
TSO support to the State Nuclear Regulatory Committee of Ukraine in the licensing of Rovno 4 and Khmel'nitsky 2 NPP units (K2R4)

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Abstract:

In 2003 the Ukrainian government decided to complete the construction without loans from the EBRD and the EU and to start-up Rovno 4 and Khmel'nitsky 2 NPP units (K2R4) in 2004. K2R4 are two VVER-1000 reactors under construction since 80th. At request of EBRD and EC RISKAUDIT assessed the to be implemented safety upgrading measures at the time of commissioning as it is planned currently by NAEK against the safety upgrading measures in the K2R4 Modernisation Programme planned in 2000. In deviation of the Modernisation Programme 2000 the operator NAEK changed the technical contents for the solution of 3 issues (issues "Develop and introduce new programme of surveillance specimens", "Rigid support of steam and feed-water lines at the outlet of the reactor building" and "Analyses to determine extent of pipeline breaks") and 19 measures were postponed from the pre-commissioning package to the phase after commissioning. The changed technical solutions for the above mentioned 3 issues would not allow resolving of the safety concerns. On demand of the regulator SNRCU the operator NAEK will implement an upgraded surveillance programme for the RPVs and the application of the no-break zone concept on main steam lines and main feedwater lines. The correct realisation of these measures allows solving of the 3 safety issues. The impact on the safety due to the postponing of those 19 measures is acceptable due to the fact that adequate preventive and/or compensatory measures are foreseen. All 19 postponed measures will be completed in the three year period after commissioning. The actual scope of measures allows upgrading K2R4 to a safety level which is acceptable for commissioning.

1 INTRODUCTION

The Memorandum of Understanding between the Government of Ukraine and the G7 on a programme to support the closure of Chernobyl NPP had as one of its principles the promotion of a high level of nuclear safety. The G7 countries, the EC and the EBRD have for many years provided support and technical co-operation to the Ukrainian nuclear sector. They developed a series of programmes designed to

- Improve nuclear safety regulation in Ukraine
- Improve operational performance of Energoatom
- Ensure the completion of K2R4 to international standards
- Create an investment programme for safety upgrades of all existing NPP in Ukraine for which K2R4 when completed would be the prototype.

The K2R4 completion and modernisation programmes derived all its safety conditionality from the above mentioned programmes.

Since 1997 RISKAUDIT is involved in the safety review of the Modernisation Programmes for the Ukrainian NPPs with VVER-1000 (B-320). The programmes were developed for K2R4 by the Kiev Institute Energoprojekt /4/.

For the completion and modernisation of K2R4 RISKAUDIT performed an assessment of the K2R4 modernisation status against nuclear safety criteria /5/. The Final Safety Assessment Report was the basis for the Loan Approval Procedure of the EBRD and the EC /6/.

In the frame of different TACIS projects, RISKAUDIT provides together with the Ukrainian TSO SSTC a technical assistance to the SNRCU in the licensing of the Rovno 4 and Khmelnytsky 2 NPP units (K2R4) commissioning.

When the Ukrainian Government took the decision to start K2R4 in 2004, the most urgent task was to evaluate the safety level related to the safety upgrading of the NPPs Khmelnytsky 2 and Rovno 4 and to provide the Nuclear Regulatory Authority of Ukraine (SNRCU) with relevant recommendations (Task 1 of the EU project UK/TS/27) /1/. On the request from EBRD and EC the experts of RISKAUDIT had to assess the performed safety modernisation measures of the units at the time of commissioning as it was planned by NAEK and agreed by SNRCU /2/, /3/ against the safety upgrading measures in the K2R4 Modernisation Programme planned in 2000 (MP 2000) /5/.

Based on this assessment the EBRD and EC were able to decide on Loan Agreements for the safety modernisation of K2R4 after start-up.

RISKAUDIT reviewed the present Ukrainian programmes taking as a reference the measures of the former Modernisation Programme 2000 for K2R4 /4/-/6/ and the generic safety issues of the IAEA /7/. This review allowed RISKAUDIT to make a statement on the following points:

- to which extent the scope of the measures in the actual programmes, decided to be implemented before the units' start-up, is in accordance with the requirements of the IAEA issue book /7/ and with the 2000 modernisation programme for K2R4 (planned to be implemented "before the commissioning");
- to which extent the whole scope of the measures (before and after start-up) would meet the safety level that would be achieved in the case of implementation of all measures that were planned in the 2000 modernisation programme for K2R4.

The review of the estimated cost and the implementation schedule were not included within this project. However, for the measures to be implemented after commissioning, RISKAUDIT noticed the information related to the planned realisation time-frame. In those cases where some measures planned in 2000 are substituted by some others, a technical evaluation of their adequateness was carried out.

