Support to Ukrainian NRA in Licensing Activity Related to the Completion and Safety Upgrading of Rovno 4 and Khmelnitsky 2 and Safety Upgrading of Zaporozhie 6

Final Assessment Report for the Loan Approval Procedure

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CONTENT

1. INTRODUCTION

1.1 Framework of the project

In the framework of the TACIS programme, the Commission of the European Community (CEC) signed a contract with Riskaudit IPSN-GRS International in order :

• to provide technical support to the Nuclear Regulatory Authority (NRA) of Ukraine for the licensing activities related to the construction and modernisation of Rovno 4 and Khmelnitsky 2 units (VVER 1000/320) ;

• to provide an independent technical advice to the co-lenders organisations in order to evaluate whether the two completed Nuclear Power Plants will be able to be in line with western safety objectives and practices.

Riskaudit was acting as a Consultant representing four European Technical Safety Organisations (TSOs):

- AEA-T, United Kingdom
- ANPA, Italy
- GRS, Germany
- IPSN, France

Technical leadership was ensured by GRS supported by IPSN.

Within the framework of this project, each European Technical Safety Organisation was in charge to provide technical safety expertise in identified technical areas, on the basis of application of internationally recognised safety principles (e.g. INSAG 3 published by the IAEA Director General's International Nuclear Safety Advisory Group) and codes of practice (e.g NUSS Codes of Practice adopted by the IAEA's Board of Governors), and of on the basis of application at a deeper technical level of Western European safety practices which have been recognised by national regulatory bodies.

Additionally, in order to provide NRA also with technical evaluation based on the application of Ukrainian regulations and practices, a specific sub-contract has been provided by Riskaudit to the Ukrainian Technical Safety Organisation (STC).

In consistency with the Terms of Reference which have been provided to Riskaudit by CEC, following tasks had to be covered :

- Definition of safety objectives to be met after the implementation of the Modernisation Programmes
- Safety evaluation of the Modernisation Programmes proposed by the utilities
- Assessment of utility report on the existing status on the NPPs.
- Licensing procedure
- Conclusions.

For each of these tasks, technical reports (/1/, /2/, /2A/, /3/, /4/, /5/, /10/), have been produced by Riskaudit and transmitted to both, NRA and CEC.

1.2 Safety objectives

Within the frame of its contract, Riskaudit had firstly to propose to NRA a definition of safety objectives to be met after the implementation of the Modernisation Programmes, and then to check if these objectives will be met.

The safety objectives proposed by Riskaudit /3/ and approved by NRA include some general provisions, as well as some specific ones.

By implementation of the defence in depth concept centred on several independent levels of protections, including successive barriers preventing the release of radioactive materials to the environment, the overall objective is that design arrangements, equipment classification, achieved quality and operation practice prevent accidents with a high confidence. It must be ensured that, for all accidents taken into account in the design of the plant, even those of very low probability, radiological consequences, if any, would be minor; and the likelihood of severe accidents with serious radiological consequences would be extremely small.

Through use of reliable structures, components, systems and procedures, accident prevention is of first priority. Additionally, taking into account that prevention of accidents cannot be a sufficient guarantee, it has to be assumed that abnormal occurrences and accidents may happen, and that necessary additional protection is needed by incorporation of engineered safety features. These are provided to halt the progress of an accident and when necessary to mitigate its consequences.

Capability of systems to perform their function in all conditions, in which they are called to operate, has to be ensured by high level quality of equipment and components (including adequate surveillance and in-service inspection) for which qualification to operate under given conditions must be proven. In addition, suitable provisions have to be taken in order to minimize the risks of multiple failures due to common cause.

Attention should also be given to accidents of very low likelihood but more severe (Beyond Design Basis Accidents). Preventive measures have, if necessary, to be taken in order to reduce their probability of occurrence and procedural measures should be provided for managing their course.

Suitable provisions associated also with clear management structure and adapted safety culture have also to be made to ensure reliable and safe operation, and to minimize the risk of operator errors.

1.3 Safety status of Rovno 4 and Khmelnitsky 2 units

a) Basis for design

The construction of Rovno 4 and Khmelnitsky 2 units, commenced according to the original design for Soviet VVER 1000/V320. The design basis was the Soviet "General Safety Principles of Nuclear Power Plants during Design, Construction and Operation" /OPB-73/ which provides a multi-stage system of safety precautions and also the „Regulation for NPP Nuclear Safety“ /PBYa-04-74/.

The experience feedback from the design and construction of similar units was partially introduced. In this period of time the OPB-73 was replaced by the OPB-82, this had an influence on the projects, also as well as measures and requirements, developed after the Chernobyl accident (OPB-88 and complementary specific rules e.g.).

b) Description of Safety Features

According to the guideline OPB-73, quality assurance during design, manufacture, erection, start of operation and operation shall represent the first stage of the safety precautions. The second stage shall comprise the technical installations and the organizational measures compensating deviations from the intended operation. The third step of the safety precautions shall be the equipment of the nuclear safety installations.

The Soviet guideline OPB-73 and its subsequent versions claim the achievement of the protective aims of sub-criticality, core cooling and long-term residual heat removal, as well as enclosing radioactive materials according to the barrier principle. The barriers for retention of the radioactive fission

products are the fuel rod cladding, the reactor pressure vessel and connected components as well as the full pressure containment.

To a major extent the design of the V-320 type corresponds to these global requirements.

Essential parts of the safety system are located in the reactor building outside the containment, where the protection against the loads of an airplane crash are guaranteed by a physical separation.

On each plant, there is a three-train design of the safety installations, each train having a capacity of 100 %. The trains are largely independent and mostly physically separated. Each train of the engineered safeguards is supplied by its own emergency power supply. Instrumentation and control (I & C) are designed redundantly, partially with electronic modules and partially with relay connections with an open-circuit mode. I & C are subdivided into the emergency protection system (reactor protection system - initiation of the reactor scram) and the protection system for the control of the safety system (reactor protection system without initiation of the reactor scram).

The systems in the containment are protected against mechanical loads due to pipe ruptures, such as jet forces, pressure waves and flying parts. Containment integrity during accidents is ensured by the isolating valves of the building.

The following accidents and initiating events were considered for the engineered safeguards design of the Rovno 4 and Khmelnitsky 2 units:

- loss-of-coolant accidents
- transient accidents, like, for example, secondary side leakages (break of main steam line break), loss of off-site power, reactivity accidents
- External events, e.g. earthquakes, airplane crashes, etc.

The « maximum design basis accident » is the spontaneous break of the primary coolant pipe with coolant escaping on both sides, assuming loss of off-site power. Loss-of-coolant accidents, according to OPB-73, are considered to be controlled, if the fuel-rod-cladding temperature is lower than 1200 C, the oxidation depth lower than 18 % of the initial thickness of the cladding tubes and the proportion of the reacting zirconium lower than 1% by mass of the claddings.

1.4 Modernisation Programmes /7,8/

Having in mind that the overall objective for both Rovno 4 and Khmelnitsky 2 units is to reach *„an acceptable safety level comparable to the one achieved on Western NPPs erected during the same period“*, the Engineering support of the Project Management Group (“Kiev Institute“ ENERGOPROEKT) within the frame of the overall project on the completion and modernisation of these two units, proposed Modernisation Programmes. Taking into consideration the internationally recognised fact that *„design safety philosophy and conception of VVER 1000/320 correspond to the modern safety principles“*, the proposed Ukrainian upgrading programmes is *„not intended to change the safety philosophy and conception as well as existing design basis“*. The main goals of the Modernisation Programmes are:

- *„to eliminate the non-conformance with the current safety norms (Ukrainian regulation), having an impact on safety or to propose compensatory measures in order to reach an acceptable safety level,*
- *to improve reliability of safety-significant systems and equipment,*
- *to implement the IAEA recommendations developed in the frame of the IAEA extra-budgetary programme on VVER 1000/320, in order to meet the international practice and experience“*.

The Modernisation Programmes were developed in a three steps approach. A revision 0 of the document has been prepared and commented by the NRA as well as by the IAEA. On this basis, a more structured version (revision 1) has been prepared and submitted to the NRA in the summer 96. This version has been deeply evaluated for NRA, firstly by STC of Ukraine in order to check the proposed version in view of the Ukrainian regulation and practice, and secondly by Riskaudit in order to check the proposed version in view of the Western European practices, also taking into account internationally recognized documents, such as the INSAG 3 and NUSS Codes of practice. On this basis, the NRA has issued its official comments which have been taken into account in the 3rd version of the programmes (revision 2) which has been issued beginning November 96.

The Modernisation Programmes consist of three parts:

- part 1 is a generic programme including all measures to be included (or already included for some of them) on VVER 1000 operating and under construction in Ukraine,
- part 2 presents the Modernisation Programme to be implemented in unit 2 of Khmelnitsky NPP, (both before and after start-up),

- part 3 presents the Modernisation Programme to be implemented in unit 4 of Rovno NPP, (both before and after start-up).

In parts 2 and 3 are included:

- the list (but also technical description) of the proposed measures,
- information on the improvement measures already implemented,
- information on safety improvement measures which will be (or are underway to be) implemented within the frame of other programmes for Ukrainian VVER-1000 units (such as for example „generic“ or „branch“ programmes, operating organization plans from Rovno 4 and Khmelnitsky 2 units); in such cases Riskaudit recommended that NPPs systematically define for review
- objective of the measure
- content
- schedule of implementation
- brief description of the status of implementation of measures and concise information on financial and planning needs.
  (This part has not been subject for the present review.)

All measures proposed in the Modernisation Programmes are classified in 3 groups:

- safety improvement measures
- reliability improvements
- operation improvements

Information are also given on the planned schedule for implementation.

1.5 Evaluation

1.5.1 Methodology for the evaluation of the Modernisation Programmes

The safety evaluation of the Modernisation Programmes which have been performed (see /1/, /2/, /2a/) took as a basic assumption that essential design and operational safety weak points for this type of reactors have been previously identified through all the series of works performed on VVER 1000/320 reactors by international or Western organizations such as Riskaudit (/9/, /11/-/14/), IAEA, WANO,...

The objectives of the safety evaluation were:

- to verify on the basis of international knowledge published on this type of reactors, enriched by specific input data and assessment for Rovno 4 and Khmelnitsky 2, the completeness of the proposed modernisation measures,

- to check the adequacy of the measures, in order to provide an independent judgement of the safety of the modified plant in front of Western practices. For that it has been considered that Western-European practices to solve a technical question were acceptable if transferable to VVER type plant, and if a global consistency can be found.

- to assess the implementation schedule of the proposals.

The judgement process to determine if a modification has to be implemented before start-up or after start-up /4/, relies on a categorisation of the safety issues, in relation with a determined safety function, depending on :

- the frequencies of occurrence of initiating events which are relevant to the issue,

- the potential consequences of the considered initiating events regarding core behaviour and confinement of the radioactive products,

- the reliability of the safety functions necessary to ensure the prevention of accidents and to limit their consequences.

Within the frame of the review work, different sources of information have been used. Regarding background information on VVER 1000/320 safety issues, two main sources have been used :

- The Riskaudit safety evaluations on Stendal A and Rovno 3, (plant specific evaluations /9/,/11/,/12/).

- The IAEA document on ranking of generic safety issues for VVER 1000/320 NPPs /6/. (**Appendix 2** contains a comparison between safety issues of the IAEA Issue Book and Modernisation Programmes Rovno 4 and Khmelnitsky 2)

This have been completed by other sources, such as information provided by NRA and its Ukrainian technical support regarding specific Rovno 4 and Khmelnitsky 2 data.

In front of identified safety issues, following source of information has been used :

- technical proposals given in the Modernisation Programmes.
- oral information given by NPPs on measures intended to be implemented in some other frames (e.g « branch programmes », « operational programmes »).

1.5.2 Status of the existing equipment

The construction was suddenly stopped in 1990 and since then no further work was carried out. The construction progress of Rovno NPP, Unit 4 and Khmelnitsky NPP, Unit 2 is such that some buildings and systems are relatively close to completion and that others are at different stages. The main buildings exist. As the construction was suddenly almost stopped in 1990, it has to be understood that some equipment and parts are already installed, some are stored on site, some are still with the various manufacturers and some are still not manufactured.

1.5.3. Limits

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

- Rovno 4 and Khmelnitsky 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, and so, no specific calculations have been performed in the frame of this project. It has however to be pointed out that the « generic knowledge » on VVER 1000/320 has been enriched during the evaluation process by specific input data provided by NRA, NPPs or their support organisations.
- It was assumed that all activities linked with future studies to be performed and improvements to be implemented will be done using the best practice.
- It has been assumed that information provided by the NPP was correct.

It has also to been said that if the modifications cannot be implemented according to the recommended schedule, technical discussions should be organised in order to judge on resulting safety impact, and to agree on compensatory measures when necessary.

For those measures not included in the Modernisation Programmes (/ 8 /) but which has been said to be included in branch or operational activities, Riskaudit stated its opinion on the need to implement

corresponding modifications. On the basis of information given by NPPs on measures intended to be implemented in some other frames the Riskaudit safety evaluation report /2/ was modified /2a/.

In cases where studies are proposed, Riskaudit recommends (even if not explicitly written) 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 NRA/Riskaudit/STC all along the licensing process up to their implementation and commissioning.

2. FINDINGS

2.1 Modernisation Programmes

Detailed information :

- on the safety issues to be solved,
- on the corresponding (if any) modernisation proposals,
- on the Riskaudit evaluation and recommendations,

can be found in the Riskaudit main reports (/1/, /2a/).

A synthetic overview of the modernisation proposals and of the Riskaudit recommendations is given in **Appendix 1**.

Thereafter, a short conclusion for each technical area considered during the review is presented. Main improvements, either proposed by the industry or recommended by Riskaudit are shortly explained and linked with the corresponding level of defence in depth. A brief conclusion related to the overall improvement of the corresponding technical area is then proposed.

2.1.1 Core and fuel handling

a) Control rods and fuel bending

It is known that malfunctions have occurred in the operation of reactor shutdown rods of numerous VVER 1000, and therefore, in the Modernisation Programmes, the utility has proposed a set of measures in order to solve this safety issue. The proposal has been supported by Riskaudit who has recommended complementary measures in view of the latest development.

b) Optimisation of fuel loads

The Modernisation Programmes includes some aspects related to optimization of fuel loads (low leakage, burnable absorbers, ...).

c) Xenon and power control

The NPP has proposed to improve Xenon and power distribution control system. During evaluation of Modernisation Programmes revision 1, Riskaudit has recommended the implementation of an automatic system (see also § 2.1.6).

d) Boronmeter

The replacement of existing unreliable boronmeter is foreseen in the NPP Modernisation Programmes.

e) Reactor core subcriticality monitoring

It has been proposed to install a new monitoring system of neutron flux in order to achieve a sufficient monitoring of subcriticality.

It has been recommended by Riskaudit to implement this upgrading before start-up.

f) Leak tightness control

A measure was proposed in the Modernisation Programmes for improvement of the leak tightness measuring system.

g) Conclusion

By implementation of proposed or recommended measures, control of power and corresponding reliability will be improved under all conditions.

2.1.2 Integrity of the pressure retaining boundary

a) RPV embrittlement and its monitoring

Different measures have been proposed in order to improve level 1 of defence in depth.

It is firstly proposed to reduce the neutron flux at the reactor vessel welds facing the core. This is a positive preventive measure which will permit to reduce the brittle fracture potential of the RPV by reducing the increase of transition temperature.

Secondly, a set of measures have been proposed in order to reduce by implementation of preventive measures (warm-up of ECCS parts) the risk of RPV thermal shock, and so, brittle fracture potential.

Additionally, some improvements are also planned in order to better substantiate critical brittleness temperature. This concerns mainly types and number of surveillance specimens (still originally proposed to be located above the core), new design of containers and procedure to clarify the transfer of results to wall conditions, but also improvement of the fluence monitoring.

To complement the NPP proposals, one main action has been recommended by Riskaudit to be introduced in the Modernisation Programmes : repositionning of the irradiation surveillance specimens into the gap between core and RPV wall.

This recommendation (which has been accepted for revision 2 by the utility) will permit, having a better surveillance programme, to have a clear picture, all along the plant life, of the actual RPV embrittlement issue.

b) Primary pipes

It is known from previous evaluations on similar NPPs that behaviour of primary pipe whip restraints may be debatable. In order to deal with this issue, the NPP proposed to check the anti-whipping devices and pipes calculation (to improve if necessary) but also to implement a complex diagnostic system aiming to monitor piping and equipment during operation. This later system will contribute to reveal early deviations from design conditions, and help to prevent serious consequences.

