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COMMITTEE FOR TECHNICAL AND ECONOMIC STUDIES ON NUCLEAR ENERGY DEVELOPMENT AND FUEL CYCLE

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COMMITTEE FOR TECHNICAL AND ECONOMIC STUDIES
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47TH SESSION
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REPORT BY SLOVENIA

NUCLEAR FACILITIES AND THE FUEL CYCLE

This is the first report of Slovenia, as an observer country, to the NEA Committee for Technical and Economic Studies on Nuclear Energy Development and Fuel Cycle. Slovenia has one operating nuclear power plant, one research reactor, one central radioactive waste storage for LIL solid radioactive waste from non-power users of nuclear energy and one uranium mine and mill in a decommissioning stage. The activities on these facilities are presented further in more detail in this report.

THE KRŠKO NUCLEAR POWER PLANT

Description of the facility

The Krsko Nuclear Power Plant (the Krsko NPP) is the only nuclear power plant in Slovenia. It is situated on the left bank of the Sava river in the south-eastern part of Slovenia. It is a Westinghouse designed and constructed two-loop PWR with originally installed capacity of 632 MWe. The design of the Krsko NPP is similar to other Westinghouse PWRs of the same type operating in the USA, Belgium, Switzerland, Korea and Brazil. The construction started in 1974; on the basis of a special permit, the first fuel loading was accomplished in May 1981 and the plant was synchronised to the grid in October of the same year. After an authorised trial operation, full power was reached in August 1982. A special permit for the beginning of commercial operation was granted to the Krsko NPP in February 1984 by the Slovenian Electro energy inspectorate, which was at that time competent for the licensing of nuclear facilities. Licensing was done on the basis of preliminary and final safety reports following vendor country regulations, with the assistance of several missions from the IAEA. The Krsko NPP was built as a joint project of the electric utilities of Slovenia and those of the neighbouring Croatia. The NPP has had a continuous backfitting and upgrading program and a large modernisation program, including the replacement of steam generators with power uprate (6.3%) and a full scope simulator. The site organisation and the operational safety practice are similar to those in Western Europe.

The long-term policy for the nuclear power remained the same as in the previous year, therefore:

- The objective is to maintain stable operation and high level of operational safety in the Krsko NPP, both during its operation and after the shutdown,
- During the period of operation the conditions for its safe decommissioning should be established,

- Prior any decision to premature shut down of the plant is made, energy supply reliability has to be ensured. This decision needs to be taken at least ten years in advance accompanied by measures to replace its share in the national power production.
- To improve the operational safety all measures recommended by international missions are implemented.

Fuel Cycle

In 1996 the Slovenian Government has adopted a long-term strategy for the spent fuel management that will be revised every three to five years. According to current strategy, the decision on location of nuclear spent fuel disposal site will be adopted in Slovenia by the year 2020. The options are the construction of repository in Slovenia and/or Croatia. The disposal of the nuclear waste in the third countries will be also considered. It is planned to have the disposal of spent fuel available by the year 2050.

Currently, Krsko NPP operates in 12 months fuel cycles using fuel elements manufactured by Westinghouse Electric Company. The reactor core is composed of 121 fuel assemblies at an average enrichment of 4.3% U-235. Each fuel assembly consists of a 16 by 16 array of 235 fuel rods, 20 guide thimbles for control rods and instrument guide thimble. More than 700 fuel assemblies were irradiated in 18 fuel cycles.

The fuel reliability indicator (FRI) represents the I-131 specific activity corrected for I-134 contribution from dispersed uranium in the primary coolant circuit, normalised to the constant value of the cleaning speed. The FRI values are presented in Fig. 1.

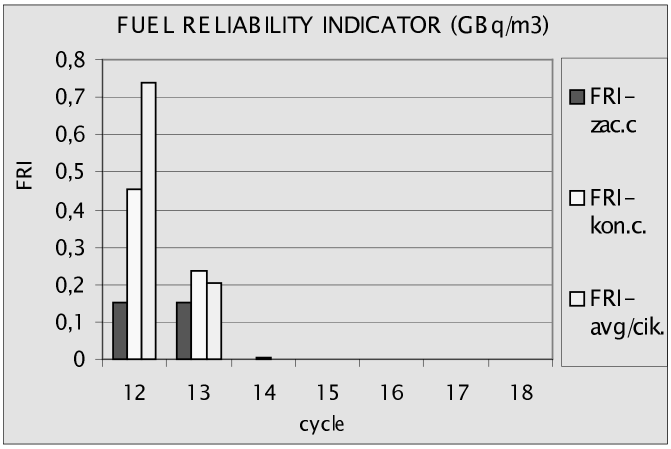

Fig. 1. Fuel reliability indicator.

