-Operational Safety Analysis Report of Mochovce Radioactive Waste Repository	16 - 20 May 1994
IAEA Mission - Review of Seismic Safety of Bohunice and Mochovce NPPs	Seismic safety of NPP	31 October - 4 November 1994
RISKAUDIT (IPSN and GRS)	Review of Mochovce NPP Safety Improvements	May - December 1994

For the realization of the “Mochovce NPP Safety Improvement Programme”, SE-EMO elaborated, in collaboration with VUJE, technical specifications for 87 Safety Measures (TSSM) taking into consideration the specifics of Mochovce NPP project which are issued from RISKAUDIT and SIRM reports and also the experience of J. Bohunice V-2 NPP and Dukovany (see table 1). As a result, some differences are raised between “Mochovce NPP Safety Improvement Programme” and the IAEA document “Safety Issues and their ranking in NPP-WWER 440/213”. These differences are:

- I&C 04 was dropped from the field of I&C problems - Ergonomic of the control room. After the replacement of the whole control system, this is no more an issue for Mochovce NPP. Safety Measure I&C 12 concerning the replacement of computers for in-core instrumentation system was completed

- 2 Safety Measures specific to Mochovce NPP have been added in the area of electrical systems
- in the confinement area, a Safety Measure has been added aiming at the application of the results of the full scale experiment prepared in the framework of PHARE program
- in the area of accident analysis, the analyses “Blackout” and “Total loss of RHR” which are in the document “Safety Issues and their ranking in NPP-WWER 440/213” as separate issues (AA 14 and AA 15), are in the “Mochovce NPP Safety Improvement Programme” covered by one safety measure AA 09
- in the time of the definition of “Mochovce NP Safety Improvement Programme”, the solutions for the “Surveillance programme” (contract with VUJE) and “Training programme for operation personnel” (in relation with the realization of the full scale simulator) were already under way and therefore they are not included in this programme (OP 09 and OP 11 according to “Safety Issues and their ranking in NPP-WWER 440/213”).

Table 2

AREA	III	II	I	NOT RANKED
General	1	2		
Reactor core		1		
Component integrity	1	4	1	
Systems	2	12	3	
Instrumentation & Control		8	2	1
Electrical power supply		2	3	2
Containment	1	3	1	1
Internal hazards	2	4	3	
External hazards	1	1	1	
Accident analyses		5	8	
Operation				11
<b>Total</b>	<b>8</b>	<b>42</b>	<b>22</b>	<b>15</b>

The ranking of the different safety issues is issued from IAEA document “Safety Issues and their ranking to WWER 440/213 NPPs” with the difference that it was completed for the additional Safety Measures related to the specific situation of Mochovce NPP which did not have any ranking by the IAEA. The definition of the different rankings is reported in table 2.

It is important to highlight that no Safety Issue of WWER 440/213 NPPs has a level 4 ranking.

TSSMs have been the basic documentation for the contracts negotiation with the suppliers of the different solutions to the safety issues. EUCOM (consortium FRAMATOME-SIEMENS), SKODA Praha, ENERGOPROJEKT Praha, Russian organizations with ATOMENERGOEXPORT (Russia) as the leader and VUJE are the organizations selected for the realization of TSSMs.

Table 3

Definition of Safety Issues Ranking According IAEA	
Category I	Departure from recognized international practices. Action is required to resolve the issue.
Category II	Are of safety concern. Defence in depth is degraded. Action is required to resolve the issue.
Category III	Are of high safety concern. Defence in depth is insufficient. Immediate corrective action is necessary. Interim measures might also be necessary.
Category IV	Are of the highest safety concern. Defence in depth is unacceptable. Immediate action is required to overcome the issue. Compensatory measures have to be established until the safety problems are resolved.

7 SMs are addressed directly by SE-EMO and they are supposed to be solved by its own capacities or in collaboration with other organizations. As an example, we can mention the issue of the new emergency operating procedures which is being solved by an integrated team including SE-EMO and the Belgian Westinghouse subsidiary specialists. These Safety measures are oriented on the organization on the organization of the operation. (Area "Operation" according to "Safety Issues and their ranking to WWER 440/213 NPPs")

OP 02 - Emergency operating procedures

OP 04 - Safety culture

OP 05 - Experience feedback

OP 06 - Quality Assurance Programme

OP 07 - Data and document management

OP 08 - Philosophy on use of procedures.