Additionally, complementary proposals have been given in the programme. These concern both the implementation of the leak before break concept and fatigue monitoring system which will improve prevention of accidents.

c) Steam and Feedwater piping integrity

Different measures have been proposed by the plant in order to improve prevention of accidents. Corresponding safety problems are presented in a systematic way in pipe whip hazard chapter (§ 2.1.6)).

d) Steam generator collector integrity

In order to reduce the potential of steam generator collector integrity loss, numerous measures have been given by the NPP, such as design improvement of the steam generator blow down system aiming to improve water chemical conditions in steam generator bulk water in order to reduce corrosion attack to the headers and also, improvement and automation of water chemistry control system monitoring the content of impurities in bulk water promoting corrosion attack.

This, associated with recommendations given by Riskaudit for future, In-service inspection will permit to improve prevention of primary to secondary leakage accidents.

The development and implementation of measures have been proposed (up to now not in detail) in order to cope with a DN 100 leakage which can be retained under some conditions (extended ISI; stable crack demonstration, ...).

e) Steam generator tubing integrity

The utility has included in its Modernisation Programmes a specific item related to non-destructive testing activities. Eddy current activities are planned. It has been proposed to establish a tube plugging criterion.

It has also been proposed by the utility to improve preventive non-destructive in-service inspection methods for different components (SG, RPV). This has been supported by Riskaudit.
Additionally to these preventive measures, it has been recommended by Riskaudit to re-introduce a measure which existed in Modernisation Programmes revision 1 (and not in revision 2) on the implementation of a system for monitoring primary circuit leakage in steam generator.

f) Conclusion

The integrity of pressurized components will be improved under all conditions by a better monitoring of the embrittlement process and by various measures ensuring a better prevention of breaks. Prevention and mitigation measures to deal among others with the steam generator collector integrity problems will also be developed.

2.1.3 Electrical supply

a) Internal distribution

It has been proposed by the NPP to improve the electrical power supply system category I reliability by replacing numerous equipment (existing inverters, breakers, transformer bushing, ...). A recommendation has been given by Riskaudit in order to accelerate the speed of replacement for safety related components. From previous analysis, it is known that some questions can also be raised for some other equipment such as cables and cable penetrations. Regarding the cables a methodology has been proposed to be developed in order to assess residual lifetime of cables in view of future modification. Regarding the cable penetrations, situation has already been improved on each plant.

b) Diesel generator sets

An additional diesel generator is planned to be installed and reliability of existing DGs is proposed to be improved. These actions are supported by Riskaudit who has given some recommendations for further implementation.

c) Direct current

Replacement of batteries has been proposed by the plant. The goal is to increase the discharge time to 1 hour.
Here also, some recommendations have been provided by Riskaudit for further implementation.
An additional item is also recommended by Riskaudit in order to check the lightning protection system capability.

d) Conclusion

The capacity of AC and DC power distribution will be better adjusted to the safety function, reliability of the systems will be increased. These measures will participate to the improvement of the level 1, 2, 3 and 4 of the defence in depth.

2.1.4 Instrumentation and Control

a) Reactor Control & Protection System

Recommendations have been given to upgrade the reactor power control system to improve Xenon and power distribution control. Additionally, Riskaudit has recommended NPPs to develop a strategy of automatic control and limitation of Xenon oscillation. Riskaudit recommended to link the automatic control with the increased functionality of the In-Core-Instrumentation System (see also b) and 2.1.1).

b) In-Core-Instrumentation System

No measure has been proposed for this area in the utility Modernisation Programmes. A recommendation has been given by Riskaudit to increase functionality of the In-Core-Instrumentation System.

c) Out-core neutron flux control

At low power, the neutron flux monitoring sensitivity of the existing control system is low, and so the NPPs proposed in the Modernisation Programmes to replace the existing equipment by a new one with more sensitive sensors. This proposal has been supported by Riskaudit.

d) Power unit control computer system

The power unit control computer system will be improved. Riskaudit recommended to replace also the UCTF of the 2nd generation in Khmelnitsky 2 by one of the 3rd generation. In Rovno 4 it is already implemented.

e) Control room data processing system

It is proposed in the Modernisation Programmes to install a SPDS and of a PAMS but also the upgrading of control room computer system.

f) Other safety I&C upgrades

- Replacement of the impulse lines to the transducers;
- Replacement of sensors, transducers and secondary instruments, e.g. level for the pressurizer and steam generators;
- Installation of a facility for detection of steam under reactor head;

g) Plant monitoring and diagnostic systems

Numerous improvements have been either proposed by the plant or recommended by Riskaudit in order to improve monitoring and diagnostic systems.

h) Conclusion

The functionalities and the reliability of I&C will be improved, resulting in a better control of the reactor in a wider range of plant conditions.

The measures will improve levels 2, 3 and 4 of the defence in depth concept.

2.1.5 Containment

a) Structural aspects

Within the frame of structural aspects, a set of studies aiming to demonstrate the adequacy of the containment structure and its ability to withstand DBA and loads resulting from different hazards (seism, wind, ...) has been proposed by the utility. Also, the Modernisation Programmes propose a measure aiming to improve existing containment state monitoring and to develop a system for cable monitoring. No measure was proposed in the Modernisation Programmes to resolve the pre-stressing tension losses problem because this will be treated in a generic programme. A recommendation has been introduced by Riskaudit on this issue.

Another item has been recommended by Riskaudit to be included in the Modernisation Programmes. It concerns an analysis of the containment in the worst severe conditions (ultimate strength capabilities), including bottom slab and sump behaviour.

b) Test procedure

It has been proposed a specific item dealing with the improvement of measuring devices for containment vacuum test.

c) Conclusion

The proposals will improve the reliability of the last barrier during DBA and BDBA (levels 3 and 4 of the defence in depth).

2.1.6 Internal and external hazards

Both, internal and external hazards (including man made and natural events) have been considered in the analysis. For each type of hazards, two aspects have been evaluated, the first one related to correction of known deficiencies, the second one to the existence of a full safety demonstration which should be used to identify if needed complementary improvements.

a) Pipe break and pipe whip hazard

Some specific measures have been proposed by the utilities in order to correct identified safety problems. This concerns mainly weaknesses identified on the secondary systems (steam and water pipes). These measures which are linked with the improvement of levels 2, 3 and 4 of the defence in depth are positive but limited to the treatment of know deficiencies, so it has been recommended by Riskaudit that a full scope analysis be performed in order to identify possible complementary weak points for further improvement.

b) Internal flooding

One measure has been proposed to deal with an analysis to be performed in order to identify possible weak points for further improvement. This measure is positive and it has been recommended by Riskaudit that this study be exhaustive and systematic.

c) Missiles

No generic measures have been proposed, and here also performance of an exhaustive study has been recommended, with the same objective as for previous points (a and b).

d) Drop of heavy load

The improvement of polar crane (implementation of interlocks to avoid wrong path of loads) that has been proposed is already implemented together with the polar crane equipped by double-handle device. Moreover, container drop analysis has been realised, and so it has been considered by Riskaudit that the situation was satisfactory.

e) Fire

Two types of measures have been proposed in the Modernisation Programmes : corrective measures for known deficiencies (e.g. replacement of equipment such as fire doors, switches, combustible petroleum oil, installation of complementary devices such as fire valves, improvement of resistance rate, definition of actions to maintain safe shut-down and long-term subcriticality in case of fire in the cable compartment under MCR, ...) and performance of an exhaustive deterministic fire analysis in order to identify and to correct possible complementary weaknesses.

The proposed approach is considered by Riskaudit as satisfactory. On some specific points, recommendations have been given for further steps.

f) Aircraft crash, toxic gases, external explosions

Measures (studies and modifications if necessary) have been proposed in the Modernisation Programmes. Situation is considered by Riskaudit as satisfactory.

g) Earthquake

In the Modernisation Programmes a special measure is foreseen which consists of several additional investigations in order to obtain supplementary data which will allow either to confirm determined seismic level or to take appropriate decisions.

Regarding the aspect of the earthquake as an initiating event, it has been recommended by Riskaudit that an exhaustive study be performed in order to identify possible needed improvements.

h) Extreme temperature conditions

No measure has been proposed originally by the utilities. Regarding hot temperature, situation was satisfactory. A study has been recommended to be performed for extreme low temperature in order to identify needed modifications (heating systems are not classified), engagement is taken in revision 2.

j) External flooding, Tornado

Existing situation is satisfactory regarding external flooding. On tornado aspect, a study is proposed to be performed.

k) Conclusion

Implementation of preventive measures and in depth assessment associated with determination and implementation of complementary improvements will result in an effective reduction of associated risks. The likelihood of common cause failures will be reduced.

2.1.7 Systems

a) Control of reactivity

Within the frame of accident analyses it has been recommended by Riskaudit that scram signal list be re-analysed, taking into consideration the new DBA list (see § 2.1.8). Depending on analysis results, complementary signals (such as high level in pressurizer, high level in SG, fast decrease of SG pressure) may be necessary. In such a case, this will improve level 2 and 3 of defence in depth.

Additionally to the proposal related to the reliability improvement of Boron concentration measurement, it has to be noticed that after Riskaudit recommendation given on Modernisation Programmes revision 1, the utilities plan to perform a study and to implement necessary improvement measures to prevent Boron dilution. This is satisfactory, but a complementary NPPs proposal has been given to deal specifically with the ECCS heat exchangers water slug dilution issue. On this item Riskaudit gave a recommendation on the schedule which has been accepted in The Modernisation Programmes revision 2.

b) Control of water inventory

Regarding the possibilities of a break in all reactor states (especially under cold shutdown situation), no measure has been proposed by the NPPs. Such an item has been recommended by Riskaudit to be introduced in the programme under the accident analyses list review.

Regarding primary pump seals LOCA, no measures were proposed by the utilities, and therefore a specific recommendation has been given by Riskaudit (tests and improvements if necessary) on Modernisation Programmes revision 1, this has been included in Modernisation Programmes revision 2.

In the present situation, it has been recommended by Riskaudit to exchange thermal insulation of main pipes in order to solve the ECCS sump filtration issue (which may lead to blockage of the recirculation).

As already mentioned (§ 2.1.2) the NPPs proposed to limit the risk of thermal shock on the RPV wall by heating up ECCS parts. Such an action is positive for accident prevention.

Regarding separation of ECCS from primary system, it has been confirmed by the NPPs that within qualification item, it will be checked that valves located inside the containment are already qualified to operate under LOCA situation. The situation is satisfactory.

From previous evaluation it is known that it should be demonstrated that primary water purification components are able to withstand accidental conditions. No measure has been proposed in the Modernisation Programmes, but it has been understood that this issue will be also considered under the qualification item (see h).

c) Cooling function

Numerous modifications have been proposed to improve normal feedwater system.

The protection of emergency feedwater pipes against the risk of multiple rupture is treated in hazard chapter (§ 2.1.6).

In order to deal with the re-supplying of the EFW tank, a measure has been proposed in the Modernisation Programmes (additional make-up system).

Regarding the qualification of BRU-A (water or isolating valves) steam generator safety valves (replacement, qualification in accordance with functional requirements) and of Pressurizer PORV, the proposals given in the Modernisation Programmes will permit to increase levels 3 and 4 of defence in depth.

d) Primary pressure control

A measure has been proposed by the utilities to deal with cold over pressurisation problem. This measure (use of ECCS safety valve) was not acceptable. A very significant recommendation has been given by Riskaudit (installation of a specific device) in order to improve level 2 of the defence in depth.

e) Confinement

Regarding the extension of the confinement (ECCS sump lines problem), no measures have been proposed in the Modernisation Programmes. It is recalled that a problem on the non-isolable part of this line may lead to a V. LOCA. In order to improve level 2 and 3 of the defence in depth, a recommendation has been given during the evaluation of Modernisation Programmes by Riskaudit to deal with this issue.

On this crucial V. LOCA problems, it has also been recommended in Modernisation Programmes revision 1 by Riskaudit, that a study be performed to check all lines going through the containment and to analyse (for improvement if necessary) all possibilities of containment by-pass. As it has been understood in Modernisation Programmes revision 2 that a systematic study will be performed. In this case the situation will be satisfactory.

f) Link with accident studies

No detailed list of DBA and BDBA has been proposed by the utilities in the Modernisation Programmes. This among other is true for events occurring in shutdown states and on possible break or leak in the ECCS (used as RHR) and therefore specific recommendations to consider these cases have been given by Riskaudit.

As already mentioned (§ 2.1.2), a measure is included in the Modernisation Programmes to deal with the SG collector rupture issue. Complementary recommendations have been given by Riskaudit (introduction of preventive measures, rules for studying, possible consequences, ...).

No exhaustive measures are included in the utility proposal to deal with total black-out issue, total SG feedwater loss, total loss of the cold heat sink and ATWS. Recommendations have been provided by Riskaudit in order, after studying, if necessary to reduce the probability of such events and/or to reduce the consequences in case of occurrence.

Finally, it has to be mentioned that the issue related to hydrogen release during normal and post-accidental conditions has been included in the proposed Modernisation Programmes. Two proposals have been given covering normal operation including shutdown, DBA situations and severe accidents. A recommendation has been given by Riskaudit in order to prioritise the proposals.

h) Classification, qualification

The NPP has proposed an item dealing with this item. The proposed approach was totally not satisfactory and a complementary recommendation has been given by Riskaudit. Basically, the main concern is related to the qualification „proof“ which can not for Riskaudit be limited to passport documentation. Documents such as test reports or calculation reports should be also available for review on the file or complementary works would be necessary.

i) Conclusion

The measures proposed by the utility complemented by the ones recommended by Riskaudit will improve the prevention of accidents, the reliability of the safety systems and of their capabilities so as to allow a better control of DBA and proper management of BDBA permitting to prevent core degradation and mitigation of the consequences.

2.1.8 Accident analysis

In the Modernisation Programmes, it is proposed to amend the DBA list and to perform corresponding analysis. No list was yet available. A methodology for classification of DBA has been recommended to be used by Riskaudit which recommended also to include in the new list some initiating events, mainly those which can occur during shutdown states (primary break, loss of heat removal with low mass inventory, water slug dilution, e.g..) (see also § 2.1.7).

Regarding BDBA, the same action (new list) has been proposed in the Modernisation Programmes. Use of PSA methodology to better define such a list has been recommended by Riskaudit which has also recommended to include some particular events.

The code verification issue was not addressed in the Modernisation Programmes because already included in a „generic programme“. It has been recommended by Riskaudit that such programme and results be presented for review.

It has finally proposed by the NPPs to realise a PSA level 1. It has been stated by Riskaudit, that the results of PSA performed before start-up can only give some highlights on some sequences but can not be considered as really specific. It was recommended by Riskaudit that revision of PSA after start-up be introduced. This engagement is included in revision 2 of the Modernisation Programmes.

2.1.9 Operational Safety

a) Organisational structure

There is no specific measure in the Modernisation Programmes related to organisational structure and management modernisation, because already included in the frame of „operational“ programme. Riskaudit has recommended that organisational structure be revised in order to be in consistence with recommended IAEA guidelines.

b) Quality Assurance Programme

Within the programme, it is planned that the plant shall elaborate and implement a quality programme, meeting Ukrainian requirements and also IAEA recommendations. Some recommendations which are included in revision 2 have been given by Riskaudit for further implementation steps.

c) Technical specifications

There is no specific proposal related to technical specification upgrading in the Modernisation Programmes. A recommendation to develop such a document according to Western approach is given by Riskaudit.

d) Maintenance programme

Improvement of maintenance and repair procedures has been proposed. Riskaudit has provided recommendation on schedule aspect on Modernisation Programmes revision 1 which have been introduced in Modernisation Programmes revision 2.

e) Surveillance tests and programme

An item has been given in the Modernisation Programmes by the utility aiming to improve the situation. This proposal is supported by Riskaudit. Recommendations given by Riskaudit on Modernisation Programmes revision 1 have been introduced in Modernisation Programmes revision 2.

f) Normal operating procedures

A proposal is given in the Modernisation Programmes. The situation is satisfactory but recommendations have been given by Riskaudit for implementation steps.

g) Emergency operating procedures - Training

Complementary to the amendment of DBA and BDBA lists, it is planned to develop mitigation procedures (symptom-oriented). This proposal is satisfactory, but complementary recommendations have been given by Riskaudit on scope and schedule.