Modernisation and Power Upgrade of the NPP

The Krsko NPP modernisation program, performed during the years 1997-2000 consisted of four projects: supply (design, manufacture and transport) of steam generators, steam generator replacement (installation: removal/replacement), power uprate analyses and supply of full-scope simulator. The project was entitled the Krsko NPP Modernisation due to close relationships between those four projects and their influence on plant safety and long-term operation. The specific goals of the Krsko NPP Modernisation were:

- To increase the overall operational safety, minimise the risk of environmental radioactive releases and reduce the number of plant trips and unplanned shut-downs,
- To improve the qualifications of operational staff in compliance with the international standards,
- Increase the plant availability to a level over 85% percent and standardise plant refuelling outage duration to approximately 35 days,
- Uprate the plant's nominal thermal power by 6.3%, from 1882 MWth to 2 000 MWth,

- To reduce the operational costs of energy produced,
- To sustain the operation over plant's anticipated lifetime until 2023.

The program started in 1995. In December 1996 contract was awarded for supply of two new steam generators and in February 1998 the Krsko NPP awarded the contract for the steam generator replacement project both to the Consortium Siemens-Framatome. The project was performed on a "turnkey" basis, which means that the Contractor supplied all engineering, fabrication and site activities, and preparation of the modification packages. The contractor for safety analyses was Westinghouse, the supplier of full-scope simulator was the Canadian company CAE (Canadian Aerospace Electronic).

Work reports together with the revised Updated Safety Analyses Report (USAR) including revised Krsko NPP Technical Specification represented the documentation submitted to SNSA as the basis for issuing license. Based on the review and assessment of the documentation SNSA issued temporary license for the plant operation on the uprated power, because "Leak-Before-Break" (LBB) concept as part of uprate analyses is still under review.

The steam generators were successfully replaced during the outage in June 2000. The start-up tests were successfully implemented and new power level achieved as planned. The operation of the power plant is stable and reliable.

The Krsko NPP full scope simulator enables training of the operators by simulating the activities that are performed from the main control room and from the local shutdown panels. It has been built in accordance with the American standard, ANSI/ANS-3.5. The licensing process was finished on March 1, 2000. After the final phase of simulator acceptance testing, it was ready for training in April 2000. The simulator has the capability to simulate to some extent beyond design bases accidents.

Performance Indicators

In 2001, the Krsko NPP generated over 5,257,087.5 MWh (5.2 TWh) of electrical energy at the output of the generator, or 5,036,275 MWh (5.0 TWh) net. This is the highest yearly production of electric energy during the lifetime of NPP. The generator was connected to the electrical grid for 7821.53 hours or 86.29% of the total number of hours in the year. The electrical production was 0.27% lower than planned, because of power reduction when the flow of the Sava river was too low to operate at a 100% power. The total production of electrical energy in Slovenia was 12,904.2 GWh, the share of the nuclear energy production being 39.04 %. The most important operational indicators are shown in Table 1, while their changes over several years are presented in the Figures 2 to 7.

In addition to the record production and load factor, the operational reliability of the Krsko NPP was also at a very high level. In 2001, there were no abnormal events or automatic shutdowns. A planned manual shut-down took place during the 2001 annual outage.

The charts in Figs. 2 to 7 present the main operational data for the entire period of commercial operation of the Krsko NPP and enable a comparison to be made between the results in 2001 and the previous period.