2 METHODOLOGY

In 2000, up to the EBRD request, RISKAUDIT checked the evolution /5/ /6/ of the Modernisation Programme /4/. The conclusions drawn in 2000 should have been a basis for the Loan Agreement. Their extract is presented here-below:

The proposed measures complemented by those recommended by RISKAUDIT are considered to be complete and adequate to cope with internationally recognised safety deficiencies for this type of plant.

The schedule for modernisation is acceptable from safety point of view.

Qualitative inspections have been performed by Eastern suppliers on Rovno 4 and Khmelnytsky 2 units. After implementation of corrective measures for weak points already identified, after completion of proposed plans for inspection and after correction of corresponding possible weak points, the quality status of the plants will be in line with the quality achieved in Western plants.

It was assumed that the Modernisation Programme for K2R4 (revision 2) /4/ together with the recommendations presented in the RISKAUDIT report no. 120 /6/ is a reference point for the present review because it deals, in general, with the essential weak points for reactors of VVER-1000/V-320 type, that have been previously identified through actions performed by RISKAUDIT (/8/-/14/) and international organisations such as IAEA, WANO.

In accordance to the Terms of Reference /1/ RISKAUDIT checked to which extent the actual programmes that the Ukrainian side intends to apply to K2R4 is equivalent to the 2000 Modernisation Programme for K2R4, both at the time of the commissioning of two units and the time when all safety upgrading measures identified by the programmes will be implemented or whether corresponding measure(s) are already implemented.

For that, RISKAUDIT compared:

- the pre-commissioning package of measures committed in the MP 2000 with the measures presently decided to be implemented before the commissioning;
- whole MP 2000 (147 measures) with the whole package of measures presently decided by NAEK (both before and after commissioning).

It has to be mentioned that no systematic in-depth assessment of adequacy of each measure has been performed. However in those cases where measures planned in Modernisation Programme 2000 were changed an engineering judgement was carried out. RISKAUDIT underlines that only internationally accepted practices must be applied during all activities of the plants upgrading (studies, design, new equipment manufacturing, mounting, commissioning and operation). The corresponding monitoring of implementation will have to be done separately.

However, in the frame of the present review, in the cases where some measures, planned in 2000, are substituted by some others (preventive and/or compensatory), a technical expert judgement of their adequacy was carried out.

All conclusions drawn in this report are valid under certain limits which are given hereafter.

- Rovno 4 and Khmelnytsky 2 units have been considered as «standardised» VVER 1000/320 models. It has been considered that the generic knowledge on this type of plants was fully applicable to these two units. The knowledge gained in former safety analysis related to K2R4 has been enriched during the evaluation process by specific information provided by SNRCU, NAEK or their support organisations.
- It was assumed that all activities linked with future studies to be performed and improvements to be implemented will be adequate to internationally recognised state of the art practice.
- It has been assumed that information provided by NAEK was correct.
- In cases where studies have to be performed, RISKAUDIT recommends to implement additional upgrading measures if the results of the studies demonstrate the necessity.
- The overall RISKAUDIT judgement is valid to the condition that those measures not included in the Modernisation Programmes will also be assessed by SNRCU all along the licensing process up to their implementation and commissioning.

The IAEA issue book /7/ and the RISKAUDIT reports on the assessment of the Modernisation Programmes K2R4 (reviewed in 2000) and other VVER Modernisation Programmes /8/-/14/ are the main sources of information for the known weak points. For measures foreseen in the frame of actual programmes that the Ukrainian side intends to apply to K2R4 the fundamental piece of information is given in the documents /2/, /3/, /15/, and /16/. Additional Information was provided during the meetings with SNRCU, NAEK and SSTC held in January 2004.

3 RESULTS OF THE EVALUATION

3.1 General

RISKAUDIT noticed that NAEK intends to implement all 147 measures of the Modernisation Programme reviewed in 2000. Major part of the measures listed in the MP 2000 is still planned to be implemented before the commissioning, other measures would be realised at latest in three years after commissioning. The proportion between the measures to be applied “before” and “after” has not been significantly changed.

In comparison with MP 2000, the present situation is as follows:

- 23 measures are brought forward from the former post-commissioning package and will be implemented before commissioning;
- 102 measures have not been changed neither in schedule nor in the technical contents;
- 19 measures are postponed from the former pre-commissioning package and will be implemented after commissioning;
- 3 measures - technical contents has been changed and so the proposed technical solutions would not allow resolving of the safety issues.

From the 147 measures identified in the K2R4 Modernisation Programme:

- 80 measures will be implemented before the commissioning and
- 64 measures will be completed after the commissioning.

In this listing the 3 measures for which the technical contents has been changed are not included.