The realization of the Safety Measures is divided into the following phases:

### **Studies and analyses phase**

The different safety issues have been analyzed and a conception of a technical solution (Basic Design) has been proposed whenever there was a need for a modification. The results of the analyses and the proposed technical solutions have been evaluated by all participating organizations, including VUJE, and are currently being reviewed with the Regulatory Body UJD.

### **Design preparation phase**

Once the conception of the technical solution is approved, the modification of the NPP design is accepted through the "Change Procedure" according to the different QA Programmes and the decree 105/81, and then, the General Designer works out the amendment to the design documentation. The role of the General Designer (EGP) concerns the coordination between the technical solution and the original conception of the NPP design, including the solution of the interfaces with other systems (I&C, Power supply) and the consequences on the civil engineering part. When necessary the engineering services of Russian designers are ensured through the contract of SE with ATOMENERGOEXPORT.

Amendments to the design documentation are approved by the Regulatory Body UJD.

## Realization of Safety Measures

Safety Measures aiming at the modification of systems or civil engineering structures (that is to say having an impact on the “hardware”) are performed by the prime contractor of the civil engineering part or equipment part and their final subcontractors. In case EUCOM is the supplier of some equipment, this will be purchased through SE, EUCOM elaborating the detailed specification. The results of the Safety Measures which have no consequence on the “Hardware” will be demonstrated in the Safety Analysis Report and possibly in the following supporting documentation.

It is clear that the realization of such an important Safety Improvement programme is a long term process. Therefore the priority is going to category III and II SMs with the aim of their full implementation or the introduction of such measures leading to the lowering of the category.

Share of safety measures among the organizations is following:

EUCOM	48 %
SKODA	15 %
EGP	15 %
SE-EMO	8 %
VUJE	6 %
ATOMENERGOEXPORT	6 %

Total costs of the safety measures which have been or shall be implemented within this program at unit 1 and 2 are about 82 billion Sk (approx. 410 mil. DEM).

By the end of April 1998 51 safety measures have been fully implemented partially leading to the lowering of the category.

## 5. PRE-OPERATIONAL SAFETY ANALYSIS REPORT

The licensing for the operation of Units 1 and 2 is based on Pre-operational safety analysis report (POSAR) and conducted according to the international recognized standards. The whole conception is issued from the US NRC RG 1.70 and for the accidental analyses constituting a part of this report, the IAEA document “Guidelines for Accident Analysis for WWER Nuclear Power Plants” is used taking into account the Slovak legislation in force.

The POSAR has been submitted to UJD by the licensee in January 1998. UJD established the review and assessment team including Slovak and International technical support organizations. The result of assessment are as follow:

- comments to POSAR
- requirements for additional information
- setting measures for POSAR improvement
- basis for regulatory body permission for the fuel loading and for achieving the first reactor criticality.

## 6. MAIN MILESTONES OF START-UP ACTIVITIES AND COMMISSIONING OF UNIT 1 OF MOCHOVCE NPP

The commissioning of Unit 1 started on August 21, 1997 when the activities of the first stage of hydraulic test began.

There are regulatory body hold-points during commissioning according regulation:

- hot functional tests
- fuel loading
- readiness for criticality
- physical start-up tests
- power increase at different power levels
- operation.

Following steps of commissioning have been taken since August 1997 till June 1998.

*August 21, 1997 – October 27, 1997*

First stage of hydraulic test, temperature of primary circuit 120 °C

*October 28, 1997 – October 30, 1997*

Containment pressure test

*October 30, 1997 – January 22, 1998*

Pre-service inspections

*January 23, 1998 – February 27, 1998*

Second stage of hydraulic test – temperature of primary circuit 260 °C

*March 2, 1998 – March 8, 1998*

Containment pressure test

*March 8, 1998 – April 26, 1998*

Pre-service inspections

*April 27, 1998 – May 3, 1998*

Fuel loading

*June 9, 1998*

First criticality