Table 1. Safety and operational indicators of the Krsko NPP (y. 2001)

Safety and Operational Indicators	Year 2001	Average
Availability factor (%)	88.94	82.69
Load factor (%)	87.64	78.96
Forced outage factor	0	1.36
Net electrical energy production (GWh)	5036.27	4287.02
Reactor shut-down - manual (Number)	0	3.48
Reactor shut-down - automatic (Number)	0	0.27
Outages duration (Days)	40,38	55,65
Fuel reliability indicator (FRI) (GBq/m^3)	0.0017	0.12

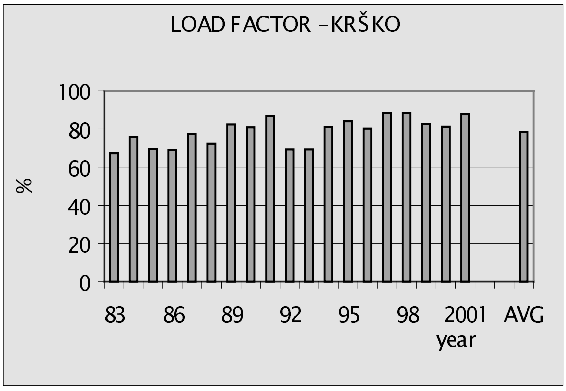

Fig. 2. Load factor.

