OPERATIONAL EXPERIENCES AND FUTURE PLANS FOR HUNGARIAN SPENT FUEL STORAGE

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ABSTRACT

Paks Nuclear Power Plant is the only commercial generating NPP in Hungary. It has four VVER-440 type reactor units. Since 1989, the plant has provided almost half of the total electricity generated in the country. A Modular Vault Dry Store (MVDS) type of storage facility started operations in 1997 to provide for interim storage of the spent fuel generated at Paks site. The modular storage facility was constructed in three phases. Its capacity is now 4950 storage locations for individual spent fuel assemblies.

Further enlargement of the interim storage facility will need a new licensing application. As the selection of the existing storage technology was carried out more than 10 years ago a two-step re-selection process was initiated in 2000 for the further extension of the interim spent fuel storage facility. The aim of the new selection process was to make sure that the adopted technology is not just safe but economical too. In 2003 a decision was made to continue the extension of the existing facility using the MVDS technology.

A general review of the operational experience was carried out in 2003 to provide feedback for the further operation and the extension of the storage facility.

This paper gives an overview of the experience gained during the six to seven years of operation detailing the operational results, difficulties and modifications made during this period. It also describes briefly the re-selection process and the proposed modifications for the further enlargement of the interim storage facility.

INTRODUCTION

Hungary is situated in Central Europe and is a candidate country to join the European Union in spring of 2004. Having limited natural resources, the nuclear industry plays an important role in the nation's electricity supply. Currently, there are four main nuclear facilities in the country. Three of them are nuclear reactors and the other one is an interim spent fuel storage facility.

Paks Nuclear Power Plant is the only commercial generating NPP in Hungary. It has four VVER-440 type Pressurized Water Reactor units. Since 1989, the plant has provided 40-50 % of the total electricity generated in Hungary. The new fuel has been imported from Russia, and spent fuel was shipped back to the country of origin until the beginning of the 1990s. Since then, some of the spent fuel shipments were delayed, and some of them were completely cancelled thus creating a backlog of spent fuel filling all storage positions at the plant. In order to assure the continuous and reliable operation Paks NPP's management decided to implement an independent spent fuel storage facility and chose GEC-Alsthom's Modular Vault Dry Storage design in 1992. Following an extensive licensing procedure the Interim Spent Fuel Storage Facility (ISFSF) was commissioned in 1997.

The two other nuclear facilities are Russian-type research and training reactors. Both of them are located in Budapest, the capital city of the country. The Budapest Research Reactor was commissioned in 1959. The facility is operated by Atomic Energy Research Institute. The training reactor at the Technical University of Budapest is used mainly for teaching purpose. All spent fuel assemblies generated during the operation of these reactors are stored at each site. At the Budapest Research Reactor an external storage pool was constructed 100 m from the reactor. No spent fuel has been discharged from the training reactors since its commissioning in 1971. Since it was assumed that the spent fuel from the research and training reactors would be shipped back to the country of origin, the storage of such fuel was not taken into consideration in the original design of the Paks ISFSF.

INTERIM SPENT FUEL STORAGE AT PAKS SITE

According to the fuel strategy that was effective at the construction of the Paks NPP the Soviet Union undertook to take back the spent fuel for reprocessing without returning any product or waste from it. The first transport of spent fuel took place in 1989, but altogether less than 2332 spent fuel assemblies were returned.

To overcome the above-described difficulties with the spent fuel storage at the NPP site the investigation of the alternative storage strategies was carried out in the beginning of the 1990s. As a result of this evaluation and selection process the Modular Vault Dry Storage system was selected from seven equally safe and reliable storage technologies. The main factor of this decision was the fact that the MVDS technology has provided the lowest spent fuel cladding temperature during storage. Having only limited experience at that time on the behaviour of the VVER spent fuel under dry conditions it was judged to be an important issue.

The possibility of the use of Russian reprocessing services still exists, but since commissioning of the Paks storage facility all spent fuel assemblies taken out from the decay pools of the reactors are stored at ISFSF adjacent to the NPP.

General features of the storage facility

The MVDS is illustrated on Fig.1 and provides for at least 50 years of interim storage for VVER-440 fuel assemblies in a contained and shielded arrangement. The fuel assemblies are stored vertically in individual fuel storage tubes, the matrix of storage tubes being housed within a concrete vault module that provides shielding. To prevent the development of eventual corrosion processes, the fuel assemblies are in an inert nitrogen environment inside the storage tubes.