Training aspects have also been discussed even if no measure was proposed on the Modernisation Programmes. For future step, Riskaudit has recommended that the whole system be reviewed as it seems to be planned.

h) Emergency plans

No measure is given in the Modernisation Programmes. Here also, for future step, a review of the existing situation is necessary.

i) Conclusion

The measures either proposed by the NPPs or by Riskaudit will contribute to the achievement of an overall safety culture of plant personnel.

2.1.10 Radiation Protection

a) Radiation Protection Program

It was suggested to foresee the development of a ″Radiation Protection Program″. This requirement is in compliance with requirements of Ukrainian Regulatory Authorities. Activities on this issue are mentioned in explanatory note of revision 2.

b) Radiological protection monitoring system

It has been proposed by the utilities to replace the radiation monitoring systems by a more modern one ensuring the monitoring of more functions. This is satisfactory.

c) Personnel dosimeters

The situation has already been improved. This is satisfactory.

d) Automatic environmental radiological monitoring system

A measure has been proposed by the NPP to install an additional automatic system to monitor radiological situation in the environment. The proposal has been supported and further recommendations have been provided for consideration during the next steps.

e) Conclusion

The improvements proposed in the field of radiation protection will result in an increase of both personnel and public protection in different situations. This, together with the ALARA principles implementation will be checked within the next steps of the project.

2.2 Quality status

2.2.1 Objective

Qualitative inspections have been performed by Eastern suppliers on Rovno 4 and Khmelnitsky 2 units, considering the following aspects:

- mechanical,
- metallurgical,
- civil works,
- electrical,
- I&C,
- turbine.

These activities have been performed under Goskomatom contracts which have been approved by the NPPs.

To have a sufficient confidence on main circuits/components quality, additional activities performed regarding metallurgical aspects have been especially supervised by a Western contractor following a Riskaudit recommendation given during the evaluation of NPPs proposed methodology.

The corresponding reports have been independently reviewed by Riskaudit in order to assess whether the quality status of these plants could be in line with quality achieved in Western plants.

2.2.2 Status and quality of the documentation

The documentation is present at various stages of completeness. As the construction stopped at a given moment and as some equipment is still at the manufacturers' premises, the documentation is not always available. Some documentation has still to be found, but it seems that the latter does not concern important items. If corrected, situation can be satisfactory (see also 2.2.3 f).

2.2.3 Main Results

a) The performed activities represent a noteworthy and appreciable undertaking to approach the problem of the technical verification of the acceptability of equipment already installed on the plant. However, the inspections should be mainly considered as a first insight into the plant status to evaluate the quality status of equipment and materials. It has been recommended by Riskaudit that prior to commissioning, a complete and systematic inspection programme be developed and implemented together with commissioning programme.

b) Conservation status of mechanical equipment is considered in general acceptable even if some repairs or limited replacements are necessary. The same opinion is valid for electrical components on both sites. It has been understood that NPPs will take necessary repair/replacement action. Situation will be satisfactory.

c) The supervisions activities confirmed that organisation, applied methodology, acceptance criteria and reporting comply with the applicable Ukrainian rules at the moment of manufacturing and erection.

d) Regarding civil structures, the situation appears different from site to site. On Rovno NPP conservation status is acceptable. This is not the case in Khmelnitsky 2 unit where the cables (tendons) of the cylindrical part of the containment have to be replaced according to the original supplier (inspection reports). Once this action will be performed, situation will be satisfactory.

e) As far as I&C equipment is concerned, the situation appears quite different. A large part of these materials need to be replaced because of damage or obsolescence. After replacement, situation will be satisfactory.

f) A specific „Metallurgical Quality inspection“ programme was part of the general „Quality Inspection“ programme sponsored by the European Commission in order to evaluate the quality of the mechanical components implemented and to generate more independent conclusions. The document inspection confirmed that the traceability of the technical documentation is almost complete, with some exceptions, which can be easily corrected. The companies and personnel involved were qualified enough to deal with local practices. Some of them are able to comply with Western standard organisation and produce high quality work. The inspection and surveillance actions were complementary to those performed during the construction. They confirmed that the equipment complies with the rules & norms applicable in Ukraine. For some main components (Reactor pressure vessel, steam generator) complementary optimised inspections were considered for particular purposes (inner surface, collector ligaments). They did not reveal any unexpected situation regarding the results available from previous inspections. All detected sub-surface indications are within the Ukrainian acceptance criteria; only some surface indications were identified, and their repairs have to be considered later. To some extent the scope was not broad enough; it has shall done later.

The preservative measures to keep the installed equipment free from environmental degradation during the interrupted erection phase were not found to be totally satisfactory. Surface deterioration (oxidation and rust traces, paint deterioration, ...) on components and their supports are concerned by curative measures and have to be considered during the completion phase, or even earlier.

A set of gammagraphic films were found to be in acceptable shape after a long storage period. Evidence of differences in practice has been shown, when compared to Western practice. Analysis of these suggests that the techniques used are adequate as regards actions within the Ukrainian codified system. Comparison with Western practices, which usually comes out in favour of those, does not allow any definitive conclusion to be reached regarding a global judgement on reduced safety margins for Eastern NPPs. This question will be reflected in a completion project because it requires a global assessment, including safety and design analyses.

Short and mid-term recommendations are given for improvement of preservation conditions, repair of surface deterioration on the equipment and their supports, as well as random replacement of the most seriously damaged supporting systems, the reconstitution of a complete manufacturing and construction documentation, additional focused and optimised inspections will be considered for the dissimilar welds, and further consideration will be given to the development and qualification of inspection techniques during the completion phase.

3. CONCLUSIONS

The proposals of the utilities and their partners to complete and upgrade Rovno 4 and Khmelnitsky 2 units (being both of the latest VVER generation 1000/320 model), and the status of installed equipment have been reviewed by Riskaudit in the framework of this Tacis project in order to provide an independent judgement of the safety of the modified plants on the basis of internationally accepted safety objectives and Western practices.

The evaluation was conducted in accordance with the prior conditions :

- The information provided by the NPP in the Modernisation Programmes and the additional upgrading proposals developed in other national programs were considered by Riskaudit as input data.
- The evaluation is based on comprehensive generic knowledge on VVER 1000/320 safety deficiencies which has been enriched by specific input information on Rovno 4 and Khmelnitsky 2 units provided by Ukrainian experts during technical evaluation meetings. Riskaudit did not perform any specific calculation in the frame of this project.

The safety evaluation performed by Riskaudit is based on the application to these units of safety practices used in Western countries and not to the application of Ukrainian rules and standards applied for operating NPPs in Ukraine.

The evaluation of the Modernisation Programmes leads to the following conclusion.

To the condition that all Riskaudit recommendations will be taken into account and that all proposed and recommended measures will be properly implemented :

- The construction, management and operation of the plants will be in line with the fundamental principles set out in International Atomic Energy Agency (IAEA) documents. These include, in particular the, IAEA Safety Series N° 75 - INSAG-3, and the Nuclear Safety Standards (NUSS) Codes of Practice.
- Each level of the defence in depth concept will be significantly increased.
- The upgraded plants will be able to achieve a safety level in line with Western safety objectives and practices, for both aspects design and operational safety.

- 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.
- 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 plant will be in line with the quality achieved in Western plants.

It has also to be pointed out that successful implementation of Modernisation Programmes on Rovno 4 and Khmelnitsky 2 units may have also a positive impact for further improvements of existing operating Ukrainian VVERs.

ACRONYMS

AC	Alternating Current
AEA-T	AEA - Technology
AKRB	Radiation monitoring system
ALARA	As Low As Reasonable Achievable
ANPA	Agenzia Nationale per la Protezione dell' Ambiente
ATWS	Anticipated Transient Without Scram
BDBA	Beyond Design Basis Accident
BRU-A	Steam dump to the atmosphere
CEC	Commission of the European Community
CPS	Control and Protection system
CPS-AR	Control and Protection system - absorbing rods (clusters)
DBA	Design Basis Accident
DC	Direct Current
DG	Diesel generator
DN	Nominal Diameter
ECCS	Emergency Core Cooling System
ECR	Emergency Control Room
EFW	Emergency Feedwater
EMI	Electromagnetic interference
GRS	Gesellschaft für Anlagen- und Reaktorsicherheit
GZN-195M	Type of main coolant pump
IAEA	International Atomic Energy Agency
I & C	Instrumentation and Control
INSAG	International Nuclear Safety Advisory Group
IPSN	Institut de Protection et de Sûreté Nucleaire
ISI	In-service Inspection
K2	Khmelnitsky NPP, unit 2
LOCA	Loss of coolant accident
MCP	Main coolant pump
MCR	Main control room
NPP	Nuclear Power Plant
NRA	Nuclear Regulatory Authority of Ukraine
NUSS	Nuclear Safety Standards
OPB	General regulations for nuclear power plant safety
PAMS	Post Accidental Monitoring System
PBYa	Rules for nuclear safety of reactors in NPPs
PORV	Power operated relief valve
PSA	Probabilistic Safety Assessment
R4	Rovno NPP, unit 4
RHR	Residual heat removal
RPV	Reactor Pressure Vessel
RTZO	Electrical Distribution Board
SAR	Safety Analysis Report
SG	Steam Generator
SPDS	Safety Parameters Display System
STC	Scientific and Technical Centre on Nuclear and Radiation Safety
Tacis	Technical assistance to SIS

TOB	Technical Substantiation of Safety (Safety Report)
TSO	Technical Safety Organisation
SWS-A	Service Water System - A
UCTF	Unit complex of technical facilities
V-320	Type of VVER-1000
V. LOCA	Loss of Coolant Accident with containment by-pass
VVER	Soviet origin pressurized water reactor
WANO	World Association of Nuclear Operators

REFERENCES

/1/ Evaluation of the Modernisation Programmes (Rovno 4 and Khmelnitsky 2), revision 1
Riskaudit, TACIS/U/TSO/VVER/02, Report N° 10.2, 15/11/1996

/2/ Evaluation of the Modernisation Programmes (Rovno 4 and Khmelnitsky 2), revision 2
Riskaudit, TACIS /U/TSO/VVER/02, Report N° 10.2, 15/11/1996

/2a/ Evaluation of the Modernisation Programmes (Rovno 4 and Khmelnitsky 2), revision 2
Riskaudit, TACIS /U/TSO/VVER/02, Report N° 10.2 A, 5/11/1997

/3/ General Safety Objectives
Riskaudit, TACIS/U/TSO/VVER/02, Report N° 7, 23/4/1996

/4/ Approach for the review of the upgrading programmes Rovno 4/Khmelnitsky 2
Riskaudit, TACIS /U/TSO/VVER/02, Report N° 7a

/5/ Riskaudit remark on licensing procedure (Rovno 4 and Khmelnitsky 2)
Riskaudit, TACIS /U/TSO/VVER/02, Report N° 6

/6/ Safety issues and their ranking for VVER-1000 Model 320 Nuclear Power Plants
IAEA-EBP-VVER-05
3/1996

/7/ Modernisation Programmes for the Ukrainian Nuclear Power Plants with VVER-1000 (B-320), revision 1
Consortium KIEP-MOHT-ENAG, 6/1996

/8/ Modernisation Programmes for the Ukrainian Nuclear Power Plants with VVER-1000 (B-320), revision 2
PART 2. POWER UNIT 2 OF KHMELNITSKY NPP
PART 3. POWER UNIT 4 OF ROVNO NPP
Kiev Institute Energoproject, 10/1996

/9/ Safety Evaluation of VVER 440/213 and VVER 1000/320 Reactors in Rovno NPP Units 1,2 and 3
Riskaudit, TACIS WW.91.03/03.01/b 023, 12/94

/10/ Plant Quality Status of Rovno 4 and Khmelnitsky 2 Units
Riskaudit, Tacis/U/TSO/VVER/02, Report N° 11, 11/1997

/11/ A Partial Assessment of Stendal VVER-1000/320-1000 (B-320)
DES Report No. 74, IPSN, Fontenay-aux-Roses 1992

/12/ Sicherheitstechnische Bewertung des KKW Stendal, Block A, vom Typ WWER-1000/W-320
GRS-99; GRS; Köln 1993

/13/ Nuclear Safety Expert for Modernisation Kalinin NPP Unit 3
Riskaudit Report N° 78; Fontenay-aux-Roses/Berlin 1997

/14/ Nuclear Safety Expert for Modernisation Kozloduy 5&6
Final Report GRS, IPSN, Fontenay-aux-Roses/Berlin 1997

Appendix 1: Compilation of the results „Evaluation of the Modernisation Programmes Rovno 4 and Khmelnitsky 2 units“

Structure and Contents

Hereafter the results of the evaluation of Modernisation Programmes have been compiled in a table. In the table the upgrading measures are grouped in specific technical areas, as defined in the technical evaluation report:

- Reactor Core and Fuel Handling (K)
- Components Integrity (C)
- Electrical power supply (E)
- Instrumentation and Control (I)
- Containment and building structures (F)
- Hazards (H)
- Systems Analysis (S)
- Accident Analysis (A)
- Operational Safety (O)
- Radiation Protection (R)

For each technical area the correspondent upgrading measures (items) are collected and associated with the following statements.

- N°: Number of the item in this table (for each area starts numbering with a specific letter, see above)
- Number of the item in the Modernisation Programmes
- Corresponding chapter in the technical evaluation report (Riskaudit)
- Short description of the item

– Date of implementation (proposal of Riskaudit):

  - b: before the start-up
  - a: after the start-up
  - Measures which may lead to problems difficult to be solved during implementation or studies which may lead to further requirements are identified with the symbol (P). It has to be pointed out that this assessment is purely based on personnel judgement and not technically argumented. This personnel judgement (not engaging Riskaudit responsibility) has been added by the autors of the report following a strong requirement of the Austrian member of the Phare-Tacis expert group.

– Riskaudit recommendation:

  - agreement: In case of full agreement on the proposal in the Modernisation Programmes - no comment is given
  - modification: Agreement in principle, but modification on proposals are needed

In some cases an item has been treated in different technical areas. In such a situation an cross reference is given.