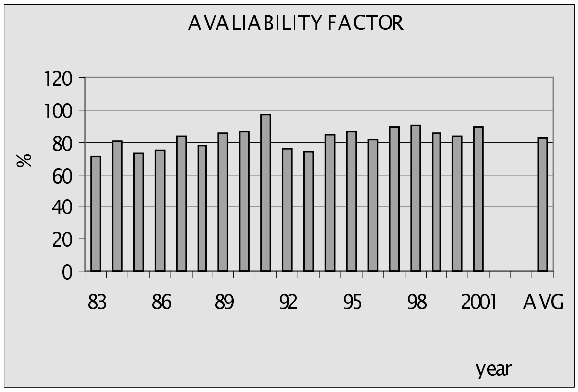

Fig. 3. Availability factor

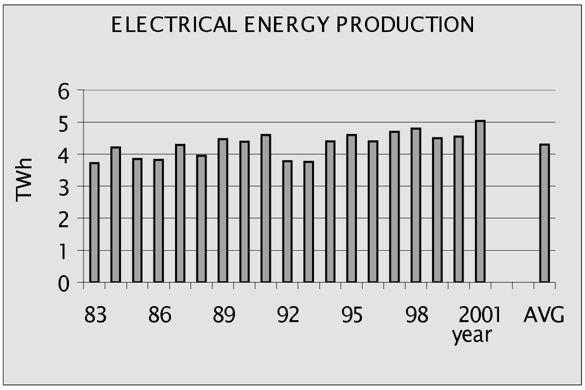

Fig. 4. Electrical energy production

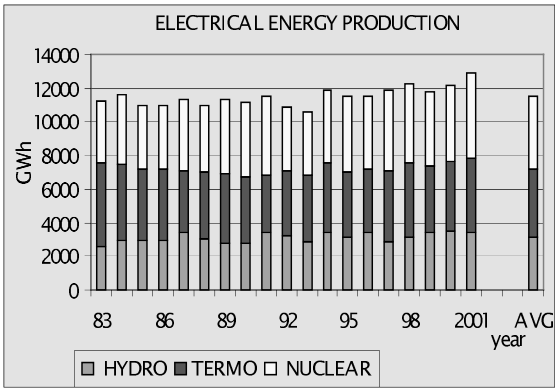

Fig. 5. Electrical energy production

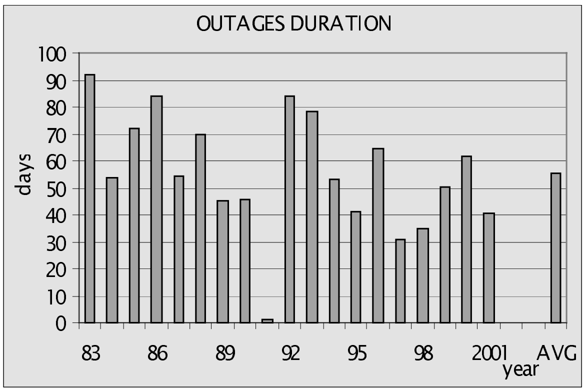

Fig. 6. Outages duration

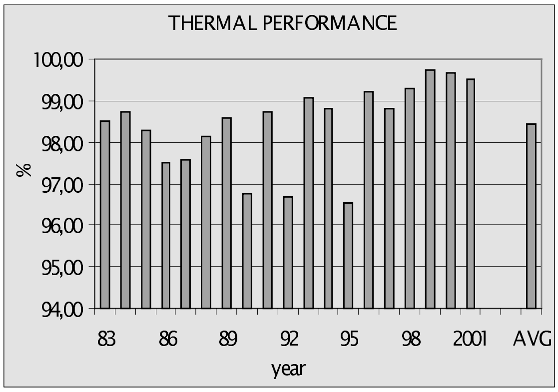

Fig. 7. Thermal performance

Periodic Safety Review

The comprehensive safety review of NPP Krsko is regularly performed according to the US regulations, which do not stipulate PSR. Extensive work that is an essential part of the PSR has therefore already been done by NPP Krsko in the areas of PSA, updating Final safety analysis report, safety upgrading programs and safety impact analysis of plant modifications (Regulatory Compliance Program, Integrated Safety Assessment Project, etc.). The need for conducting a PSR for NPP Krsko according to the EU practice has been recognised both by NPP and regulator (SNSA).

In January 2001 the SNSA issued a decision requesting the Krsko NPP to prepare a PSR program and determine a schedule for the implementation. The program, which was required to be in accordance with the IAEA safety philosophy and with the EU practice, was approved by the SNSA in July 2001 following the IAEA peer review. According to the milestones determined in the decision the PSR report of the Krsko NPP will be completed by the mid December 2003 and submitted to the SNSA for review and approval.

The PSR is going to be built-in into the new legislation. Typically an interval of 10 years, based on the international experience, will be specified.

Reracking of the Spent Fuel Pit

At the NPP Krsko all spent fuel is stored in a spent fuel pool. Approximately 2/3 of the pool are occupied by racks having 828 positions for the storage of spent fuel. During the outage in 2001, 36 fuel elements were removed from the core. At the end of the year 2001, 630 fuel elements (approximately 258 t of heavy metal) were stored. Five positions are occupied by containers and one by control rods. Other unoccupied positions are thus available for further storage of spent fuel, which is sufficient for only two years of operation of the NPP Krsko. Data on the number of spent fuel assemblies in the spent fuel pit of Krsko NPP are shown in Table 2.

Table 2. Data on the quantity of spent fuel at NPP Krsko

Year	Number of spent fuel elements in the spent fuel pool, cumulative per year	Annual increase
1983	40	40
1984	82	42
1985	122	40
1986	154	32
1987	194	40
1988	226	32
1989	266	40
1990	314	48
1991	314	0*
1992	358	44
1993	406	48
1994	406	0**
1995	442	36
1996	470	28
1997	498	28
1998	530	32
1999	562	32
2000	594	32
2001	630	36

*There was no refuelling in the year 1991.
**In the year 1994, the outage started in December 1994, and the fuel was reloaded in January 1995.

The Krsko NPP will run out of capacity for storing of the spent fuel assemblies after the 2003 refuelling outage. Because of that the Krsko NPP will increase the capacity of the existing Spent Fuel Storage Pool (SFP) to 1750 spent fuel assembly storage locations. All required analyses will assume 2450 spent fuel assembly storage locations for eventual extended plant lifetime of 20 years and adequate spent fuel pit capacity. The pool was reracked for the first time in 1983, increasing its capacity from 180 to 828 fuel assembly (FA) storage locations. The SFP cooling capacity was increased in 1985 by adding the second heat exchanger.

Technical reports (analysis) are in progress. The manufacturing of racks and other equipment shall be finished in August 2002 and the installation of new racks will start in September 2002. Installation of an additional heat exchanger is completed. Installation and turnover package will be completed by the end of 2002.

Radioactive Waste

The Low and Intermediate Level Radioactive Waste (LILW) generated in the Krsko NPP are stored in the adjacent radioactive waste building. The storage capacities in the Krsko NPP are almost filled up, but in the NPP the technical measures are implemented (i.e. super compaction, incineration, separation), to provide potentially the safe interim storage until the end of the lifetime. For the more voluminous replaced equipment waiting for decontamination there is the new multipurpose building, in which the steam generators are stored.

Slovenia has prepared the strategy on LILW management, which is now in the phase of reconciliation on interministerial level before it is going to be submitted to the Government and to the Parliament.

Various radioactive substances in liquid, gaseous and solid form that are generated during the operation of the NPP are processed by a system for treatment of radioactive waste. In order to minimise releases to the environment, the system is designed for collection, processing, storage and packaging of waste into a suitable form. Three main subsystems for radioactive waste management are in use: for liquid, solid and gaseous radioactive waste.