Decay heat is removed by a once-through buoyancy driven ambient air flow across the exterior of the fuel storage tubes, through the vault and the outlet stack. There is no direct contact between the fuel assemblies and the cooling airflow.

A similar type facility has been in operation at Fort St. Vrain in Colorado, USA since 1991. Another storage facility where the Canister Handling Machine was designed based on the Paks MVDS Fuel Handling Machine is in operation at the Hanford Site in Washington, USA since 1999.

The Paks storage facility functionally can be divided into three major structural units. The first one is the vault module where the spent fuel assemblies are stored in the vertical tubes. These vault modules include a minimum of three or maximum five vaults depending on the geometrical arrangement. Each vault is capable of accommodating 450 spent fuel assemblies.

The second major structural unit is known as the charge hall where the fuel handling machine travels during the fuel handling operations. The charge hall is bordered by the reinforced concrete wall of the ventilation stack on the one side and by a steel structure with steel plate sheeting on the other side.

The third major unit is the Transfer Cask Reception Building (TCRB) in which the reception, preparation, unloading and loading of the transfer cask takes place. The fuel handling system and other auxiliary systems are installed in the TCRB.

The fuel assemblies are transported to the MVDS from the at-reactor pool using the C-30 transfer cask and its railway wagon. The transfer cask is received in the TCRB where it is removed from railway wagon and prepared for fuel assembly unloading. The fuel is raised into a drying tube directly above the cask where the fuel assembly is dried prior to being lifted into the fuel handling machine. The fuel assemblies are transferred, within the fuel handling machine, to the vertical fuel storage tubes in the vaults.

Once the fuel handling machine has moved away from the storage tube the air is evacuated from the tube and replaced with nitrogen gas. Then the tube is connected to the built-in nitrogen system that monitors the storage environment of the spent fuel assemblies.

Licensing and construction

The licensing process in Hungary for the Independent Spent Fuel Storage Facility was very complex. The required permits relate to each other both in time and in their logic. A number of new, earlier not requested permits were required. Some authorities began to develop and publish the general requirements during the implementation process.