RISKAUDIT performed a peer review for each of the 147 measures /17/. The review identified several deviations from the Modernisation Programme reviewed in 2000 both in schedule and in the approaches for the issue resolving (technical contents of the measures). In the following chapters is an overview provided on the identified deviations from the approach in MP 2000.

3.2 Deviations related to the change in the technical contents

3.2.1 RPV embrittlement surveillance

The deviation concerns the issue

- Develop and introduce new programme of surveillance specimens (MP issue 12351)

As it was committed in 2000, NAEK will implement some modernisations before the commissioning: e.g. new containers for specimens, increased number of specimens. However, in comparison with the MP 2000 the most efficient solution (placement of the specimens¹ in the beltline region in front of the core) is now excluded.

¹ Surveillance specimens must be located near the inside vessel wall in the beltline region so that the irradiation history duplicates as far as possible the physical constraints of the system, the neutron spectrum, temperature history and maximum neutron fluence experienced by the RPV inner surface.

RISKAUDIT considers that this is a significant drawback. In order to provide knowledge about the RPV status for the whole lifetime a representative embrittlement monitoring has to be ensured from the beginning of operation. Therefore, and taking into account the high importance of the issue (category III, IAEA /7/), RISKAUDIT concluded that it is not acceptable to start up the units K2R4 without a clear and justified strategy for the representative embrittlement surveillance. The regulator SNRCU fully agreed with this conclusion and required an improved RPV embrittlement surveillance.

RISKAUDIT recommended that:

R1: NAEK proposes urgently a substantiated method for the representative embrittlement surveillance. According to the state of the art practice the most representative surveillance can be provided by an appropriate location of the specimens (in the beltline region in front of the core). Due to radioprotection reasons such a solution should be realised before commissioning.

As result from thus NAEK proposed to the SNRCU to discuss the solutions intended to fulfil these recommendations. Then SNRCU requested RISKAUDIT together with other expert organisations to participate in technical discussion in order to ensure the technical assistance in the preliminary evaluation of principles found in these solutions.

Regarding the recommendation *R1*, NAEK presented the main features of an improved surveillance programme as it is now intended to be realised prior to the K2R4 commissioning. NAEK rejected the solution with the specimens in the beltline region because it could induce constraints for RPV inspection and increase the risk of cracking. But NAEK proposed a new programme based on the principles of the original standard surveillance programme with the following improvements /18/:

- The use of flat containers and optimized orientation in order to reduce neutron flux difference between specimens
- The use of improved neutron dosimetry within the containers as well as temperature monitoring
- The use of upgraded ex-vessel dosimetry for each fuel cycle
- The use of an upgraded Monte-Carlo based method for neutron transport calculations.

As a complementary programme, NAEK committed to contract NRI in order to benefit from the ongoing irradiation at Temelin, unit 2 and NIIAR of the archive materials from K2R4 RPVs. The transposition of the results from Temelin NPP, unit 2 where the specimens are located in the beltline, as well as the results from NIIAR would allow enriching the database for the K2R4 RPVs embrittlement.

On the basis of the information presented on the new solution, a team of Western experts (DGSNR, GRS, JRC and IRSN) made the following statements:

- In comparison with the original standard programme the improved programme will increase the quality of RPV surveillance.
- However the specimens are located in an area with complicated geometry, high neutron flux gradient and high neutron flux variations. In addition, the use of ex-vessel dosimetry needs an extrapolation to determine the fluence on the inner surface of the beltline region. Therefore, the correlation between the fluence at the inner surface of the beltline region and the dosimetry results at the specimen's location and outside the vessel is a major issue, which needs thorough validation and a conservative evaluation of uncertainties.
- Although it does not address fully the validation of the correlation, the NRI complementary programme can contribute to the validation of the extrapolation from the ex-vessel dosimetry to the inner surface fluence.

As a conclusion, the team of Western experts considers that, as long as there is no measurement of the fluence inside the vessel in front of the core, the uncertainties on the fluence calculation (correlation on the one hand between the ex-vessel dosimetry and the inner surface fluence and on the other hand between the specimens dosimetry and the inner surface fluence) are large. Consequently, they must be evaluated within a few years of operation. These uncertainties have to be taken into account when assessing the effect of embrittlement on the vessel lifetime.

Some complementary measures should be taken in order to reduce the uncertainties (such as determining the fluence by analysing samples scraped off from inside the surface of the beltline region).

The improved surveillance programme together with the complementary NRI programme is based on a justifiable method and so fulfils recommendation R1 provided that the following commitments taken by NAEK during the meeting are fulfilled.