In the year 2001, 217 standard 200 L drums with solid LILW were stored, with total activity of 4432.04 GBq. From the beginning of its operation until the end of 2001, the Krsko NPP produced 13,582 standard drums of LILW, which amounts to 2,852.22 m^3. In the previous years, the volume of generated waste was reduced by using the following methods: compaction, supercompaction, drying and incineration. At the end of the year 2001, the volume of stored waste at the Krsko NPP was 2,207.5 m^3.

In the year 1999, a special facility was constructed for the storage of two old steam generators, i.e. the so-called Decontamination Building. Old steam generators with the volume 600 m^3 and activity 8.79 E+12 Bq were stored at the end of the year 2000.

THE TRIGA MARK II RESEARCH REACTOR AT BRINJE

The Research reactor TRIGA Mark II of the Jozef Stefan Institute was designed for experimental work, training of the NPP personnel and preparation of radioactive isotopes for medicine, industry and nuclear chemistry. It is situated in the vicinity of Ljubljana and has a 250 kWth General Atomic pool reactor. TRIGA was initially licensed in 1966 as an IAEA project and was re-licensed for steady state and pulse operation after refurbishment and reconstruction in 1992.

In 2001 reactor operated 165 days and produced 279 MWh of thermal energy. Altogether 704 samples were irradiated in the F-channel and reactor rotary system. 1500 samples were irradiated in the pneumatic transfer system. The reactor also worked for the pulse mode, 15 pulses were performed. For experimental purposes several core changes (fuel removing) were made.

In year 2001 there were 210 shutdowns of reactor, 13 of them unplanned. The reasons of unplanned shutdowns were loss of off-site electrical power (5) and operators' errors.

Altogether 94 fuel elements are kept in the reactor building. They are situated in the reactor core (56) and in the fresh fuel storage (38). There was no fuel damage in 2001.

In 1999 used fuel of the TRIGA reactor was returned permanently to USA under the "US Foreign Research reactor Spent Nuclear Fuel Receipt Program". Altogether 218 used fuel elements were returned, including 26 with 70% enrichment. One of the fresh fuel elements, which was bent and was unusable, was also returned. Fuel was loaded into special transport containers (NAC legal weight truck cask) and transported via the port of Koper to USA by sea route. Together with Slovenian fuel also spent fuel from Italy and Romania were loaded. All costs of transportation were covered by the USA.

THE CENTRAL INTERIM STORAGE FOR RADWASTE AT BRINJE

Central Radioactive Waste Storage at the Jozef Stefan Institute in Brinje is used for interim storage of LIL solid radioactive waste from the TRIGA reactor centre and other small waste producers, such as medical, research, and industrial applications of ionising radiation. The responsibility for operation of the interim storage was in 1999 transferred from the Jozef Stefan Institute to the Agency for Radioactive Waste Management. The storage facility is a near-surface concrete building covered with earth. This building with an area of 26.7 m per 10.5 m and a height of 3 m is subdivided by concrete walls into nine storage sections and an entrance area.

In the year 2000 ARAO made a plan of remediation and refurbishment of the storage facility. The total waste amounts to 774 pieces of waste with the total assessed activity of 3,700 GBq.

THE ŽIROVSKI VRH URANIUM MINE AND MILL

The Zirovski Vrh Uranium Mine and Mill was in operation in the period from 1985 to 1990. Its lifetime production was 607,700 tons of ore corresponding to 452.5 tons (U_3O_8 equivalent) of yellow cake. Both the mine and the mill are undergoing decommissioning and re-mediation of surface disposal of 1,548,000 tons of mine waste and red mud, and 593,000 tons of mill tailings respectively.

In year 2001 the decommissioning of the Zirovski vrh mine was performed on the basis of the Operational plan of activities and amendments to this plan. Works were performed on preparation of the mine for permanent abandoning of uranium mining in the future and for permanent deposition of ore that was already excavated. The influence of the mine on the environment stayed on the same level as in previous years, since there was only one minor intervention carried out to decrease it. The values of annual effective doses were very low.

During the year 2001 on 2 pre-prepared locations in the mine 11,666 t of uranium ore was deposited (average content of 421 g/t). On the Jazbec mine waste disposal site, 5,500 t of poor uranium ore was deposited (average content of 191 g/t).