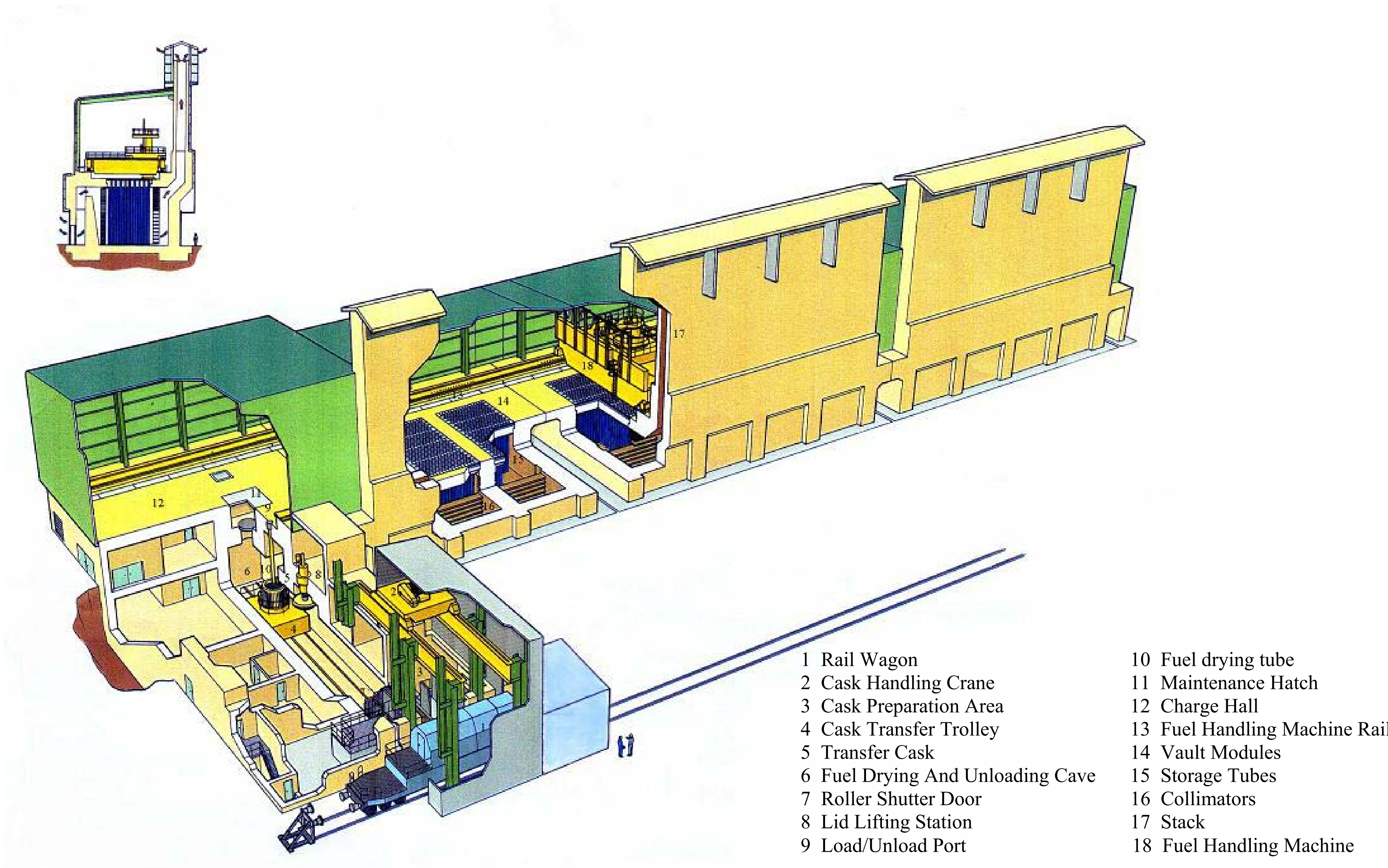

Fig. 1 Paks MVDS

The main authorities issuing their permits involve several other authorities in the course of their licensing process. The situation was complicated with the fact that some regulatory processes were in a way connected with each other. It was necessary to address more than 20 different authorities during the original licensing of the facility.

At the beginning of design work the Hungarian regulation contained no specific prescriptions on spent fuel storage facilities. Revision and comprehensive elaboration of the nuclear regulation to cover the new type of facilities were only in an initial stage. Therefore, an agreement was reached as a result of the negotiations between the competent authority and the operator of the NPP that the relevant US regulations should be considered as authoritative. The licensing process to begin construction lasted for 14 months and was finished by February 1995.

Due to its modular nature the MVDS facility has been constructed according to the operational needs of the of the nuclear power plant. The TCRB and the first three storage vaults were constructed in 1996. Commissioning of the facility took place in 1997 by filling the first storage vault with 450 spent fuel assemblies. Construction of the second and third vault modules, each with four storage vaults was finished in 1999 and 2002 respectively.

The present total capacity of the ISFSF permits 4950 fuel assemblies to be stored in 11 vaults. This capacity is based upon the amount of the spent fuel arising from the Paks reactors over an operating period of 10 years.

Although the original design of the Paks MVDS made provision for an enlargement to accommodate all the spent fuel generated during the lifetime of the Paks NPP, some of the licenses issued by the competent authorities expire with the completion of the 11 vaults. This means that the further enlargement will need a new licensing application.

Operation of the Paks MVDS

According to the modified Atomic Energy Act that became effective parallel with the commissioning of the facility, a new agency called Public Agency for Radioactive Waste Management (PURAM) was established in 1998. PURAM was designated to carry out the multilevel tasks in the field of the radioactive waste management including the interim storage of the spent fuel.

Operation of the Paks MVDS was started by the operator of the Paks NPP. A multi-step take-over process was started following the establishment of PURAM. As part of this process PURAM has bought the existing TCRB and the first storage module and the site from the NPP. They have taken over on a step-by-step basis the licenses necessary for the operation. The subsequent enlargements were managed by PURAM. In spite of this takeover, the NPP still has tasks regarding the facility. The NPP staff provides the operation of the ISFSF in a contractual arrangement with PURAM.

The quantity of the spent fuel assemblies stored in the ISFSF at the end of 2003 was 3407.

OPERATIONAL EXPERIENCE

During the 6-7 years of operation of the facility there were just a few technical difficulties. Recently, the increased level of the crud on the fuel assemblies transferred from the reactors results in more frequent HEPA filter changes in the ventilation system of the fuel preparation room in the Transfer Cask Reception Building. In spite of this difficulty, the evaluations of the operation through the radiation protection aspect show good results. Both the radiation releases and the personal exposures are low compared to the radiation protection limits.