N°	Item in R4/K2 Mod. Progr.	Chapter in Risk-audit Report	Item	Concerned DID Level				Date of imple-mentation	Riskaudit Recommendation
				1	2	3	4		
			Core						
K1	11111	2.1.2	Monitoring of subcriticality during shutdown	x	x			b	
K2	14211	2.1.2	Improvement of neutron flux control measurement	x	x			b	
K3 (I)	11211	2.1.2	New control strategy (Xenon oscillation and power distribution)	x	x			a	Riskaudit recomm. automatic system when available (P)
K4	11212	2.1.2.2 2.1.5.2	Study of new control strategy	x	x			a	
K5 (I)	25111	2.1.4.2	Implementation of refueling strategy	x	x			b	improvement of nuclear codes is necessary
K6	25131	2.2.1.2	Use of improved engineering margin factors	x	x			a	
K7	11221	2.3.1.2	Measures to improve drop time of reactor shut down rods and fuel bending		x	x		b	consideration of Gidropress list is recommended
K8	11222	2.3.1.2	Introduce „heavy weight“ control rods		x	x		b	
K9	14281	2.3.3	Replacement of CPS drives	x	x			b	
K10	20111	2.4.1	Monitoring of fuel rods leak tightness (new system as part of refuelling machine)	x	x			a	
K11	30141	2.4.2.3	Implementation of methodology to determine the correspondence between damaged fuel operational limit and primary coolant activity by reference isotopes.		x			a	Comments for further steps
K12	20121	2.5.1.2	Develop equipment for completing fuel assembly placing procedures in loss of power		x	x		a	

N°	Item in R4/K2 Mod. Progr.	Chapter in Risk-audit Report	Item	Concerned DID Level				Date of imple-mentation	Riskaudit Recommendation
				1	2	3	4		
K13	20131	1.1.9	Sufficient storage capability to ensure emergency reloading			x	x	a	Comments for further steps
K14	33111	2.5.3	To develop equipment for transportation of the spent CPS AR clusters from the reactor and for their burial at the NPP site (with compacting)	x				a	
K15	33112	2.5.3	To develop equipment for transportation of the spent CPS AR clusters from the reactor and for their burial at the NPP site (without compacting)	x				a	
			Components						
C1 (S)	12331	3.1.2	Heating up to 20° C (ECCS active part)			x		b	
C2 (S)	12321	3.1.2	Heating up to 55° C (ECCS passive part)			x		b	
C3	12311	3.1.2	Standard system of reactor vessel of radiation load monitoring	x	x			b	
C4	12361	3.1.2	Verification of residual life of reactor vessel	x				a	
C5	12351	3.1.2	Develop and introduce new programme of surveillance specimens		x			b	change to safety improvement
C6	12341	3.1.2	Replace irradiation specimen from above the core in the water gap		x			a partly b	Before implementation calculation of characteristics of neutron/radiation field
C7	12352	3.1.2	Develop a system for monitoring of radiation load to determine remaining life time	x				a	
C8 (K)	25111	3.1.2	Optimisation of fuel loads (fuel strategy)	x				b	quantify benefit of shielding

N°	Item in R4/K2 Mod. Progr.	Chapter in Risk-audit Report	Item	Concerned DID Level				Date of imple-mentation	Riskaudit Recommendation
				1	2	3	4		
C9	12221	3.2	Develop and introduce facilities and systems to implement „leak before break“ concept	x	x			a	linking to leak detection system necessary
C10 (H)	12211	3.5 (6.1)	Rigid support of steam and feedwater lines at the outlet of the reactor building			x	x	b	
C11 (H)	26211	2.1.1 (6.1)	Recalculation of strength of piping essential to safety; implementation of measures	x				b	
C12	26212	3.2	Measures to increase strength of piping if necessary (link to 26211)	x				b	
C13 (S)	12411	3.3 (7.8.1)	Development and implementation of measures to control leakage primary/secondary circuit DN 100	x	x	x	x	b	pay attention to ISI documents (P)
C14 (I)	28111	3.2	Implement a full diagnostic system		x			a	
C15 (I)	28113	3.2	Implement a vibration diagnostic system		x			b (K2) a (R4)	
C16 (I)	28116	3.2	Implement a primary circuit leakage detection system		x			b	specific conditions for leak detection systems
C17 (I)	28117	3.2	Implement a residual fatigue lifetime diagnostic system		x			b	
C18 (S)	12421	3.3	Develop and introduce a SG leakage control system		x	(x)		b	proposal is deleted, but should stay in Modernisation Programmes
C19 (I)	26131	3.3	Implementation of secondary coolant parameter automatic control system for normal conditions		x			b	collector status has to be provided „b“
C20 (S)	22111	3.3	Modernisation steam generator blowdown system	x				b	

N°	Item in R4/K2 Mod. Progr.	Chapter in Risk-audit Report	Item	Concerned DID Level				Date of imple-mentation	Riskaudit Recommendation
				1	2	3	4		
C21	12441	3.4	Develop and implement a criterion for preventive plugging of SG-tubes		x			a	
C22 (H)	12211	3.5	Providing „rigid embedding“ of steam and feedwater pipelines at 28.8m level					b	(P)
C23 (H)	17321	3.5	Analyses to determine extent of pipeline breaks					b	
C24	34111	3.6	In-service inspection of RPV by TV or ultrasonic inspection		x			b	
C25	21114	3.6	Procedure for determination of defects inMCP-195M	x	x			a	
C26	12371	3.7	Introduction of an equipment set to manufacture and anneal high quality gaskets for the main joint	x				b	
C27	12381	3.7	Reconstruction of the upper head sealing assemblies	x				-	issue deleted; already implemented, demonstration necessary
C28	26132	3.7	Implementation of primary coolant parameter automatic control system for normal conditions		x			a	
C29	12391	3.7	Strength calculation of the air duct weld of reactor top head	x				a	
C30	12431	3.7	Strength calculation of the reactor vessel head	x				b	
C31	21211	3.7	Strength analysis of make up nozzle thermal shield	x				a	
C32	26111	3.7	Chemical water treatment with higher inventory of alkaline metals	x				-	issue deleted; already implemented, demonstration necessary
C33	26121	3.7	Programme to determine inventory of alkaline metals	x				-	issue deleted; already implemented, demonstration necessary

N°	Item in R4/K2 Mod. Progr.	Chapter in Risk-audit Report	Item	Concerned DID Level				Date of imple-mentation	Riskaudit Recommendation
				1	2	3	4		
C34	31361	3.7	Develop evaluation criteria for metal state	x				-	issue deleted; will be implemented in branch programme, demonstration necessary
C35	34241	3.7	Install tools for maintenance of upper unit nozzles						issue deleted; already implemented, demonstration necessary
C36	33221	3.7	Install displacement indicators for piping					a	
			Electrical Supply						
E1	15111	4.1	Replacement of all inverters for the emergency power supply			x		b	some comments for further steps
E2	15121	4.2	Increase of battery discharge time			x	x	b	
E3	15131 +(24111)	4.3	Analysis of additional sources of energy for safety systems				x	b	some comments for further steps
E4	15132	4.4	Improvement of emergency DG reliability			x	x	b	
E5	15211	4.5	Replace 6 kV switches			x		a	
E6	24211	4.6	Procedures to assess residual lifetime of cables	x	x			a	some comments for further steps
E7	24221	4.7	Fit additional self contained emergency lighting fixtures			x	x	a	
E8	17131	4.8	Replacement of input switching devices of RTZO type switchboards			x		b	
E9	15221	4.9	Replacement of cable penetration	x				-	issue deleted; already implemented, demonstration necessary
E10	24421	4.10	High voltage transformers bushings replacement	x				b	some comments for further steps
E11	24311	4.11	Analysis of external power grid	x				b	
E12	24131 (24121)	4.12	Computerized monitoring turbine generator stator windings	x	x			a	

N°	Item in R4/K2 Mod. Progr.	Chapter in Risk-audit Report	Item	Concerned DID Level				Date of imple-mentation	Riskaudit Recommendation
				1	2	3	4		
E13	24122	4.12	Computerized monitoring 6 kV motor stator windings	x	x			a	
E14	24111	4.13	Implement a multi-channel system "Regina"		x			b	some comments for further steps
E15	24441		Install stand-by transformers		x	x		b	in R4 already implemented
E16	31351		Programme for replacement of electrical wiring		x			b	
			I&C						
I1 (C)	11211	5.1	Upgrading reactor power control system to improve Xe and power distribution	x	x			a	
I2	14271	5.1	Electromagnetic Interference (EMI) immunity			x	x	b	
I3	-	5.1	Improvement of unit control computer (UCTF)	x	x			-	in 14331 included, rec. to replace UCTF-U of the 2. generation
I4 (K)	14211	5.2	Replacement of neutron flux monitoring system	x	x			b	
I5	14221	5.2	Implementation of reactivity measurement	x	x			b	some comments for further steps
I6	14231	5.3	Separate impulse lines for primary circuit pressure measurement			x		b	
I7	14421	5.3	Replacement sensors, transducers and secondary instruments		x			b,a	compensatory measures before start-up for H_2 measurement
I8	14251	5.3	Monitoring the gas volume under the reactor cover (post accident monitoring system)			x	x	b	5-point transducer after start-up implemented
I9	23111	5.3	Modernisation of monitoring generator process parameters	x	x			a	
I10	14111	5.8	Redesign temperature monitoring racks for protective tube units	x	x			b	
I11	14261	5.8	Replacement Computer and software (Hindukush, SM-2M))	x	x			a	

N°	Item in R4/K2 Mod. Progr.	Chapter in Risk-audit Report	Item	Concerned DID Level				Date of imple-mentation	Riskaudit Recommendation
				1	2	3	4		
I12	14321	5.11	Improvement of the turbine regulating system		x			a	
I13	14241	5.11	Improvement water level measurement in SG	x	x			b	
I14	28511	5.12	Develop Technical Support Centre				x	b (R4) a (K2)	
I15	28124	5.12	Implementation television for closed premises	x				b	
I16	14331	5.13	Replace power unit control system (Titan 2)	x	x			b (R4) a (K2)	software must be produced to appropriate standards
I17	14411	5.13	Implement data storage (black box)			x		a	
I18	28411	5.13	Implement a system displaying safety parameters (SPDS)			x	x	b (R4) a (K2)	software will require appropriate validation and verification
I19 (C)	28111	5.16	Introduction of a full- diagnosis systems		x			a	
I20	28112	5.16	Introduction of a computerized network for diagnosis		x			a	
I21 (C)	28113	5.16	Implementation vibration diagnosis system		x			b(K2) a(R4)	
I22	28114	5.16	Implementation loose parts diagnosis system		x			b(K2) a(R4)	
I23	28115	5.16	Implementation noise diagnosis system for SG headers		x			a	
I24 (C)	28116	5.16	Implementation primary circuit coolant leakage diagnosis system		x			b	
I25 (C)	28117	5.16	Implementation residual fatigue lifetime diagnosis system		x			b	
I26	28118	5.16	Implementation MCP vibration monitoring diagnosis system		x			a	

N°	Item in R4/K2 Mod. Progr.	Chapter in Risk-audit Report	Item	Concerned DID Level				Date of imple-mentation	Riskaudit Recommendation
				1	2	3	4		
I27	28119	5.16	Implementation mode diagnosis system		x			a	
I28	28121	5.16	Implementation in-core noise diagnosis system		x			b	
I29	28122	5.16	Implementation back pressure valve diagnosis system		x			a	
I30	28123	5.16	Implementation air operated valves diagnosis system		x			a	
			Containment						
B1	27211	6.3	Analysis of building structure (especially penetrations)			x		a	
B2	27212	6.3	Analysis of adequacy structure incl. Diagnostics		x	x		a	
B3	27213	6.3	Procedure of the containment state assessment during operation		x			a	
B4	27214	6.3	Prepare calculated groundings of containment reliability	x		x	x	a,b	Implementation in 2 stages
B5	32241	6.3	Improvement of containment state monitoring		x			b	
B6	32231	6.4	Develop proposals on diagnosis of forces in fitting cables		x			b	
B7	32251	6.6	Implement equipment for containment vacuum test		x			b	
			Hazards						
H1	17321	7.1.1	Analysis to determine the extent of pipeline breaks impact inside the reactor building			x		b	(P)
H2	17311	7.1.1	Develop of criteria for shut-off valves protection against internal missiles			x		a	

N°	Item in R4/K2 Mod. Progr.	Chapter in Risk-audit Report	Item	Concerned DID Level				Date of imple-mentation	Riskaudit Recommendation
				1	2	3	4		
H3 (C)	12211	7.1.1	Rigid support of steam and feed water lines			x	x	b	(P)
H4	17211	7.1.2	Complete analysis of internal flooding in Reactor compartment and Machine hall rooms	x	x	x		b	
H5	17111	7.1.3	Performance of a systematic fire hazard analysis	x	x	x		b	modification (recommendations for analysis, implementation depends on safety importance)
H6	17132	7.1.4	Coat the cable bundles with fire resistant coating	x	x			b	
H7	17112	7.1.4	Analysis of situation (fire) in cable compartment under MCR and ECR			x	x	b	
H8	17121	7.1.4	Replace combustible petroleum oil in lubrication system	x	x			a	
H9 (E)	17131	7.1.4	Replacement of input switching devices of RTZO type switchboards		x			b	
H10	17141	7.1.4	Development and implementation of fire extinguishing system special for NPP	x		x		b	
H11	17151	7.1.4	Replace fire resistant doors		x	x		b	
H12	17161	7.1.4	Install fire protection valves in air conduits			x		b	
H13	29111	7.1.4	Improve fire resistence rate of turbine hall roof	x	x			b	
H14	29112	7.1.4	Implement automatic Hydrogen dumping from generator housing	x				a	
H15	29121	7.1.4	Implement smoke prevention system for personnel evacuation			x	x	b,a	

N°	Item in R4/K2 Mod. Progr.	Chapter in Risk-audit Report	Item	Concerned DID Level				Date of imple-mentation	Riskaudit Recommendation
				1	2	3	4		
H16	29131	7.1.4	Furnishing the compartment containing electronic equipment with gas fire fighting means	x		x		b	
H17	18311	7.1.4	Analysis of possibility of air craft crash				x	b	
H18	18321	7.2.1	Analysis of risk impact on MCR (ECR) personnel of toxic gases			x	x	b	
H19	18211	7.2.1	Analysis of risk of shock wave loads		x	x		b	presentation of methodology for next step
H20	18111	7.2.2	Additional instrumental seismic instrumentation and geophysical studies		x	x		b,a	
H21 (S)	18221	7.2.2	Assessment of the risk of „average minimal temperature“ and „extreme cold condition“	x	x	x	x	b (a)	implementation in 2 steps (P)
H22	18212	7.2.2	Analysis of risk of tornado loads		x	x		b	
			Systems						
S1	11011	8.9.1	Develop materials on equipment qualification			x	x	a,b	recomm. not to limit to passport (P)
S2	12111	8.4.3	Replacement of non-qualified valves and implementation of technical and administrative measures to prevent over-pressure events	x	x			b	
S3 (C)	12321	8.2.1.2	Heating of safety injection water tanks			x		b	
S4 (C)	12331	8.2.1.2	Heating of the sump water			x		b	
S5 (C)	12411	8.8.1.2	Organisational engineering measures for management of accidents involving primary to secondary coolant leak up to D. nom. 100 mm.	x	x	x	x	b	

N°	Item in R4/K2 Mod. Progr.	Chapter in Risk-audit Report	Item	Concerned DID Level				Date of imple-mentation	Riskaudit Recommendation
				1	2	3	4		
S6	13111	8.1.2.1	Implementation of devices to measure Boron 10 concentration.	x	x			b	
S7	13211	8.2.1.2	Analysis of insulation material behaviour under LOCA conditions.			x		b	
S8	13213	8.2.1.2	Ensure residual heat removal under LOCA (replacement of insulation)			x		b	other solutions possible if demonstration of aptitude is given
S9	13311	8.3.1.1	Increase the volume of steam generator make up water.				x	a	
S10	13321	8.9.2	Replacement of steam generator safety valves.			x		b	
S11	13411	8.8.2.2	Updating of pressurizer pulse safety device to implement „Feed and Bleed“ procedure				x	b	
S12	13611	8.1.2.2 8.6.1.1	Implementation of tightness diagnosis system for ECCS exchangers.		x			b,a	
S13 (I)	14251	8.8.1.1	Steam detector under vessel head.			x	x	b	
S14	16111	8.5.4.1	Take measures to prevent radioactive release outside the containment building (MCP heat exchanger)	x		x	x	b	recommondation to study systematic all possibilities of containment bypass
S15 (A)	19311	9.1.4.2	Carry out the analysis of initiating events not taken into consideration in Technical Report on Safety Substantiation (TOB)			x		b	List should be presented 1a before SAR
S16	16121	8.5.3	ECCS suction pipes- prevention of leakage (bypass of containment)			x	x	b	check of vibration measurement -for further steps
S17	16131	8.8.3	To perform analysis and calculations of hydrogen accumulation inside the reactor plant and its release to the outside for BDBA.				x	a	

N°	Item in R4/K2 Mod. Progr.	Chapter in Risk-audit Report	Item	Concerned DID Level				Date of imple-mentation	Riskaudit Recommendation
				1	2	3	4		
S18	16211	8.8.3	Take measures to prevent explosive hydrogen concentration.				x	b,a	analysis before start-up, equipment after start-up
S19	30131	8.8.3	Hydrogen removal from the reactor plant primary circuit equipment in the process of the cool-down and "cold" shutdown and analysis of hydrogen safety	x	x			b	
S20 (A)	19111	8.8.1.1	Prepare a list of Design Basis Accidents and define a list of initiating events.			x		b	proposals of Riskaudit ; measures if necessary
S21 (A)	19112	8.8.1.1	Carry out analysis of selected accidents using modern codes			x		b	
S22 (A)	19121	8.8.1.1	Analysis of reactivity accidents			x		b partly, a	
S23	19211	8.8.2	Identification of beyond design basis accidents to be analysed. Performance of related analysis.				x	b partly, a	proposals of Riskaudit ; at least compensatory measures if necessary
S24	19311	8.3.2.3 8.8.1.2	Carry out the analysis of initiating events not taken into consideration in Technical Report on Safety Substantiation (TOB)			x		b	If necessary at least compensatory measurements have to be implemented
S25	21111	8.2b	Modernise thermal barriers to improve operational reliability and safety of GZN-195M	x				b	
S26 (C)	21114	8.2b	Develop a procedure for the determination of allowable defects in body components GZN-195M		x			a	
S27	21115	8.2b	Develop documentation and carry out auxiliary systems reconstruction to increase the time of interruption in supply of blocking water to sealing of GZN-195M			x		b	modifications can be necessary