The team of Western experts gave the following recommendations

- Both the NAEK improved surveillance programme and the complementary NRI programme should be applied (integrated surveillance programme).
- As a part of the integrated surveillance programme a thorough validation and a conservative evaluation of uncertainties of the correlation on the one hand between the ex-vessel dosimetry and the inner surface fluence and on the other hand between the specimens dosimetry and the inner surface fluence should be applied. The results of these evaluations should be provided within a few years of operation (for instance 4 years) and, if needed, complementary measures should be taken in order to reduce the uncertainties.

3.2.2 Dynamic effects produced by postulated breaks of high-energy pipes

The Modernisation Programme reviewed in 2000 by RISKAUDIT foresaw to implement two specific measures related to the issues:

- Rigid support of steam and feed-water lines at the outlet of the reactor building (MP issue N° 12211)
 - The measure foresaw a study of simultaneous breaks of more than one MFWL or/ and MSL in the Turbine Hall. The supposed common causes of such breaks could be an external event and especially an earthquake (because the Turbine Hall is not designed for a postulated earthquake). It was decided to check whether such an event could lead to a turbine hall collapse and so to an impact on MSLs and on MFWLs.
 - NAEK informed that studies are performed and it was demonstrated that there is no risk to induce a multiple break of the MSL / MFWL situated in the Turbine Hall. Therefore it was decided that there is no need in whipping restrictors on MSL / MFWL in Turbine Hall.
- Analyses to determine extent of pipeline breaks (MP issue N° 17321)
 - NAEK envisaged to carry out a study in view to find out locations of probable breaks, then to implement corresponding measures for limiting of the induced dynamic effects and so to ensure multiple breaks of MSL / MFWL between the containment penetrations and the Main Isolating Valves (compartment A-820; level 28.8 m).
 - NAEK informed that studies are performed and it was demonstrated that there is no risk to induce a multiple break of the MSL / MFWL situated on the level 28.8 m.

RISKAUDIT considered that, taking into account the experience from recently commissioned VVER 1000 (Temelin NPP), the need of in-depth investigation and of some improvement (using the state of the art practice) is confirmed. Therefore, the conclusion of NAEK that the situation is acceptable and there is no need for further activities in this frame is not satisfactory.

RISKAUDIT therefore recommended in January 2004:

R2: NAEK has to take into account the experience gained by foreign NPPs with VVERs 1000/320 (e.g. Temelin NPP) in the field of the issues related to high-energy pipes breaks and especially regarding the relevant risks on main steam lines and main feed water lines. In addition, as a preventing measure allowing reducing the likelihood of a double-ended break, 100% of welds on the main steam lines and main feed water lines should be inspected by non-destructive methods before the commissioning.

The SNRCU agreed with this recommendation and requested from NAEK, in particular, to make a decision how the experience from the Temelin NPP can be applied to Ukrainian NPPs.

At the beginning of May 2004 NAEK announced its decision to contract NRI for application of the no-break zone concept on main steam lines (MSL) and main feedwater lines (MFWL) outside the containment at K2R4 in 2004. Such a concept has already been applied at Temelin NPP, whose design is similar to K2R4's design.

NAEK decided that the volumetric examination of 100% of the MSL and MFWL welds will be performed before commissioning.

On the basis of the information presented on the new solution, a team of Western experts (DGSNR, GRS, JRC and IRSN) made the following statement:

Taking into account this information, the team of Western experts considers that recommendation R2 is being fulfilled.

3.3 Analysis of identified changes in schedule

NAEK envisaged postponing 21 formerly pre-commissioning measures and implementing them after commissioning. However, the SNRCU has not approved such a decision for two following measures of the Modernisation Programme:

- MP issue N° 12431: Strength calculation of the reactor vessel head and
- MP issue N° 29131: Furnishing the compartment containing electronic equipment with gas fire fighting means.

The impact on safety from the postponing of other 19 measures are analysed below.

3.3.1 Heating of the sump water up to 20° C (ECCS active part) (MP issue N° 12331)

- **NAEK declaration:**

The design of the heating system is being performed and the measures will be implemented shortly after commissioning. Due to the low RPV embrittlement temperature the heating is not necessary for the first years of operation.

- **RISKAUDIT statement:**

The implementation of the sump water heating means is acceptable in a three years time after commissioning. Therefore, there is no objection for schedule change.

3.3.2 *Organisational engineering measures for management of accidents involving primary to secondary coolant leak up to Dn 100 mm (MP issue N° 12411)*

- *NAEK declaration:*

Following measures would be done before commissioning:

- Preventing measures: leak monitoring, inspection of the collectors, their annealing, additional rolling of tubes in the collectors, gap increase between the collector flange edge and the SG vessel (to avoid contact after the collector dilatation), restrictors of the leak size in case of collector lid lift up, extensive periodic inspection of collectors, improvement of secondary water chemistry and of the SG blow-down and further measures.
- Operator procedures for mitigation of the primary to secondary leaks,
- Nitrogen 16 sensors on MSLs in view to provide a fast detection of even small leaks from the primary circuit,
- SAR reflects the results of performed calculations of primary to secondary leak up to Dn 100mm, PSA covers the corresponding scenarios.