Environmental impact and operational exposure from the operation

Radiation source terms of the facility could be divided into following groups:

- Direct and scattered radiation from spent fuel assemblies
- Release of the crud
- Release of cask water

The radiation of the spent fuel assemblies are minimised by bulk and labyrinth shielding. The spent fuel assemblies are stored in hermetically sealed tubes to prevent the spread of contamination. During the spent fuel handling the spread of contamination is prevented by ventilation system including HEPA filters.

As result of the bulk concrete shielding the dose rates around the facility are low. Being a dry storage facility, the liquid effluents are not very relevant. The airborne releases are dominated by the crud and end evaporated cask water during fuel handling and drying.

The radioactive releases during the seven years of operation and the corresponding limits for the selected isotopes (Co-60, Mn-54, Ag110m, Tritium and C-14) are summarised in Tables I and II.

The isotope specific limits were derived from the 10 microSv/year (1mRem/yr) dose restriction for the off-site doses.

Table I Airborne release from Paks MVDS

Year	1997	1998	1999	2000	2001	2002	Limit
Number of loaded fuel assemblies	450	497	400	500	750	420	
Co-60	1.6E4	2.3E4	1.4E4	2.0E4	2.3E4	1.8E4	7.8E09
Mn-54	1.4E4	2.2E4	1.2E4	1.8E4	2.1E4	1.8E4	1.1E11
Ag110m	1.4E4	4.1E4	1.3E4	1.9E4	2.1E4	1.6E4	7.1E09
Tritium	1.7E8	2.3E7	2.8E7	3.1E8	1.6E8	1.6E8	2.1E14
C-14	2.9E6	7.5E5	1.2E6	6.0E5	1.4E6	5.4E5	2.6E11

Comparing the isotope specific limits and the measured values it can be seen that the measured data are far below the release limits. The same conclusion can be drawn for all the isotopes determined in the radiation source terms.

The individual and collective doses of workers are shown in Table III. With one exception the radiation exposure was very low. The higher value in 2002 was due to the increased crud level on the fuel handling machine primary filter. A continuous activity monitor is going to be installed on the filter. This measurement will check the crud build-up on the filter after each fuel assembly. Hence this will give an indication for the filter exchange.

Table II Liquid effluents from Paks MVDS

Year	1997	1998	1999	2000	2001	2002	Limit
Number of the loaded FAs	450	497	400	500	750	420	
Co-60	3.1E5	3.1E5	9.9E4	4.9E+05	3.0E5	4.1E5	3.1E10
Mn-54	9.3E4	1.2E5	3.3E4	1.2E+05	5.7E4	9.2E4	1.8E12
Ag110m	8.8E5	2.4E5	5.1E4	4.2E+05	6.5E4	3.4E4	1.3E12
Tritium	6.3E6	2.3E6	2.3E6	8.4E+06	3.1E6	4.8E6	1.6E15

Table III Radiation exposure of workers

Year	1997	1998	1999	2000	2001	2002
Number of the loaded FAs	450	497	400	500	750	420
Collective dose (man Sv) (man Rem)	2.4 240	2.4 240	1.5 150	2.1 210	2.1 210	8.6 860
Highest individual dose (mSv) (mRem)	0.03 3.0	0.03 3.0	0.14 14.0	0.071 7.1	0.035 3.5	0.582 58.2

In the environment there was no measurable radioactivity as a result of the operation of the facility. The exposure of the surrounding population was calculated on measured releases and meteorological data. The calculations show negligible doses.

Operational difficulties

The MVDS is completely passive in storage mode. During this period only the monitoring system is in operation. The fuel handling systems are mainly used when fuel loading and unloading are in progress.

The spent fuel arrives in the C-30 cask into the MVDS. The transfer cask contains 30 fuel assemblies. Once a fuel loading operation has started it needs to be continued until the cask is emptied. The fuel assemblies are taken out one by one from the cask, dried and positioned in the designated storage tube. Thus the cask handling time cycle gives a good indication of the operability of the handling systems. Operational difficulties or system failures during this period could make the process time longer than the average value. The maximum, minimum and yearly average time cycles are shown in Table IV.

Table IV Cask handling time cycles

Process time in hours	1997	1998	1999	2000	2001	2002
Minimum	88.03	90.67	72.75	81.2	93.13	101.90
Maximum	185.03	125.2	121.83	241.22	186.25	190.40
Average	129.63	97.92	103.24	112.77	106.94	132.90

The average cask handling time cycle should be around 100 hours according to the estimated design value. 1997 was the commissioning period of the facility when 450 fuel assemblies were loaded. The longer than average time cycle could be explained with the problems faced during the commissioning of the facility. In the following years the time cycles were around the average value, but in 2002 it was again above the average.