N°	Item in R4/K2 Mod. Progr.	Chapter in Risk-audit Report	Item	Concerned DID Level				Date of imple-mentation	Riskaudit Recommendation
				1	2	3	4		
S28	22111	8.3.1	Upgrading of steam generator blowdown system	x	x			b	
S29	22441	8.3.1	Retroit balanced (disk) steam generator feed control valves.		x			a	
S30 (H)	18221	8.6.2.1	Carry out an analysis on possibility of ensuring the normal air conditions inside the rooms of safety system at lower ambient temperature	x	x	x	x	b,a	
S31	22351	8.6.2.1	Replacement of the air-conditioners.					b	
S32	24411	8.2.2.1.2	Installation of an additional diesel generator set	x	x			b	list of components to be backed up -for further steps
S33	13521		Installation of sealed valves 1600 diameter		x			b	only in R4 necessary
			Accident Analysis						
A1 (S)	19111	9.1.1	Prepare a list of Design Basis Accidents and define a list of initiating events.			x		b	1a before SAR justification of list
A2 (S)	19121	9.1.4.2	Analysis of reactivity accidents			x		b,a 2 steps	
A3 (S)	19311	9.1.4.2	Carry out the analysis of initiating events not taken into consideration in Technical Report on Safety Substantiation (TOB)			x		b	recomm. additional cases
A4 (S)	19112	9.1.4.2	Carry out analysis of selected accidents using modern codes			x		b	
A5 (S)	19211	9.2.1.2	Identification of beyond the design basis accidents to be analysed.				x	b,a	recomm. additional cases
A6	19411	9.2.1.2	Carry out level 1 and 2 probabilistic safety analysis.			x	x	b,a 2 steps	
			Operational Safety						

N°	Item in R4/K2 Mod. Progr.	Chapter in Risk-audit Report	Item	Concerned DID Level				Date of imple-mentation	Riskaudit Recommendation
				1	2	3	4		
O1	31211	10.2	Develop General NPPs Quality Assurance programs.	x	x	x		b	modifications (e.g.independent quality review body)
O2	32111	10.3	Improve operation procedure for safety related reactor systems			x		b	
O3	32112	10.4	Improve verification and testing procedure of safety-related reactor system			xx		b,a	
O4	30111	10.5 10.7	Improve technical instructions and normal operation procedures on reactor equipment and systems	x	x			b	
O5	30112	10.6	Improvement of maintenance and repair procedures for reactor equipment and procedures	x	x			a	
O6	31111	10.9	Develop an information system "Computer-aided history of NPP equipment operation"	x				a	
O7	30121	10.12	Include the list of works involving a nuclear hazard into the regulatory documents.		x	x		b	
O8	30211	10.12	Elaboration of accidental procedures			x	x	a,b	
O/1	NPP-progr.	10.	Improvement of the organisational structure and management	x	x	x	x	b	
O/2	NPP progr.	10.	Personnel training programme	x	x	x	x	b	
O/3	NPP progr.	10.	Emergency planning				x	b	
			Radiation Protection						
R1	**33211**	11.	Enhance the function of the existing radiation protection	x	x	x	x	b	
R2	**33212**	11.	Replace of the radiation monitoring system AKRB-03	x	x	x		a	

N°	Item in R4/K2 Mod. Progr.	Chapter in Risk-audit Report	Item	Concerned DID Level				Date of imple-mentation	Riskaudit Recommendation
				1	**2**	**3**	**4**		
R3	**33231**	11.	Development and implementation of an automatic radiation monitoring system			x	x	b,a	
R4	Branch progr.	11.	Development and implementation of an automatic environmental radiation monitoring system	x	x	x	x	b	

Appendix 2: Safety issues for VVER-1000 comparison IAEA (Issue-Book)- Rovno 4 and Khmelnitsky 2 Modernisation Programmes

IAEA-Code	Issue Name	Measures in MP Rovno 4/Kh 2
General		
G1	Classification of components	11011
G2	Qualification of equipment	11011
G3	Reliability analysis of safety class 1 and 2	19411
Core		
RC1	Prevention of inadvertent boron dilution	19121,13111, 13611
RC2	Control rods insertion reliability/ Fuel assembly deformation	11221,11222,14281
RC3	Subcriticality monitoring during reactor shutdown conditions	14211,14221,11111
	Low leakage strategy	25111
Components Integrity		
CI1	RPV embrittlement and its monitoring	12311,12341,12351, 12352,12321,12331, 12361, 25111
CI2	Non-destructive testing	12221,21114,34111, 12441
CI3	Primary pipe whip restraints	12221,28116,17321,12211
CI4	Steam-generator collectors integrity	22111,26131,26132,26121,26132,12411
CI5	Steam generator tube integrity	12441,33212,31311
CI6	Steam and feedwater piping integrity	12211,17321,12221, 26131,26132,22412
Systems		
S1	Primary circuit cold overpressure protection	12111
S2	Mitigation of SG primary collector break	19112,19311,30211,12411,12421,22111
S3	MCP coolant pump seal cooling system	21111,21115,24411
S4	Pressurizer safety and relief valves qualification for water flow	11011,13411
S5	ECCS sump screen blocking	13211,13213
S6	Emergency core cooling system sump-tank and suction lines integrity	16121

IAEA-Code	Issue	Measures in MP Rovno 4/Kh 2
	Name	
S7	ECCS heat exchanger integrity	13611
S8	Power operated valves on the ECCS injection lines	Already solved
S9	Qualification of SG safety and discharge valves for operation with water	11011,13321,12411
S10	SG safety valves performance at low pressure	13321 (Need not obvious. Residual risk : available PSA show sequence $< 10^{-7}$/y).
S11	SG level control valves	22441
S12	Emergency feedwater makeup procedures	13311
S13	Cold emergency feedwater supply to SG	24411
S14	Ventilation system of control rooms	measures already implemented
S15	Hydrogen removal system	16131,16211
Instrumentation and Control		
IC1	I&C reliability	14321,14421,14231, 14421,23111,14241, 14331,15111,14111
IC2	Safety system actuation system	14231, 14331
IC3	Automatic reactor protection for power distribution and DNB	14211
IC4	Control rooms	14331,28511,28411
IC5	Control and monitoring power distributions in load follow mode	14261,14221,11211
IC6	Monitoring of mechanical equipment status	28111,28112,28113,12221 28114,28115,28116, 28117,28118,28119, 28121-28124
IC7	Primary circuit diagnostic system	28111,28112,28113,12221 28114,28115,28116,26132 28117,28118,28119, 28121-28124
IC8	Reactor vessel head leak monitoring system	28116

IAEA-Code	Issue	Measures in MP Rovno 4/Kh 2
	Name	
IC9	Accident monitoring instrumentation	14251,14411,16211
IC10	Technical support centre	28511
IC11	Water chemistry control and monitoring equipment (primary and secondary)	26131,26132
Electrical power supply		
EP1	Off site power supply via stand-by transformers	24311,24441
EP2	Diesel-generator reliability	15131,15132,24411
EP3	Protection signals for emergency diesel generators	15132
EP4	Power supply for accidents and events control	24411,15131,15132
EP5	Emergency battery discharge time	15121
EP6	Ground faults in DC circuits	24122
Containment and building structures		
C1	Containment bypass	16111,13611
---	Structural aspects	27211,27212,27214,32231
Internal Hazards		
IH1	Systematic fire safety analysis	17111
IH2	Fire prevention	17121,17131,17132, 17151,29111,29112
IH3	Fire detection and extinguishing	17141,29131
IH4	Mitigation of fires effects	29121,17161,17112
IH5	Systematic flooding analysis	17211
IH6	Protection against flood for emergency electric power distribution boards	17211
IH7	Protection from dynamic effects due to ruptures of steam and feedwater pipelines	17321,26211,26212,12211, 273111
IH8	Polar crane interlocking	already introduced
---	Missiles hazards	17311
External Hazards		
EH1	Seismic design	18111
EH2	Analysis of natural environmental conditions of NPP site	18212,18221

IAEA-Code	Issue	Measures in MP Rovno 4/Kh 2
	Name	
EH3	Man induced external events	18311,18321,18211
Accident Analysis		
AA1	Scope and methodology of AA	19111,19112
AA2	QA of plant data used in AA	19112,19121,19311
AA3	Computer code and plant model validation	19112
AA4	Availability of accident analyses results for supporting plant operation	30211,19311,19112
AA5	Main steamline break analysis	19112,19111
AA6	Overcooling transients related to pressurised thermal-shocks	19311
AA7	Analysis of SG collector rupture accidents	19112,19311
AA8	Accidents at low power and shutdown operation conditions	19111,19311
AA9	Severe accidents	19211,16131,16211
AA10	Probabilistic Safety Assessment	19411
AA11	Accidents connected with boron dilution	19121,13111,19311
AA12	Accidents connected with drop of spent fuel container	already done
AA13	ATWS-type accidents	19311,19211
AA14	Total loss of electrical power	19211
AA15	Total loss of heat sink	19211
---	Loss of feedwater	13411,19211
Operational Safety		
OP1	Normal operation procedures	30111
OP2	Emergency operating procedures	30211,30111
OP3	Limits and conditions	32112,32111,30111
M1	Need for safety culture improvements	Included in different measures
M2	Exchange of operational experience	31111
M3	Quality Assurance Program	31211
M4	Management of documentation keeping	30111,31111
PO1	Philosophy of procedures application	30111,30211

IAEA-Code	Issue	Measures in MP Rovno 4/Kh 2
	Name	
PO2	Program for conduct of inspections and tests	32111
PO3	Communication system	Already solved
Trai 1	Program for conduct of inspections and tests	32112
EM 1	Emergency centre	28511
Personnel protection and radiation safety		
RP1	Radiation protection and monitoring	33211,33212,33231

Riskaudit Comments on the IRR Report

„Safety Relevant Issues and Measures Khmelnitsky 2 and Rovno 4 NPPs“

(IRR Vienna, June 1997)

EXECUTIVE SUMMARY

1. Introduction/Framework

As part of its due diligence, the European Bank for Reconstruction and Development (EBRD) has to verify whether the "Completion and Safety Upgrade of Khmelnitsky 2 and Rovno 4 NPPs Project" (K2R4 Project) meets the EBRD policy requirements on nuclear safety.

The due diligence of the safety aspects of the project is being supported by a Riskaudit-led Consortium[1] of Western Technical Safety Organisations (TSO) under a TACIS project. The TSO Consortium performed an independent safety assessment of the project and produced in January 1998 the Riskaudit report No. 120 "Final Safety Assessment Report for Loan Approval Procedures". The information provided by the NPP in the modernisation programmes and the additional upgrading proposals developed in the other national programmes were considered by Riskaudit as input data. The evaluation was based on comprehensive generic knowledge on VVER 1000/320 safety deficiencies which has been enriched by specific input information on K2R4 provided by Ukrainian experts during technical evaluation meetings. Riskaudit did not perform any specific calculation in the framework of this project. The safety evaluation performed by Riskaudit is based on the application to these Units of internationally recognised safety principle and of safety practices used in Western countries.

As part of its own review process, the Austrian Bundesminister für Umwelt, Jugend und Familie requested the Austrian Institute of Risk Research (IRR) of the Academic Senate of the University of Vienna to perform its own technical assessment of this project. The main task was to identify the most relevant safety issues and review and evaluate whether they are properly addressed within the frame of the K2R4 project. Results of this assessment are given in the IRR-Report No. 14a "Safety Relevant Issues and Measures Khmelnitsky 2 and Rovno 4 NPPs“, Vienna, June 1997.

The Riskaudit report No. 120 concludes that, to the extent that all Riskaudit recommendations will be taken into account and that all proposed and recommended measures will be properly implemented:

- The construction, management and operation of the plants will be in line with the fundamental principles set out in International Atomic Energy Agency (IAEA) documents. These include, in particular the IAEA Safety Series No 75 - INSAG-3, and the Nuclear Safety Standards (NUSS) Codes of Practice.

- Each level of the defence in depth concept will be significantly increased.

- The upgraded plants will be able to achieve a safety level in line with Western safety objectives and practices, for both design and operational safety.

[1] The Consortium of Technical Safety Organisations (TSO) comprises Riskaudit GRS/IPSN International; AEA Technology (UK); ANPA (Italy); GRS (Germany); and IPSN (France).

- 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 (in particular the choice between measures that must be implemented before start-up and those that can be implemented during the first few years of operation) is acceptable from a safety point of view.

- After implementation of corrective measures for weak points already identified, completion of proposed plans for inspection and after correction of corresponding possible weak points, the quality status of the plant will be in line with the quality achieved in Western plants.

The EBRD commissioned Riskaudit in April 1998 to advise the Bank whether all issues raised and comments made in the IRR report have been taken into account in the final safety assessment for the loan approval procedure. Riskaudit was asked to check whether the conclusions of the Riskaudit Consortium are still valid in view of the IRR report.

2. Evaluation Process

The statements presented in the IRR Report have been checked with reference to the safety evaluation conducted by Riskaudit of the specific modernisation programme revision 2 proposed by the Ukrainian central utility for completion and safety improvement of the Rovno 4 and Khmelnisky 2 Nuclear Power Plant, takin,g into consideration the generic and operational programmes valid for all VVER 1000 and under development in Ukraine.

This safety evaluation included:

- the verification of the completeness of the modernisation programme and of the generic and operational programme to give adequate consideration to all existing recommendation made for the VVER 1000

- the verification of the acceptability of the proposed measures with reference to the Western European safety practices.

- the verification that postponing the implementation of some of the measures to after start up could be accepted from a safety point of view.

All technical statements and/or safety concerns, presented in the IRR report have been reviewed by Riskaudit with the objective of checking whether the basis for the statement were consistent with the reactor design, status and improvement programme and in such case whether the conclusion drawn was relevant to good safety practices accepted by Western European regulators.

3. Overview

Several of the statement made in the IRR report (areas logistic, safety culture) include other than purely technical aspects such as economical, political, societal as well as concerning safety culture.

Indeed in these areas progress are needed, however the completion and modernisation of K2R4 has to be seen as a key factor in installing the dynamic of improvement that will benefit also to all operating Nuclear NPPs.

Regarding nearly all technical areas (core, component integrity, systems, instrumentation and control electric power, containment, internal and external hazards, accident analysing ...), IRR statements evidenced insufficient informations regarding the objectives and content of the programmes or are not justified with regards to Western safety practices.

Some areas of concern such fuel and waste management where not included in the scope of Riskaudit evaluation. However it is known that programmes in these areas are under development in Ukraine with the support of international organisations especially in relation with the decommissioning of Chernobyl and that adequate technical solutions exists for all these problems.

4. Conclusion

The IRR report does not present any new relevant technical safety issues or safety upgrading measures which had not yet been considered in the K2R4 project. All technical areas discussed by IRR were already known and have been treated by the Riskaudit Consortium of Technical Safety Organisations.

The last version of the modernisation programme for K2

R4 (as well as the detailed evaluation report produced by Riskaudit) were obviously not yet available to IRR at the time when they prepared their report. The IRR statements suffer from this lack of essential information. As a consequence, some of the comments and conclusions presented by IRR on technical areas are incomplete or not up-to-date.

Evaluations of economic, logistic, political, and social aspects in Ukraine cannot be commented in detail by Riskaudit. However, Riskaudit expects that the situation concerning those issues will improve and that completion of these two plants at a Western safety level will be one of the elements of the expected improvement.

The general IRR conclusion asserting that the planned completion and modernisation of Khmelnitsky Unit 2 and Rovno Unit 4 will not fulfil the nuclear

safety requirements of the EBRD policy is not valid because it is based on information not proven, not justified or incomplete.

In the view of Riskaudit, the conclusions of its report No.120 to the European Commission and other co-lenders on the safety aspects of the K2 R4 project remains valid.