Moreover, an in-depth analysis of possible algorithm of automatic actions is under way (pilot SU NPP) with the intention to cope with a large primary to secondary breake. After finalisation of these activities, the found and approved solution would be implemented on K2R4 (after commissioning).

- *RISKAUDIT statement:*

The detecting means (planned to be implemented before the commissioning) and developed procedures would allow fast operator actions in order to manage such an accident. The implemented preventive measures intend to reduce drastically the frequency of the Initiating Event (Dn 100 mm). Therefore, there is no objection for the schedule change.

In the frame of the TACIS project UK/TS/29 the experts will review the analysis of large primary to secondary leaks (SAR).

3.3.3 *Diagnostic systems (MP issues N° 28113, 28121 and 28114)*

Related measures:

- Vibration diagnostic system (MP issue N° 28113)

The implementation was planned to be started before commissioning and the completion was foreseen after commissioning. Actually the implementation is planned after commissioning. The measure is only related to safety and to availability.

- In-core noise diagnosis system (MP issue N° 28121)

The implementation was planned to be realised before commissioning. Now the implementation is planned after commissioning. The measure is related to safety and to availability.

- Loose parts diagnosis system (MP issue N° 28114)

The implementation was planned to be started before commissioning and the completion was foreseen after commissioning. Now the implementation is planned after commissioning. The measure is only related to availability.

- *NAEK declaration:*

Following measures would be done before commissioning:

SPNI (start-up measurements systems) will be implemented for the phase of commissioning, especially for Vibration of RPV internals, Thermo-hydraulic characteristics of under the RPV lid, Vibro-acoustic of reactor, Pulsation of pressure and movement of the reactor installation.

After commissioning the complex diagnostic system will be installed. It will cover all the parameters foreseen in the issues 28113, 28121 and 28114.

- *RISKAUDIT statement:*

The implemented compensatory measures (SPNI) are able to cover the major part of the needed parameters. Therefore, there is no objection for schedule change.

3.3.4 Primary circuit leakage detection system (MP issue N° 28116)

The implementation before commissioning was planned in 2000. Now the implementation is foreseen after the commissioning. The measure is related to safety and to availability.

- *NAEK declaration:*

The implementation is foreseen after the commissioning. Compensatory measures exist; they will allow coping with the issue in the frame time between commissioning and the definitive implementation of the leakage detection system. In particular, the operator will establish a daily balance of the primary circuit inventory; it will allow detecting a leak with a high accuracy. Existing measurements for monitoring the humidity, temperature, pressure in the containment and the level in the containment drain sumps allow a fast identification of a leak (alarms).

Technical specifications for safety operation specify a maximal allowed leak (in case of exceeding, the units would be led to a cold shutdown state). In case of leak (even below the allowed flow rate) a TV camera installed in the containment would allow its approximate localisation. Then, after cooling down, a visual inspection would allow to precise it.

The definitive system will be implemented in 3 years time after commissioning.

- *RISKAUDIT statement:*

The implemented compensatory measures provide a significant improvement in the field of leak diagnostic. Therefore, there is no objection for the schedule change.

3.3.5 *Implement a residual fatigue lifetime diagnostic system (MP issue N° 28117)*

- *NAEK declaration:*

The system is designed and the pilot equipment is currently installed on ZNPP for approbation. After finalisation of the approbation process the system will be adapted for all Ukrainian plants including K2R4 (during the 3 years period after commissioning).

As a compensatory measure, all transients that could lead to change of the parameters will be recorded and taken into account in the data bank of the fatigue lifetime diagnostic. The new I&C system for K2R4 allow to record all needed parameters.

- *RISKAUDIT statement:*

The described measures will allow a comprehensive data bank of needed parameters in the meantime, between the commissioning and the implementation of the definitive system. Therefore, there is no objection for the schedule change.

3.3.6 *Introduction of an equipment set to manufacture and anneal high quality gaskets for the main joint (MP issue N° 12371)*

- *NAEK declaration:*

A compensatory measure is implemented: the procedures of the main RPV flange sealing are improved, in order to decrease the risk of main gasket deformation. Therefore, there is no urgent need for the equipment foreseen in 2000. Moreover, the deformation would be detected by the existing means, and the gasket would be replaced or repaired.

- *RISKAUDIT statement:*

The described compensatory measures will allow providing an adequate quality of the main flange tightness. Therefore, it is accepted that the measure could be postponed or even deleted.