If, during the cask unloading or loading, a failure influencing the handling process occurs, then the spent fuel assembly handling is stopped at a safe position and the failed system is repaired. The longer than average cask handling time cycle shows that during the cask handling process unexpected failures have occurred.

Based on the recorded system failures and the annual reports of the operation a general overview was carried out in 2003 on one hand to review the causes of the above-described longer than average cask handling time cycles and on the other hand to provide feedback for the additional operation and enlargement of the facility. Summarized data of review are shown in Table V. The recorded data include all the operational difficulties from minor ones to the more significant.

Table V Summary of the recorded system failures

	1997	1998	1999	2000	2001	2002
Fuel handling machine	159	42	72	43	48	40
Fuel drying system	14	11	-	8	4	-
Ventilation system	4	3	-	13	-	6
Liquid waste system	4	17	5	3	-	3
Others	18	15	20	40	26	10

The detailed review of the failures of the systems showed that the typical difficulties were associated with:

- failure of the seismic restraints of the fuel handling machine
- failure of the inflatable seal in the fuel drying system
- blockage of the filters in the liquid waste system
- problems with fan belt in the ventilation system

According to the yearly reviews of the operational experience some modifications were introduced. In 1998 the modifications concentrated on the difficulties experienced during the commissioning phase. As part of these, the fuel handling machine seismic restraints and fuel grabbing related problems were solved.

In 2000 the filter in the liquid waste system was replaced to solve the blockage problem. In 2002 modifications of the weight sensing system and the odometer of the fuel handling machine were carried out.

The general review of the system failures revealed that majority of the problems were associated with the fuel handling machine seismic restraints. The much longer than average cask handling times during the commissioning phase and in 2002 were caused by this failure. Based on this information a review is going to be initiated to determine the possible modification on the seismic restraints to avoid this inconvenient, but not safety related, operational difficulty.

In spite of above detailed operational difficulties more than 3400 spent fuel assemblies were handled one by one and stored safely in the facility.

FUTURE PLANS

Taking into account the amount of the spent fuel assemblies that will be generated by the end of the anticipated lifetime of the Paks NPP, there will be a need for interim storage of at least 11,000 fuel assemblies. This actual number could be influenced by different factors like the applied fuel strategy in reactors or the possible life extension of the NPP.

As the selection of the existing dry storage technology was carried out more than 10 years ago, PURAM initiated a two-step re-selection process in 2000 for the further extension of the interim spent fuel storage capacity at Paks site. The aim of the new selection process was to make sure that the adopted technology is not just safe, but economical too. Based on preliminary evaluation of the available storage technologies an informal international tender was issued to look for possible alternative storage solutions. Evaluation of the different informal tenders showed that other concrete based storage technologies (either concrete casks or storage systems with horizontal spent fuel arrangement) could be economical alternatives to the existing MVDS technology. Then a new formal international tender was issued to make the final decision. It was highlighted in the invitation for the tender that the Hungarian manufacturing contribution would be an important factor. For this invitation just two proposals were received by PURAM. One of them was from the designer of the existing MVDS technology and the other one was for a concrete cask system.

Based on the evaluation of the tender information a decision was made in 2003 to continue the existing storage facility with the construction of a new five-vault module. It is expected to be in operation in 2007.

The preparation of necessary documents for the licensing of the further enlargement was started in September of 2003. Based on the existing operational experience and cost reducing changes, some technical modifications are proposed although the basis of the storage technology is going to be the same (MVDS). The proposed modifications can be summarized as follows:

- The rubber O-ring sealing of the storage tube lids will be replaced by double metallic seal rings.

- The storage tube seal integrity monitoring system, which was previously continuously supplied with nitrogen, will be simplified by coupling together the storage tube seal interspaces.
- The array of storage tubes in the charge face structure will be modified. Instead of the triangular pitch pattern the tubes will be arranged in a square pitch. This will enable each vault to contain 527 storage tubes instead of 450 within the same plan area
- Conditions for the storage of the inhermetic fuel assemblies and fuel assemblies from the research and training reactors will be assessed.

The revised license application is planned for submission to the Hungarian licensing authority in July 2004.