RISKAUDIT REPORT N°136

Riskaudit Comments on the IRR Report „Safety Relevant Issues and Measures Khmelnitsky 2 and Rovno 4 NPPs“

Content

List of acronyms

Atomaudit	Ukrainian Expert Organisation
CEC	Commission of the European Community
CPS	Control and Protection system
DOE	Department of Energy (USA)
EBRD	European Bank for Reconstruction and Development
ECCS	Emergency Core Cooling System
EQ	Equipment Qualification
EU	European Union
IAEA	International Atomic Energy Agency
I&C	Instrumentation and Control
INSAG	International Nuclear Safety Advisory Group
IRR	Austrian Institute of Risk Research
K2	Khmelnitsky NPP, Unit 2
LBB	Leak Before Break
LOCA	Loss of Coolant Accident
MP	Modernisation Programme
NTD	Non DestructiveTesting
NDE	Non Destructive Examination
NPP	Nuclear Power Plant
NRA	Nuclear Regulatory Authority of Ukraine
NUSS	Nuclear Safety Standards (IAEA)
PSA	Probabilistic Safety Assessment
PTS	Pressurized Thermal Shock
R4	Rovno NPP, Unit 4
RPV	Reactor Pressure Vessel
SG	Steam Generator
OPB	General Soviet Regulations for Nuclear Power Plant Safety
TMI	Three Mile Island NPP (USA)
VVER-1000	Soviet Origin Pressurized Water Reactor
Xe	Xenon

Introduction/Framework

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The due diligence of the safety aspects of the project is being supported by a Riskaudit-led Consortium[2] of Western Technical Safety Organisations (TSO) under a TACIS project. The TSO Consortium performed an independent safety assessment of the project and produced in January 1998 the Riskaudit report No. 120 "Final Safety Assessment Report for Loan Approval Procedures". The information provided by the NPP in the modernisation programmes and the additional upgrading proposals developed in the other national programmes were considered by Riskaudit as input data. The evaluation was based on comprehensive generic knowledge on VVER 1000/320 safety deficiencies which has been enriched by specific input information on K2R4 provided by Ukrainian experts during technical evaluation meetings. Riskaudit did not perform any specific calculation in the framework of this project. The safety evaluation performed by Riskaudit is based on the application to these Units of internationally recognised safety principle and of safety practices used in Western countries.

As part of its own review process, the Austrian Bundesminister für Umwelt, Jugend und Familie requested the Austrian Institute of Risk Research (IRR) of the Academic Senate of the University of Vienna to perform its own technical assessment of this project. The main task was to identify the most relevant safety issues and review and evaluate whether they are properly addressed within the frame of the K2R4 project. Results of this assessment are given in the IRR-Report No. 14a "Safety Relevant Issues and Measures Khmelnitsky 2 and Rovno 4 NPPs“, Vienna, June 1997.

The Riskaudit report No. 120 concludes that, to the extent that all Riskaudit recommendations will be taken into account and that all proposed and recommended measures will be properly implemented:

- The construction, management and operation of the plants will be in line with the fundamental principles set out in International Atomic Energy Agency (IAEA) documents. These include, in particular the IAEA Safety Series No 75 - INSAG-3, and the Nuclear Safety Standards (NUSS) Codes of Practice.

- Each level of the defence in depth concept will be significantly increased.

[2] The Consortium of Technical Safety Organisations (TSO) comprises Riskaudit GRS/IPSN International; AEA Technology (UK); ANPA (Italy); GRS (Germany); and IPSN (France).

- The upgraded plants will be able to achieve a safety level in line with Western safety objectives and practices, for both design and operational safety.

- 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 (in particular the choice between measures that must be implemented before start-up and those that can be implemented during the first few years of operation) is acceptable from a safety point of view.

- After implementation of corrective measures for weak points already identified, completion of proposed plans for inspection and after correction of corresponding possible weak points, the quality status of the plant will be in line with the quality achieved in Western plants.

The EBRD commissioned Riskaudit in April 1998 to advise the Bank whether all issues raised and comments made in the IRR report have been taken into account in the final safety assessment for the loan approval procedure. Riskaudit was asked to check whether the conclusions of the Riskaudit Consortium are still valid in view of the IRR report.

The work performed by Riskaudit is technically oriented. Results achieved during the course of the TACIS-funded safety assessment of the K2R4 project have been used as main source of information. Riskaudit comments on the IRR report are presented hereafter.

Each area of concern identified by IRR is commented upon by Riskaudit, using:

- IRR statements and/or safety concerns (No. of pages and headlines in accordance with IRR report); and

- Riskaudit's comments including technical conclusion

Additionally to this evaluation of each area of concern, general Riskaudit comments are provided as well as an overall conclusion.

A tabular summary of IRR important safety-related issues with the corresponding Riskaudit view is attached to the report.

General Riskaudit comments

Safety issues mentioned in the IRR report have mainly two origins:

- evaluation reports produced by IAEA, DOE, Riskaudit,
- Austrian analysis results on VVER 1000 safety.

Considering the sources of information of IRR, all comments on safety issues presented in the IRR report have been carefully examined by Riskaudit in order to check if additional aspects have to be included in the Riskaudit analyses for further demand.

Obviously, IRR suffers of a lack of information. It appears that some key elements were not known by IRR:

- existence of Modernisation Programme revision 2 (MP)
- existence of generic programmes valid for all Ukrainian VVERs 1000
- existence of operational programmes.

This lack of information casts a shadow over the IRR report.The evaluation methodology used by IRR as well as their technical safety goals are not visible. It is not obvious that such goals exist, this explains certainly the inconsistencies found in the report (for example between components integrity part and I&C chapter).

Evaluation of technical IRR statements

Area: Logistics

(i) IRR statements - General (page 24)

(1) A number of issues concern the infrastructural and logistic preconditions of NPPs. Besides technical, these issues include economic, political and societal aspects and, if at all, usually cannot be resolved by a set of relatively simple measures. They have a considerable influence on the nuclear safety and may be ranked even up to the highest category IV as "not acceptable".

Riskaudit comment:

2. Classification of safety issues by IAEA is based on technical criteria which are not applicable for such societal conditions. Utilisation of IAEA ranking is not pertinent.

   The importance of the infrastructural and logistic issues in Ukraine is recognised, even if it can not be the task of a technical safety organisation like Riskaudit to evaluate in detail the economic situation, the nuclear infrastructure, and similar non technical issues. Nevertheless, it has to be pointed out that the situation concerning the infrastructural and the logistic situation has been improved since the Chernobyl accident. In particularly in the last years progress were achieved, partly by support of Western countries (e.g. communication systems). Situation will continue to be improved in the frame of the modernisation programme and of other national and international programmes.

   To certain extent the IRR evaluations pertaining to infrastructural and logistic issues seem to be predominantly predictions for which no justification is given.

Therefore it is not justified that logistic issues be ranked in the highest IAEA category IV.

(i) IRR statements - Safety Culture (page 27-29)

(2) Note that safety culture programs do not in themselves represent safety culture. Such programs are merely the initiation of a process which has to be taken over by knowledgeable, well-educated and prepared, and highly motivated persons. The lack of such persons in Ukraine is in part the result of their poor income due to the critical economic situation in the country.

(3) The success of safety culture programs is hindered by the difficulties of involved persons to change their traditional attitude to nuclear safety.

Riskaudit comment:

1. Safety culture is that assembly of characteristics and attitudes in organisations and individuals which establishes that, as an overriding priority, nuclear plant safety issues receive the attention warranted by their significance (IAEA INSAG4). That means that safety culture concerns the requirement to match all safety issues with appropriate perceptions and action. Nevertheless, the modernisation programme and the associated branch and operational programmes aim at, on one hand, bridging the gap between the former safety requirements valid at the design period and the current international practices, and on the other hand, improving the operational safety in operating procedures, management, plant operation, training, emergency planning in order to enforce the « safety culture ».

   In any case, safety culture is a general attitude which of course has to be improved but which can not be transferred only with safety culture programmes but rather through practical exercises. In that direction the implementation of the K2/R4 modernisation programme together with the shut down of Chernobyl will permit to significantly improve Ukrainian safety culture.

2. Real efforts are done at the level of governmental organisation as well as at the level of NPPs in order to improve the whole nuclear energy production organisation. The NPPs operators have taken significant steps to clarify management expectations for safety and safety culture. Strengthening of safety culture in operation is a permanent action.

3.2 Area: General

(i) IRR statements - Preservation and Mothballing (page 32-34)

(1) One of the most important general safety-relevant problems for K2/R4 is that at least during 1990-1993 conservation and mothballing were marginal, or not accomplished at all, because of the moratorium. The economic crisis ...

During the moratorium, responsibility for handling problems of the unfinished units was transferred to the managers of the nuclear plants.

(2) Any comparisons concerning mothballing with Temelin NPP units are inappropriate because construction work at Temelin has been continuous....

(3) Concerning the state. .Quality of existing erected parts of the installation has not yet been examined.
Furthermore the qualification of existing components called to operate under accidental conditions will be addressed ....Riskaudit has announced a specific report on this key issue.

(4) From this point of view the estimated costs and completion time for the K2/R4 project are questionable because the basis for the estimation is incomplete. These estimations must be judged as too small. A thorough evaluation of the status of the equipment has to be performed in order to provide a sound basis for cost and time estimations. This sound basis is still missing.

(5) Unknown and unpredictable difficulties can be expected in the process of checking the degradation level of installed equipment. The possibilities to check certain equipment, cables, constructions, and check for the presence of hidden defects, etc. will be reduced. Because of the reported restricted funds in the Ukrainian nuclear industry, uncertainties will occur in the results from the field tests of equipment. It is also questionable whether all parts of damaged or degraded equipment will be replaced. Thus, higher rates of equipment failure during the start-up phase and initial operation have to be expected, which could have a very negative effect on plant reliability and safety.

<u>Riskaudit comment:</u>

1. Information given by IRR can not be supported. Inspection results demonstrate the acceptability of conservation status even if some repairs or limited replacements are necessary (identified and planned). Transfer of the responsibility for handling problems of the unfinished units to the managers of the nuclear plants during the moratorium time was certainly the best solution.

2. It is important to take note of the inspection results demonstrating the acceptability of the existing quality status.

3. Qualitative inspections have been performed on Rovno 4 and Khmelnitsky 2 units, considering the following aspects: mechanical, metallurgical, civil works, electrical, I&C and turbine.
   In the Riskaudit report N° 120 it was announced a specific report on quality but not on qualification. This specific report on quality gives a positive statement on methodology and results of the quality inspection.

4. A sound basis for cost and time estimations exists. The cost and time estimations are based on the evaluation of the status of the equipment (quality inspection).

5. The inspections performed have to be considered as insights into the plant status to evaluate the quality status of equipment and materials. It has been recommended by Riskaudit that prior to commissioning, a complete and systematic inspection programme be developed and implemented together with the commissioning programme. Conservation status of mechanical equipment is considered in general acceptable even if some repairs or limited replacements are necessary and planned. The same opinion is valid for electrical components on both sites. NPPs are taking necessary repair/replacement action.

(i) IRR statements - Qualification of Equipment (page 34-35)

(2) Riskaudit has also identified this issue and recommends a "Branch Programme for Accidental Qualification of Existing Equipment". According to their preliminary judgement, this issue potentially requires extraordinarily time-consuming and/or expensive measures and should be implemented after start-up of K2/R4 (Riskaudit, 1996).

(3) Equipment qualification appears to be a critical path on the way to complete the K2/R4 NPPs. Unknown difficulties can be expected due to the unsatisfactory mothballing and conservation situation. This might also lead to higher costs within this area.

(4) In qualifying equipment, the categories safety-related and non-safety-related have to be thoroughly identified. Qualification of safety-related equipment must be performed in any case before start-up of the reactor. Thus, IRR cannot follow in general the Riskaudit recommendation on implementing a "Branch Programme for Accidental Qualification of Existing Equipment" after start-up of K2 and R4. IRR can only agree with this recommendation in the case of non-safety-related equipment.

(5) It is mandatory that impaired safety equipment be replaced rigorously. This process must be strictly observed by an independent licensing authority.

Riskaudit comment:

1. Riskaudit is not correctly cited. Riskaudit has recommended that „Accidental Qualification of Existing Equipment" issue be solved. In any case the origin of the programme, MP or branch programme, is not the key point.
   The Riskaudit judgement is also not correctly cited. In fact Riskaudit was not responsible of any evaluation regarding cost of the measures and possible difficulties for schedule implementation. This is clearly stated in the Riskaudit report.

2. The items „quality of existing equipment" and „qualification" are not linked.
   Conservation status is good, weak points are identified and planned to be corrected. Even if not under Riskaudit responsibility, it can be said that corresponding costs are known.

3. For the purpose of Accidental Equipment Qualification (EQ) program implementation, two groups of equipment are identified: new equipment and existing equipment. New equipment is equipment that will be ordered in the course of the plant completion. Existing equipment is equipment that has been installed or purchased. New equipment will be subject before start-up to EQ programme. Application of the EQ requirements to existing equipment is discussed hereafter.
   Following establishment of the EQ master list (established using a specific analysis of equipment needed to reach a safe state after an event) and the equipment service conditions, the design organisation will determine which components have already documentation (test, analysis, or combination thereof) to support EQ status. From this effort, three groups of components will be developed:

   Group 1: Equipment for which documentation to support EQ status is available.
   Group 2: Equipment for which documentation on testing and/or analysis is available, but components do not meet service conditions.
   Group 3: Equipment for which documentation to support EQ status is not available.

   A plan to allocate equipment within each group is as follows:

   Group 1 Qualified equipment
   Group 2 Additional information will be requested from manufacturer.
   Depending on the outcome, the equipment will be moved to Group 1 or 3.
   Group 3 Testing or replacement

   Group 3 components would be subject to qualification or replacement process before start-up. If not possible a similar approach as the one used generally in West (based on safety justification to be provided demonstrating for example existence of functional redundancy or low risk contribution or implementation of compensatory measure) will be recommended.

4. Impaired components would be subject to a qualification or replacement process. This process will be strictly observed by NRA.

3.3 Area: Core

(i) IRR statements - General (page 36)

(1) Russian technology for manufacturing fuel pellets and assemblies still does not involve movable burnable absorbers, neutron absorbers incorporated in the fuel pellets, updated absorbing materials for control rods, etc.

Riskaudit comment:

1. The fuel use is planned to be optimised by low leakage loading, use of burnable absorbers in the fuel and non-uniform axial distribution of this absorber. Also the nuclear design codes to describe accurately the burn-up effects will be verified on the basis of experimental data from trial operation at Zaporoshie-3. Finally, new control rod design is planned to be installed on the basis of new materials (Dysprosium Titanate, Hafnium) to achieve extended service life-time and higher efficiency.

   As an overall conclusion on fuel assemblies design, Riskaudit considers that the measures proposed in the modernisation programme will permit to significantly optimise the fuel loads.

(ii) IRR statements-Control Rod Insertion Reliability / Fuel Assembly Deformation (page 36)

(1) It is astounding that "Control Rod Insertion Reliability/Fuel Assembly Deformation", which is a generic safety issue of the WWER-1000/V-320 control rod mechanism, has apparently not yet been resolved. The root causes for the failure in several Eastern plants still remain to be identified.

(2) Among other difficulties, the unresolved problems with power control can be taken as a strong indicator for a lack of specific expertise in the involved countries; this situation appears to be aggravated by the disintegration of the Eastern system.

Riskaudit comment:

1. Malfunctions have occurred in the operation of VVER-1000 Control and Protection System (CPS). Control rods drop time exceeded their design value (4 s). In some cases, rods were hanging in the lower part of the reactor core. This issue has been carefully analysed by designer, operators and research institutes. Results have been presented and discussed with international organisations. The cause of malfunction has been identified as additional friction forces (between CPS absorbing rods and guiding channels) caused by distortion of guiding channels. For solving the problem different options were proposed. For Rovno 4 and Khmelnitsky 2, the issue will be solved before start-up by the proposed modernisation measures.

2. As previously explained, the issue related to control rods insertion reliability will not remain unresolved (has been already corrected on operating plants) and the situation can not be taken as indicator for a lack of specific expertise in the countries involved.
   Regarding control rods reliability issue, Riskaudit considers that the set of measures which will be implemented on Rovno 4 and Khmelnitsky 2 will permit to solve the safety issue.

(iii) IRR statements - Power Density Control System (page 37-38)

(1) According to Riskaudit the potentially very expensive and/or time-consuming measure will be implemented after start-up.

(2) The fact that such a measure is not the practice for Soviet-designed units operating in base load mode may decrease the priority for timely implementation. This issue is partly addressed in the Ukrainian Modernisation Programme.

Riskaudit comment:

1. The Riskaudit judgement is not correctly cited. In fact Riskaudit was not responsible of any evaluation regarding cost of the measures and possible difficulties for schedule implementation. This is clearly stated in the Riskaudit report.