3.3.7 *High voltage transformers bushings replacement (MP issue N° 24421)*

- *NAEK declaration:*

It is planned to assess a real status of the High voltage transformers bushings (connecting devices in the transformers) in order to decide on the need of their replacement. This will be done before commissioning. If the need of improvement would be confirmed, the corresponding measures would be realised after commissioning.

The original goal of the measure was to introduce modern devices allowing auto-testing. Now the tests are realised periodically.

- *RISKAUDIT statement:*

Taking into account that the measure is not safety related and that an evaluation of the bushings status would allow to precise the need of their replacement, it is accepted that the measure could be postponed or even deleted. Therefore, there is no objection for the schedule change.

3.3.8 *Monitoring the gas volume under the reactor cover (post accident monitoring system) (MP issue N° 14251)*

- *NAEK declaration:*

A pilot corresponding device has been manufactured and is being tested in Ukraine and Russia. It appeared that specific experiments are still needed in order to optimise the solution. Therefore, the device would not be available before commissioning.

The RPV level measurement is needed for BDBA (especially for the loss of SG feeding) in order to open the primary circuit blow down. The following preventive and compensatory measures are introduced:

- The likelihood of a total SG feed water loss is decreased due to additional (supplementary) DG.
- In any case the primary circuit blow down system would be opened in the case of a coolant saturation (specific alarm and operator actions).

- *RISKAUDIT statement:*

The described compensatory measure will allow decreasing significantly the need in the Monitoring of the gas volume under the reactor cover. Moreover, RISKAUDIT supports comprehensive industrial tests before implementation of the definitive solution. Therefore, there is no objection for the schedule change.

3.3.9 *Redesign temperature monitoring racks for protective tube units (MP issue N° 14111)*

- *NAEK declaration:*

The contract is signed with the supplier. But, taking into account the limited capacities of the supplier, there is a risk that all sensors would not be supplied before commissioning; in such a case they would be introduced after commissioning.

The existing equipment is able to ensure the function of in-core temperature monitoring adequately, the original goal was to introduce modern equipment for simplifying the maintenance.

- *RISKAUDIT statement:*

The existing devices can adequately ensure the function but its maintenance is difficult. Therefore the implementation is not urgent from safety point of view. Therefore, there is no objection for the schedule change.

3.3.10 *Prevent over-pressure in cold conditions (MP issue N° 12111) and Updating of pressurizer pulse safety device to implement „Feed and Bleed“ procedure (MP issue N° 13411)*

- *NAEK declaration:*

A Technical Decision is officially issued in order to introduce new functions for the pressurizer safety valves (Feed & Bleed and Cold Overpressure Protection). It was decided to follow the pilot project underway in Russia (Kalinin NPP, unit 3). The approbation phase of

the pilot project is not yet finalised, therefore the following will be done before commissioning:

- All equipment modifications needed for ensuring the new functions;
- Thermal hydraulic analyses for the new functions.

When the approbation on Kalinin NPP, unit 3 will be finalised the new functions will be put in operation (in 3 years period after commissioning).

It has to be noticed that the embrittlement temperature of the RPV is very low during the first years of operation, so the measure is not urgent. Moreover, preventing measures exist: interlocks that would stop the water injection in the primary circuit when the primary pressure is above 35 bars and its temperature is lower than 100°C. In addition, according to the procedures, the operator will disconnect the Medium Pressure Injection Pumps (TQ13, 23, 33) from the power supply.

With regard to the Feed&Bleed procedure, its need is identified essentially for BDBA scenarios linked with the total loss of SG feeding (in particular due to electrical power supply loss). Actually, introducing an additional DG will reduce the likelihood of such a scenario. It is an efficient preventive measure.

- *RISKAUDIT statement:*

Taking into account the introduced preventive measures and a good status of the RPV (very low embrittlement temperature) it is accepted that the measures could be postponed. Therefore, there is no objection for the schedule change.

3.3.11 Ensure residual heat removal under LOCA (replacement of insulation) (MP issue N° 13213)

- *NAEK declaration:*

Due to the limited capacities of the selected supplier, NAEK foresees to replace about 600 m² of insulation before commissioning and 1150 m² after (in three years time).

Currently a similar measure is being implemented on SUNPP 1. The corresponding study would identify the most critical locations where the insulation has to be replaced. The replacement on K2R4 will be planned in accordance with the aforementioned studies results.

As a compensatory measure, a specific procedure is available (as well as the corresponding equipment) for the detection of a filters capacity degradation after a LOCA. It would allow increasing the function reliability.

- *RISKAUDIT statement:*

Taking into account the compensatory measures it is accepted that the measure could be postponed. Therefore, there is no objection for the schedule change.