2. An automatic control of Xenon oscillations and power distribution is being developed. The implementation is planned for after start-up because an automatic control must be carefully examined.
   Regarding Xenon and power control, the proposed measures will permit to solve the safety issue.

(iv) IRR statements - Xenon oscillations (page 38)

(1) This issue is partly addressed in the Ukrainian Modernisation Programme.

Riskaudit comment:

1. This item is fully addressed in the modernisation programme (see also § iii).

3.4 Area: Component Integrity

(i) IRR statements -General (page 39)

(1) Reactor pressure vessel embrittlement is a generic problem of VVERs.

(2) Pressure vessel integrity is also required in the event of a large LOCA of the primary loops. In this case the pressure vessel represents the coolant container for residual heat removal from the still heated reactor core. Thus, maintaining the integrity of the pressure vessel is mandatory in order to contain radioactive material and to maintain coolability of the reactor core.

Riskaudit comment:

1. Sensivity of the RPV weld metal to neutron embrittlement depends on contents of embrittlement promoting impurities (such as Phosphorus, Copper and Nickel), but also on neutron flux. To present knowledge the content of Nickel is somewhat higher than required in the Ukrainian specification. On the other side, it is

proposed to reduce the neutron flux at the weld facing the core. This will permit to improve the situation by reduction of brittle fracture potential.

2. Pressure vessel integrity of VVER-1000 is not challenged under normal operation. However, the integrity has also to be ensured in the event of pressurised thermal shock (PTS). The large LOCA event mentioned by IRR is not a leading transient concerning vessel integrity (because the pressure of the primary circuit is quickly reduced). In any case, some improvement measures have also been proposed to reduce the risk of thermal shock.
   By implementation of the measures proposed in the modernisation programme, risk due to reactor vessel embrittlement will be significantly reduced.

IRR statements - RPV Embrittlement and its Monitoring (page 39-40)

(1) This problem is generic for all VVERs. Only limited solutions appear possible. Generally there is insufficient space for inspection of the RPV walls from the outer side on the level of the critical (high irradiated) weld.

Riskaudit comment:

1. By specific measures in the modernisation programme the cold shocks effects and irradiation on the RPV will be significantly reduced (see (i)).
   Type and number of surveillance specimen will be brought into compliance with the Ukrainian code. A new design of containers will be localised in the gap between the core and the vessel wall where the cold primary water is flowing. This new location will represent the irradiation conditions in the vessel wall with respect to energy distribution of the neutron field and irradiation temperature at a justified leading factor.
   Repositioning of irradiation surveillance specimen will permit together with other measures to better predict RPV embrittlement. It is Riskaudit's conclusion that the safety issue will be solved.

(iii) IRR statements - Non-Destructive Testing (page 40-41)

(1) ...several compromises will have to be found in reliably determining a comprehensive catalogue of material properties and conditions. The success in this area will be strongly influenced by the amount of available funding (note: the problem mentioned by IRR relates to restricted accessability and need to develop specific tools).

(2) Additional problems concern the persistent lack of qualification requirements for methods, personnel and equipment.

Riskaudit comment:

1. On operating plants, similar systems have been implemented successfully. This shows that technical difficulties can be solved.

2. The concern of IRR on LBB and NDT due to the persistent lack of qualification requirements for methods, personnel and equipment is not substantiated by IRR. Riskaudit can not share this opinion due to the fact that operating experience feedback do not confirm the IRR statement.
   By implementation of the foreseen programme, Non Destructive Examination will be performed in a satisfactory way.

(iv) IRR statements - Steam Generator Collector Integrity (page 41-44)

(1) Regular NDE inspections on possible collector cracking should be performed with manipulators.

(2) Manufacturing problems and "environmentally assisted cracking" of the steam generator, however, will still remain a problem. For both units the condenser tube material is type Cu-Ni-Fe 5-1. No replacement is proposed in the Modernization Programme, which will not allow improvement of the secondary chemical mode.

(3) Unless the information given by Atomaudit on developed hardware measures to eliminate the shortcomings is confirmed the improper design of steam generators manufactured for R4 and K2 will probably not allow their operation until the end of the plant design life time.

Riskaudit comment:

1. In order to reduce the potential of steam generator collector integrity, numerous measures will be implemented including extended in service inspection using the best techniques.

2. For a given problem, different solutions may exist. The proposed solutions given in the modernisation programme (including automatic monitoring and control system for chemical conditions of secondary bulk water) is also suitable to reduce corrosion attack.

3. The safety concern is not to know if the existing equipment will permit or not to operate up to end of plant life time. If needed those components could be exchanged. More important for safety are the surveillance of components status even if some measures (such as cleaning procedure of secondary side, low temperature stress release treatment, additionally hydraulic rolling of tubes in collector holes and modification of secondary circuit water chemistry) have been implemented to different extent in particular steam generators. Measures are proposed in the programme in order firstly to reduce the probability of primary to secondary leakage events and secondly to properly manage such events.

(v) IRR statements - Steam and Feedwater Piping Integrity (page 44-45)

(1) According to Riskaudit preliminary judgement, this issue potentially requires extraordinarily time-consuming and/or expensive measures.

(2) Failure of the highly energised and not separated steam lines on the 28.8m level between reactor building and machine hall represents a generic problem of the WWER-1000/V-320 reactors. An extreme high vulnerability exists in this area for safety-relevant pipes, e.g. of the feedwater lines to the steam generators. This problem apparently cannot be fully solved by secondary measures like rigid embedding and separating walls. Primary measures are mandatory, e.g. rerouting and separating steam lines in combination with solid protection against pipe whip in case of failure. These primary measures are very cost intensive because they require a complete redesign of an area with limited space for improved installations. This may explain why such primary measures have not yet been taken in NPPs with WWER-1000/V-320 reactors. This issue is addressed in the Ukrainian Modernisation Programme. A satisfactory technical solution, however, is still pending.

Riskaudit comment:

1. The Riskaudit judgement is not correctly cited. In fact Riskaudit was not responsible of any evaluation regarding cost of the measures and possible difficulties for schedule implementation. This is clearly stated in the Riskaudit report.

2. In the MP, the problem is planned to be firstly analysed, and in case of necessity (not yet demonstrated), a solution is planned to be implemented. Before implementation, nature of the solution (re-routing or other) will be proposed for independent evaluation. There is no reason to consider that no technical solution exists.

3.5 Area: Systems

(i) IRR statements- ECCS Sump Screen Blocking (page 46)

(1) One of the best and most cost-effective solutions appears to be the use of an insulation which is effectively protected against impinging jets resulting from possible leaks. Fiber-less insulation should be recommended to help overcome the problem. Also, a reliable fixing technology for the insulation has to be selected ; it must be able to withstand any adverse environmental condition in the endangered area inside the containment.

(2) According to a preliminary judgement by Riskaudit, this issue potentially requires extraordinarily time-consuming and/or expensive measures and should be implemented before start-up of K2 and R4.

Riskaudit comment:

1. The measures proposed in the Modernisation Programme are more complete than listed by IRR. It is also planned in this programme to replace the thermal insulation (before start-up) by fiber-less material as recommended by IRR.
   The utilisation of this new solution will permit to solve the ECCS sump screen

blocking issue ; in case of LOCA, coolability of ECCS heat exchangers will not be impaired due to blocking by fibers from insulation.

2. The Riskaudit judgement is not correctly cited. In fact Riskaudit was not responsible of any evaluation regarding cost of the measures and possible difficulties for schedule implementation. This is clearly stated in the Riskaudit report.

(ii) IRR results-SG safety and relief valves (page 47)

(1) Replacement of safety and relief valves is mandatory for the primary and secondary side in order to manage the possible fluid phases from steam to water under all emergency and accident conditions.

(2) Based on Western experience, verifying the capability of such valves in test facilities is problematic because real boundary conditions can't be recreated.
Noneless, efforts must be made to attain realistic and consistent boundary conditions for testing. Furthermore, reliable analytical verification (...) must be requested and performed.

Riskaudit comment:

1. The replacement of valves is not mandatory. In fact, what is required is for the NPPs to demonstrate the reliable operation of those components in all situations they are called to operate (including when necessary steam to water phases). Such demonstration is proposed in the modernisation programme. (In case of failure in the demonstration, the components will be replaced by qualified ones).

2. Western feedback has demonstrated that verifying the capability of such valves in test facilities is not problematic using for the test boundary conditions representatives of the reality. Such test are planned to be performed. (They are considered as more representatives than analytical verification).

As a general conclusion Riskaudit states that safety and relief valves for primary and secondary side will be demonstrated to be able to perform their function in all conditions under which they are called into operation.

3.6 Area: Instrumentation & Control

(i) IRR statement - Reactor Vessel Head Leak Monitoring System (page 49)
(1) This safety issue is generic for all VVER-1000/V-320 reactors. An adequate solution seems possible.

Riskaudit comment:

The leaktightness of the head penetrations is achieved using two concentric seals and leak detection is based upon the collection of water from the space between the seals on all the flanges. The leaktightness should be ensured by preventive

measures (quality of sealing, especially at the assembly). This measures will have to be implemented before start-up.

3.7 Area: Electrical Power

(i) IRR statements - Emergency Battery Discharge Time (page 50)

(1) Reliable solutions for this issue can be found.

Riskaudit comment:

1. No comment.

(ii) IRR statements - Residual lifetime of cables (page 51-52)

(1) According to a preliminary judgement by Riskaudit, this issue potentially requires extraordinarily time-consuming and/or expensive measures and should be implemented after start-up of K2 and R4.

(2) This issue is not addressed in the Ukrainian Modernisation Programme.

Riskaudit comment:

1. The Riskaudit judgement is not correctly cited. In fact Riskaudit was not responsible of any evaluation regarding cost of the measures and possible difficulties for schedule implementation. This is clearly stated in the Riskaudit report.

2. A measure is included in the MP in order to solve this issue.

3.8 Area: Containment

(i) IRR statements -General (page 52)

(1) If the situation described above is an accurate interpretation of the DOE report (DOE, 1987), it would appear that any severe accident which results in penetration of the bottom of the containment would result in a potentially large release of radioactivity into the environment.

Riskaudit comment:

1. The information given in the DOE report is not accurate (e.g. description of Stendal NPP containment instead of K2/R4).
   The K2/R4 containment design approach is consistent with Western practices. (Due to its very low probability Core melting is not taken as Design Basis Accident).

(i) IRR statements -Containment Bypass (page 52-53)

(2) A satisfactory solution is limited due to the specific steam generator design used and its potential to fail.

Riskaudit comment:

1. The possibilities of bypass scenarios will be systematically analysed before start-up. Modifications will be introduced if necessary. Analysis will include the calculation of the LOCA transients due to leaks from the primary to the secondary side of steam generators. Measures are planned further to reduce the frequencies of leaks from the primary to the secondary side and to cope with this accidents.

A special emphasis has been given to this important issue**.**

(iii) IRR statements -Containment Structure (page 54)

(3) Riskaudit did not address the problem of tension losses.
It has to be stressed that any deficiencies of the containment have thoroughly to be investigated and assessed.

Riskaudit comment:

1. The concern of tension losses of the pre-stressing has been addressed by Riskaudit. A specific measure (development of diagnosis of forces in pre-stressing cables and improvement of the existing containment state monitoring) is included in the modernisation programme. Additionally specific recommendation by Riskaudit has been given in order to deal with cables corrosion issue.

3.9 Area: Internal Hazards

(i) IRR statements -Fire prevention (page 55)

(1) The possibilities of fires and their effects on safety require a much more detailed treatment than performed by the IAEA experts. A minimum requirement would be a PSA.

Riskaudit comment:

1. Complementary to the modernisation measures listed by IRR, an overall fire hazard analysis is planned to be performed in order to check the adequacy of the proposed measures and to complement the programme if necessary. This approach is fully consistent with Western approach and is internationally recognised. Additionally, PSA is also planned to be performed.

(ii) IRR results: Pipeline breaks impact inside the Reactor building (page 56)

(1) According to a preliminary judgement by Riskaudit, this issue potentially requires extraordinarily time-consuming and/or expensive measures and should be implemented before start-up of K2 and R4.

(2) Special attention has to be given to the impact of pipe breaks inside the reactor building. The results have to be followed by appropriate measures.

Riskaudit comment:

1. The Riskaudit judgement is not correctly cited. In fact Riskaudit was not responsible of any evaluation regarding cost of the measures and possible difficulties for schedule implementation. This is clearly stated in the Riskaudit report.

2. The study planned to be performed includes also the analysis of this hazard inside the reactor building. Necessary modifications are also planned to be implemented.
   The proposed approach is consistent with Western approach.

(iii) IRR results: High energy pipes ruptures (page 56)

(1) According to a preliminary judgement by Riskaudit, this issue potentially requires extraordinarily time-consuming and/or expensive measures and should be implemented before start-up of K2 and R4.

(2) This issue is only partly and insufficiently addressed. Additional analytical efforts are necessary (....). The possibility of implementing such measures must be investigated.

Riskaudit comment:

1. The Riskaudit judgement is not correctly cited. In fact Riskaudit was not responsible of any evaluation regarding cost of the measures and possible difficulties for schedule implementation. This is clearly stated in the Riskaudit report.

2. The modernisation programme include the realisation of an exhaustive analytical analysis of high energy pipes ruptures hazards. Depending on the results, necessary hardware measures will be implemented.
   The proposed approach is consistent with Western approach.

3.10 Area: External Hazards

(i) IRR statements- Extreme weather conditions: low temperature (page 57)

(1) According to a preliminary judgement by Riskaudit, this issue potentially requires extraordinarily time-consuming and/or expensive measures and should be implemented before start-up of K2 and R4.

(2) The issue is partly addressed in the modernisation programme.

Riskaudit comment:

1. The Riskaudit judgement is not correctly cited. In fact Riskaudit was not responsible of any evaluation regarding cost of the measures and possible difficulties for schedule implementation. This is clearly stated in the Riskaudit report

2. The issue (analysis, definition and implementation of necessary measures) is planned to be completely addressed by the measure proposed in the modernisation programme. The proposed approach is consistent with Western approach.

(ii) IRR results: Man Induced External Hazards and Seismicity (page 57)

(1) This issue must be included into a site-specific modernisation programme.

Riskaudit comment:

1. The (site specific) modernisation programmes include measures dealing with these aspects. Analysis and necessary modifications are planned to be performed.
   The proposed approach is consistent with Western approach.

3.11 Area: Accident Analysis

(i) IRR statements -PSA (page 58-59):

(1) Under Western practice, nuclear plants are not permitted to operate until a comprehensive Probabilistic Safety Analysis (PSA) has been prepared, reviewed and approved.

(2) Until now, PSA results for VVER-1000 units have been obtained only for Balakovo-4, Kozloduy 5&6 and for Temelin 1. The PSA Level 1 study for Balakovo 4 includes a limited number of internal initiating events and the results are too optimistic.

(3) For Kozloduy 5&6,..... Human behaviour is not evaluated either and only full power conditions are covered.

(4) The expected PSA results for the Ukrainian NPPs discussed above (i.e. refer to points 2 and 3) will no doubt be much worse. In the Ukraine, three PSA projects are in various stages of development.

(5) No plans exist for conducting plant-specific PSAs for Khmelnitsky 2 and Rovno 4. ...

(6) The proposed modernisation programme is not based on probabilistic results and criteria, but merely on practical experience and deterministic assumptions. Nevertheless, it is also stated that probabilistic criteria will be used for decision making.
Without performing a plant-specific PSA the, contribution of a measure to overall NPP safety cannot be evaluated. However, PSAs can provide figures to indicate the relative safety improvement.

Riskaudit comment:

1. In most of Western countries it is not a regulatory requirement to produce a comprehensive Probabilistic Safety Analysis (PSA) for licensing.

2. PSAs have been elaborated for more NPPs than mentioned by IRR (e.g. Novovoronezh 5, Balakovo 5&6). In any case, a full PSA is planned to be performed for Rovno 4 and Khmelnitsky 2. In order to avoid lacks or optimism in the study, it is expected that this PSA will be reviewed by an independent organisation supporting the local authority for its licensing action.

3. For Kozloduy 5&6 PSA, human actions were modelised. See also comment given in 2.

4. The Ukrainians have gained some experience in the performance of PSA and have got support (hardware, software and training) from some Western companies. See also comment given in 2.

5. In the framework of the modernisation programme PSAs are planned for both units.

6. Western Safety evaluation approach is generally deterministic.

(ii) IRR statements -Rapid Reactivity Increase (page 59-60)

(1) The rapid reactivity and power increase in VVER-1000s during operation could be caused mainly by control rod ejection. ...

(2) However, in some cases (effective control rod fully inserted in the core) the rapid control rod ejection could result in fuel melting, damage to the fuel rod cladding, and damage to the primary circuit boundary. After such an accident, the possibilities to cool the core could be significantly affected. Sudden rupture of a control rod drive mechanism housing will also perforate the reactor upper unit, leading to loss of coolant accident.

(3) According to the Modernisation Programme, no plans exist to use fuel of new design, burnable neutron absorbers, or new patterns for the initial fuel loading of K2/R4.

(4) A complete set of rod ejection analyses must be accomplished for the start-up phase of operation of K2 and R4, taking into consideration the potential severity of this type of accident.

Riskaudit comment:

1. It is also true for Western PWRs that a rapid reactivity and power increase during operation could be caused by control rod ejection. Also, additional causes are possible. All of them are considered in the modernisation programme.

2. No evidence is given that the rapid control rod ejection could result in fuel melting. The performance of complete set of control rod ejection analyses is planned in the modernisation programme in order to demonstrate the contrary. In case of failure in the demonstration (not expected) modification would have to be implemented.

3. The use of new fuel design including burnable absorber integrated in fuel is proposed in the modernisation programme. The development of fuel containing burnable absorber and its use in low leakage loading is proposed as means to optimise use of fuel.

4. A complete set of accident analyses including rod ejection analyses will be accomplished for the start-up phase of operation of K2 and R4.

3.12 Area: Spent Fuel and radioactive waste management

(i) IRR statements- Spent Fuel Storage (page 61-62)

(1) A critical situation with the spent fuel storage capacity can be expected by the year 2000.

Riskaudit comment:

1. Within the frame of its safety assessment of the K2/R4 project, the Riskaudit consortium has not been requested to evaluate the safety aspects of spent fuel management programme. Such an evaluation is planned to be performed on the basis of relevant plans, which are currently being prepared by Energoatom.

(i) IRR statements- Radioactive Waste Management (page 62)

(2) There is a lack of a proper infrastructure for radioactive waste treatment and management in Ukraine.

Riskaudit comment:

1. Within the frame of its performed safety assessment of the K2/R4 project, the Rikaudit consortium has not been requested to evaluate the safety aspects of radioactive waste management. Such an evaluation is planned to be performed on the basis of relevant plans, which are currently being prepared by Energoatom.

3.13 Area: Post TMI requirements

(i) IRR results - Post TMI requirements (page 63)

(1) The important items (...) are addressed in the modernisation programme (...). It is highly recommended that this as yet unaddressed TMI requirements be included in the modernisation programme.

Riskaudit comment:

1. The post TMI lessons have been indirectly taken into consideration by the Ukrainian experts, during preparation of the modernisation programme, when they considered as sources for modifications :
   - valid regulation (which integrated post TMI lessons),
   - internationaly recognized deficiencies (found by Western experts having integrated among others post TMI lessons).

The situation as described by IRR is not complete or not correct : some items qualified as « not explicitly mentioned » (in the MP) are included either in the original project (e.g. reactor coolant system vents) or in the modernisation programme (e.g. procedure reviews).

3.14 Area: Vintage Design of K2 / R4 - Rules, Norms and Standards

(i) IRR statements- General (page 67-69)

(1) The basic safety principles of VVER-1000s are similar to those of the Western PWRs of the early 1970s. However, their original design does not appear to be organic and is too complicated; it resembles a conglomerate of a number of systems outfitted with rather old and poor-quality equipment requiring considerable protection and control automation. There are several reasons for the relatively low safety level and poor performance indicators of the plants. ...

Riskaudit comment:

1. The IRR statement is not justified and not scientifically substantiated. The construction of K2/R4 commenced in the eighties according to the original design for Soviet VVER 1000/V-320. The design basis was the Soviet "General Safety Principles of Nuclear Power Plants during Design, Construction and Operation" (OPB-73) which provides a multi-stage system of safety precautions and also the „Regulation for NPP Nuclear Safety“ (PBYa-04-74). R4 and K2 are of the model 320 following the so called «small series». The experience feedback from the design and construction of these units was introduced in VVER-1000/V-320..
   In the period of K2/R4 design and construction the OPB-73 was replaced by the OPB-82. New features of OPB 82 resulted from the operational experience feedback and from the international safety development. Among others OPB 82 includes a more accurately formulated single failure criteria and a refined classification of safety systems. These features were considered in the design of the VVER 1000 «standard» serie model 320 and have influenced the K2 and R4 projects. As a result the basic safety principles are similar with those existing for Western PWRs.

2. After the Chernobyl accident the most recent standards in force in Ukraine were developed, namely OPB 88 and its associated standards. Among the new features in OPB 88 is the consideration of Beyond Design Basis Accidents. The comparison of the Nuclear Power Plant Safety Concept contained in OPB 88 and the associated technical standards with the INSAG 3 and NUSS (IAEA) requirements establishes that the Ukrainian safety concept, as reflected in OPB 88, is comparable to INSAG 3 and NUSS (comparison is given in IAEA report (W WER-RD-69).
   The aim of the Modernisation Programme was to identify and to fill in the gap between the original design of K2/R4 and current national rules and international requirements. When upgraded, K2/R4 will fulfil most of OPB 88 requirements (only new design for NPPs of the next generation can meet all requirements) and the resulting safety level will correspond to the one achieved on existing Western NPPs.

3.15 Area: Safety Problems in Other WWER-1000/V-320 Upgrading Projects

(i) IRR statements- General (page71-74)

(1) Both options (Zaporozhie 6 NPP and Temelin NPP) are confronted with significant technical problems. Neither of the two approaches are satisfactory from the safety point of view, not to mention the economic aspect.

Riskaudit comment:

1. Temelin project cannot be compared to Rovno 4 and Khmelnitzky 2 project (different philosophy for upgrading). For this reason, the „significant technical problems“ said by IRR as encountered on Temelin can not be expected on Rovno 4/Khmelnitsky 2. Regarding Zaporoshie, IRR mentions some „significant technical problems“. Those significant difficulties are unknown to Riskaudit. In any case, the Rovno 4 and Khmelnitsky 2 objective is to improve the safety situation compared to operating VVER-1000 (including Zaporoshie 6).

4 Conclusion

The IRR report does not present any new relevant technical safety issues or safety upgrading measures which had not yet been considered in the K2R4 project. All technical areas discussed by IRR were already known and have been treated by the Riskaudit Consortium of Technical Safety Organisations.

The last version of the modernisation programme for K2/R4 (as well as the detailed evaluation report produced by Riskaudit) were obviously not yet available to IRR at the time when they prepared their report. The IRR statements suffer from this lack of essential information. As a consequence, some of the comments and conclusions presented by IRR on technical areas are incomplete or not up-to-date.

Evaluations of economic, logistic, political, and social aspects in Ukraine cannot be commented in detail by Riskaudit. However, Riskaudit expects that the situation concerning those issues will improve and that completion of these two plants at a Western safety level will be one of the elements of the expected improvement.

The general IRR conclusion asserting that the planned completion and modernisation of Khmelnitsky Unit 2 and Rovno Unit 4 will not fulfil the nuclear safety requirements of the EBRD policy is not valid because it is based on information not proven, not justified or incomplete.

In the view of Riskaudit, the conclusions of its report No.120 to the European Commission and other co-lenders on the safety aspects of the K2R4 project remains valid.

Tabular Summary of IRR Important Safety-Related Issues

for K2/R4 - Comparison IRR/Riskaudit

(The issues in the following table were selected by IRR due to their consideration on high relevance for safety and/or for financial and time efforts.)

	IRR view		Riskaudit view	
Important Safety-Related Issues	**Addressed in Ukrainian Modernisation Programme**	**Comments**	**Addressed in Modernisation Programme (Implementation : b or a)**[**]	**Comments**
Area Logistics				
Economic Situation in the Ukrainian Energy Sector (IRR)	not	The economic situation in Ukraine is characterised by a deep crisis. No domestic funds are available for modernisation projects in the energy system.	not	Not technical issue - Has been already improved and will continue to be improved. [*]
Nuclear Infrastructure (IRR)	not	After the disintegration of the USSR, an unsatisfactory situation exists in Ukraine.	not	Not technical issue - The modernisation project is planned to be conducted in close co-operation with nuclear countries. Ukraine is not isolated and not as weak as mentioned. No issue. [*]
Safety Culture (IRR)	not	The safety culture is generally insufficiently developed in Ukraine, especially on responsible levels of	not, but in operational NPPs	Safety culture cannot be improved by a „single“ measure. Has been (and continues to be) improved.

[*] Riskaudit has no specific technical competence on these items ; [**] a: implementation after start-up; b: implementation before start-up

	IRR view		Riskaudit view	
Important Safety-Related Issues	**Addressed in Ukrainian Modernisation Programme**	**Comments**	**Addressed in Modernisation Programme** (Implementation : b or a)**	**Comments**
		management.	programmes	
Spare Parts (IRR)	not	The lack of spare parts is a problem which exists for the whole Ukrainian nuclear industry.	not	Not technical issue. The utility re-organisation (pre-condition for financing) will permit to solve this issue financially. No more issue. *
Fresh Fuel (IRR)	not	The lack of fresh fuel is a problem which exists for the whole Ukrainian nuclear industry.	not	Not technical issue. There is absolutely no such problem in Ukraine. All NPPs are regularly re-loaded. Not safety issue. *
Area General				
Preservation and Mothballing (IRR)	not	This issue is not yet sufficiently investigated. Strong indications exist for minimal or missing conservation/mothballing of equipment and components, which might result in large cost overruns.	not, but „inspection activities“ and conse-quences	Demonstration of existing quality has been provided. Needed corrections are identified and are in the way to be solved.
Qualification of Equipment (IAEA, Riskaudit)	partly	This task is still pending. Implementation has not yet been satisfactorily demonstrated.	yes + Riskaudit recommend-ation (b, partly a)	Modernisation measures are planned. Safety issue will be solved.

Important Safety-Related Issues	IRR view		Riskaudit view	
	Addressed in Ukrainian Modernisation Programme	Comments	Addressed in Modernisation Programme (Implementation : b or a)**	Comments
Area Core				
Control Rod Insertion Reliability/Fuel Assembly Deformation (IAEA)	yes	This is a generic problem for VVER-1000/V-320s. It remains unresolved.	Yes (b)	Modernisation measures are planned. Safety issue will be solved.
Power Density Control System (Riskaudit)	partly	This is a TMI requirement which must be fulfilled.	Yes (a)	Modernisation measures are planned. Safety issue will be solved.
Xe-Oscillations (Riskaudit)	partly	This is a generic issue, which is not yet resolved.	Yes (a)	Modernisation measures are planned. Safety issue will be solved.
Area Component Integrity				
RPV Embrittlement and its Monitoring (IAEA)	yes	This problem is generic for all VVERs. Only limited solutions appear possible. Generally there is insufficient space for inspection of the RPV walls from the outer side on the level of the critical (high irradiated) weld.	Yes (b)	Modernisation measures are planned including re-location of surveillance specimen containers, low leakage, fluence measurement...Problem is not linked with inspection from outside. Safety issue will be solved.
Non-Destructive Testing (IAEA)	yes	See above.	Yes (a, partly b)	Modernisation measures are planned. Safety issue will be solved.
Steam Generator Collector Integrity (IAEA)	yes	This situation is insufficiently taken into account in the original VVER-1000/V-320 design. A design solution is still	Yes (b)	Modernisation measures are planned (prevention and mitigation). Safety issue

Important Safety-Related Issues	IRR view		Riskaudit view	
	Addressed in Ukrainian Modernisation Programme	Comments	Addressed in Modernisation Programme (Implementation : b or a)**	Comments
		pending.		will be solved.
Steam and Feedwater Piping Integrity (IAEA, Riskaudit)	yes	The integrity is impaired for all VVER-1000/V-320 reactors. Basic acceptable solutions are needed. Related measures might become cost intensive.	Yes (b)	Modernisation measures are planned. Safety issue will be solved.
Area Systems				
ECCS Sump Screen Blockage (IAEA, Riskaudit)	yes	A solution for this problem is generally possible.	Yes (b)	Modernisation measures are planned. Safety issue will be solved.
Steam Generator Safety and Relief Valves (IAEA, Riskaudit)	yes	This safety issue is generic. A satisfactory solution is generally possible.	Yes (b)	Modernisation measures are planned. Safety issue will be solved.
Area Instrumentation & Control				
Reactor Vessel Head Leak Monitoring System (IAEA)	yes	This safety issue is generic for all VVER-1000/V-320 reactors. An adequate solution seems possible.	Yes (b)	Modernisation measures are planned: Prevention + monitoring of primary leak. The safety issue will be solved.
Area Electrical Power				
Emergency Battery Discharge Time (IAEA)	yes	Reliable solutions for this issue can be found.	Yes (b)	Modernisation measures are planned. Safety issue will be solved.

Important Safety-Related Issues	IRR view		Riskaudit view	
	Addressed in Ukrainian Modernisation Programme	Comments	Addressed in Modernisation Programme (Implementation : b or a)**	Comments
Residual Life Time of Cables (Riskaudit)	not	This issue is not yet assessed. Corresponding measures might become cost intensive .	yes (a)	Modernisation measures are planned. Safety issue will be solved.
Area Containment				
Containment Bypass (IAEA)	yes	A satisfactory solution is limited due to the specific steam generator design used and its potential to fail.	Yes (b)	Modernisation measures are planned. Safety issue will be solved.
Containment Structure (IRR)	not	Any deficiencies of the containment have thoroughly to be assessed and corrected.	yes + specific Riskaudit recommend-ation (a, partly b)	Modernisation measures are planned. Safety issue will be solved.
Area Internal Hazards				
Fire Prevention (IAEA)	yes	The fire hazards potential and its prevention have not yet been sufficiently addressed in the modernisation programme. A PSA is necessary to take effective measures.	Yes (b)	Modernisation measures are planned. Safety issue will be solved.

	IRR view		Riskaudit view	
Important Safety-Related Issues	**Addressed in Ukrainian Modernisation Programme**	**Comments**	**Addressed in Modernisation Programme** (Implementation : b or a)**	**Comments**
Pipeline Breaks Impact Inside the Reactor Building (Riskaudit)	yes	Sufficient and reliable measures are still open.	Yes (b)	Modernisation measures are planned. Safety issue will be solved.
High Energy Pipes Ruptures (Riskaudit)	partly	This is a safety issue applicable to all VVER-1000/V-320 reactors. Basic solutions to safely separate high energy pipes are still needed. Appropriate measures are potentially cost intensive.	Yes (b)	Modernisation measures are planned. Safety issue will be solved.
Area External Hazards				
Extreme Weather Conditions: Low Temperature (Riskaudit)	partly	Assessing this issue will require performing a review of the design basis.	Yes (b, partly a)	Modernisation measures are planned. Safety issue will be solved.
Man-induced external hazards and seismicity (IRR)	partly	This issue must be assessed in site-specific investigations, which have not yet been performed.	Yes (b, partly a)	Modernisation measures are planned. Safety issue will be solved.
Area Accident Analysis				
Plant-specific PSA (IRR)	partly	The proposed modernisation programme for K2/R4 is not based on plant-specific PSA results. Thus the possibility exists that measures are taken with unknown level of impact on plant safety.	Yes (b and a)	Modernisation measures are planned. Safety issue will be solved.

Important Safety-Related Issues	IRR view		Riskaudit view	
	Addressed in Ukrainian Modernisation Programme	Comments	Addressed in Modernisation Programme (Implementation : b or a)**	Comments
Rapid Reactivity Increase (IRR)	not	A complete set of rod ejection analyses has to be accomplished for the start-up phase of operation of K2 and R4, taking into consideration the potential severity of this type of accident.	Yes (b, partly a)	Modernisation measures are planned. Safety issue will be solved.
Area Spent Fuel and Radioactive Waste				
Spent Fuel Storage (IRR)	not	A critical situation with the spent fuel storage capacity can be expected by the year 2000.	not	No technical difficulties to deal with the issue.
Radioactive Waste Management (IRR)	not	There is a lack of a proper infrastructure for radioactive waste treatment and management in Ukraine	not	No technical difficulties to deal with the issue.