3.3.12 Replacement of the steam generator safety valves (MP issue N° 13321)

- *NAEK declaration:*

NAEK will contract the supplier very soon in 2004, so the SGSVs will be installed as soon as they are manufactured (expected before commissioning, but could be after due to the limited capacities of the supplier).

As a compensatory measure, an extensive test programme is foreseen for SGSVs in order to check their adequate operation.

- *RISKAUDIT statement:*

Taking into account the compensatory action it is accepted that the measure could be postponed.

3.3.13 Hydrogen removal from the reactor plant primary circuit equipment in the process of the cool-down and "cold" shutdown and analysis of hydrogen safety (MP issue N° 30131)

- *NAEK declaration:*

GIDROPRESS prepared guidelines for de-aeration of the primary circuit during cooling down. On this basis the operating procedures are adapted so, the issue is coped with. Therefore, the main part of the measure is realised.

In addition, studies will be carried out after commissioning to analyse BDBA scenarios (excluding severe accidents) where hydrogen could be cumulated in the primary circuit. If the study would show some needs of improvement the corresponding measures would be programmed.

RISKAUDIT would review this item in depth in the frame of Task 2 of UK/TS/27 or in the follow-up projects.

- *RISKAUDIT statement:*

Taking into account that the main concern is solved (hydrogen cumulation in the primary circuit during the cooling down) it is accepted that relevant BDBA studies would be provided after commissioning.

3.3.14 Develop documentation and carry out auxiliary systems reconstruction to increase the time of interruption in supply of blocking water to sealing of GZN-195M (MP issue N° 21115)

- *NAEK declaration:*

Before the commissioning the CVCS pumps will be backed-up by new additional DG. It will allow improving the seals cooling reliability.

Moreover, in accordance with the Modernisation Programme reviewed in 2000, investigation will be continued in view to substantiate the seals' resistance during 24 hours. It is foreseen to provide such substantiation (by introducing of possibly necessary measures) within 3 years after commissioning.

RISKAUDIT would review this topic in-depth in the frame of Task 2 of UK/TS/27 or in the follow-up projects.

- *RISKAUDIT statement:*

Taking into account that the cold water injection in the seals can be ensured with high reliability (CVCS backed up by an additional DG) the situation is acceptable for the commissioning. RISKAUDIT supports the commitment of NAEK to develop (after commissioning) a solution that would allow the seals tightness during 24 hours without any cooling.

3.3.15 Replacement of the air-conditioners (MP issue N° 22351)

- *NAEK declaration:*

The capacity of the Existing Safety relevant conditioners is sufficient for providing the function in all postulated conditions. The goal of the replacement is to implement modern conditioners with higher reliability and easier for maintenance.

In addition, after replacement of major parts of the I&C cabinets with modern equipment that produce lower heat during operation, and so the required capacities of the conditioners are decreased.

Therefore, their replacement is not an urgent measure.

The contract with the supplier is signed, the procurement is started, the conditioners will be implemented as soon as they are supplied (independently of the plants outages planning). NAEK is confident in a fast implementation of the measure, but it is possible (due to limited capacities of the supplier) that it would be completed after the commissioning.

- *RISKAUDIT statement:*

Taking into account that the original conditioners are able to provide their function in all postulated conditions and the fact that the new ones will be installed within a short period of time the situation is acceptable for the commissioning.

3.3.16 Redesign of the system for measuring the water level in SG (MP issue N° 14241)

- *NAEK declaration:*

The design of a new solution is planned to be finalised before commissioning. The implementation is planned within 3 years after commissioning.

The measure is devoted to make the level measurement more precise. In the eighties some scrams occurred due to inaccurate measuring of SG level. Since, feedback from this experience allowed reducing the frequency of such events. Therefore the measure is not urgent anymore and could be introduced after commissioning.

Moreover, in case of normal feed water loss due to failure in the level regulation, the feeding of the Steam Generators would be possible through the Auxiliary Feed Water System (two pumps backed by supplementary DG) and the Emergency Feed Water System (three 100% trains backed up by DGs).

- *RISKAUDIT statement:*

Taking into account the fact that the frequency of scrams due to inaccurate measuring of SG level is decreased and that two pumps of Auxiliary Feed Water System will be backed by supplementary DG before the commissioning, the schedule change is acceptable.

3.3.17 Recommendation and activities for ongoing tasks

For the ongoing tasks RISKAUDIT gave the generic recommendation:

R3: The Ukrainian utility and safety regulator have to use the state of the art practice for all the activities needed for realisation of the measures planned before and after commissioning (studies, design, manufacturing and implementation). For this Ukrainian organisations should continue inspiring from international experience. The corresponding support and monitoring has to be ensured in further international activities.

For the fulfilment of this recommendation the Ukrainian side will get support in different ways, among other in the frame of the TACIS project “TSO Support to the State Nuclear Regulatory Committee of Ukraine in the licensing of K2R4” the EU operating organisations (OSA on RNPP and KhNPP) are carrying out an evaluation of the methods used by NAEK in the implementation of the measures. Ongoing tasks in the framework of this TACIS project are

- assistance to SNRCU in evaluation of the plant Safety Analysis Report
- assistance to SNRCU in evaluation of the Programme for units commissioning
- assistance to SNRCU in the evaluation of conformity of the equipment and constructions installed since long period of time
- assistance to SNRCU in the licensing of a number of measures indicated in the Modernisation Programme.

4 CONCLUSION

The government of the Ukraine committed to ensure the safety upgrade of Rovno 4 and Khmelnytsky 2 to international standards. The EBRD and the EC support the achievement of this goal.

RISKAUDIT performed a peer review of the actual Modernisation Programme for K2R4. The assessment were concentrated on issues, which has been changed in comparison to the Modernisation Programme 2000.

In deviation of the MP 2000 the operator NAEK has changed the technical contents for the solution of 3 issues (MP issues N° 12351 “Develop and introduce new programme of surveillance specimens”, N° 12211 “Rigid support of steam and feed-water lines at the outlet of the reactor building” and N° 17321 “Analyses to determine extent of pipeline breaks”) and 19 measures were postponed from the pre-commissioning package to the phase after commissioning.

The changed technical solutions for the 3 MP issues N° 12351, 12211 and 17321 would not allow the resolving of the safety issues. On demand of SNRCU the operator NAEK announced the improvement of the technical solutions for these issues. This includes the implementation of the integrated surveillance programme for the RPVs (including the elements recommended here above) and the application of the no-break zone concept on main steam lines (MSL) and main feedwater lines (MFWL) outside the containment as well as the 100% volumetric examination of the MSL and MFWL welds before commissioning. The correct realisation of these measures allows solving of the safety deficiencies related to the RPV embrittlement surveillance and the high-energy pipes.

The impact on the safety due to the postponing of those 19 measures is acceptable. This is because of the fact that adequate preventive and/or compensatory measures are foreseen. Taking into account the analyses presented for the 19 postponed measures (see 3.3.1 to

3.3.16) and the fact that NAEK committed to complete all measures in the three-year period after commissioning RISKAUDIT has no objection for the schedule change for each of the measures.

The actual scope of measures allows to upgrade K2R4 to a safety level which is acceptable for commissioning.

On request of EC two projects are ongoing to review the implementation of the actual safety modernisation measures before commissioning. The work is performed by EDF (Rovno 4) and Iberdrola/SOGIN (Khmelnitsky 2). If any deviation will be revealed, the safety relevance of the deviation will be assessed by RISKAUDIT together with SNRCU .

Acronyms

BDBA	Beyond Design Basis Accident
CVCS	Chemical and volume control system
Dn	Diameter
DG	Diesel Generator
DGSNR	Direction générale de la sûreté nucléaire et de la radioprotection
EBRD	European Bank for Reconstruction and Development
EC	European Commission
ECCS	Emergency Core Cooling System
EU	European Union
GRS	Gesellschaft für Anlagen- und Reaktorsicherheit mbH
IAEA	International Atomic Energy Agency
I&C	Instrumentation and Control
IRSN	Institut de radioprotection et de sûreté nucléaire
JRC	Joint Research Centre (EU)
K2	Khmelnitsky NPP, unit 2
KNPP	Khmelnitsky NPP
MFWL	Main Feed Water Line
MSL	Main Steam Line
MP	Modernisation Programme
NAEK	Utility “Energoatom”
NIIAR	State Scientific Centre of the Russian Federation Research Institute of Atomic Reactors
NPP	Nuclear Power Plant
NRI	Nuclear Research Institute (Rez, Czech Republic)
OSA	On Site Assistance
PSA	Probabilistic Safety Assessment
QA	Quality Assurance
RISKAUDIT	RISKAUDIT IPSN/GRS International
RPV	Reactor Pressure Vessel
R4	Rovno NPP, unit 4
RNPP	Rovno NPP
SAR	Safety Analysis Report
Scram	Emergency action that provides rapid reactor shutdown
SG	Steam Generator
SGSV	Steam Generator Safety Valve
SPNI	Start-up measurements systems
SSTC	Scientific and Technical Centre for Nuclear and Radiation Safety (Ukraine)
SNRCU	Nuclear Regulatory Authority of Ukraine
SUNPP	South Ukraine NPP
TACIS	Technical assistance to states of the former Soviet Union
TSO	Technical Support Organisation
TV	Television
VVER	Soviet origin pressurized water reactor (WWER)
V-320	Type of VVER-1000
WANO	World Association of Nuclear Operators
ZNPP	Zaporozhie NPP

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