Operational Experiences and Future Plans for Hungarian Spent Fuel Storage - 11184

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ABSTRACT

Paks Nuclear Power Plant is the only commercial generating NPP in Hungary. It has four VVER-440 nuclear reactor units. Since 1989, the plant has provided almost half of the total electricity generated in the country. A Modular Vault Dry Store (MVDS) dry fuel storage facility started operations in 1997 to provide for interim storage of the spent fuel that is generated at the Paks site. The modular storage facility is being increased in storage capacity to match the spent fuel output from the nuclear power plant and its storage capacity is now able to store up to 7,200 individual spent fuel assemblies.

Construction work to further extend the Paks MVDS storage capacity by an additional 2,108 storage positions in a new storage vault module was started in 2010. Further enlargements to the storage facility are licensed to accommodate up to a total of 16,159 spent fuel assemblies in a total of 33 vaults.

With the first phase construction that was started 15 year ago, the storage facility is now half of the planned final size and has had different constructional and operational experiences to the newer extension modules.

The first implementation license was issued in the mid 1990's and this permitted the construction of the Transfer Cask Reception Building and the first four Storage Modules including 4,500 storage tubes for the VVER-440 fuel assemblies.

Further enlargement of the Paks MVDS needed a new licensing application. As the selection of the storage technology was carried out in early 1990's a two-step re-selection process was initiated in 2000. The aim 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 storage facility using the MVDS technology.

Based on the lessons learned from the operational experience and the above mentioned re-selection process some important modification were licensed for further enlargement

phases. One of them was to change the fuel storage tube closure system and the storage tube monitoring system. The other important modification was to increase the total storage capacity from 14,850 storage positions to 16,519 storage positions, which plays an important role in the ongoing plant life extension for the Paks NPP.

This paper gives an overview of the experience gained during fuel storage operations and modular extensions of the Paks MVDS from 1997 through 2010, detailing the operational results, difficulties and modifications made during this period. The experiences are compiled from the point of view of the licensee (PURAM), the operator (Paks NPP), the General Designer (SOM System) and the Main designer (GEC ALSTHOM, now Babcock International Group).

INTRODUCTION

Hungary is situated in Central Europe, part of the European Union since 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 is 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 the storage positions at the plant’s decay pool. In order to assure the continuous and reliable operation of the NPP, 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. Spent fuel assemblies generated during the operation of Budapest Research Reactor are stored at the site. As part of the nonproliferation program a large amount of the spent fuel from this reactor was shipped back to Russia in 2009. No spent fuel has been discharged from the training reactors that were commissioned 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

The Paks MVDS is illustrated on Figure 1. The store provides for at least 50 years of interim storage for VVER-440 fuel assemblies in a contained and shielded arrangement.

The bare 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 corrosion and degradation processes, the fuel assemblies are housed 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.

The Paks storage facility can be divided functionally 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 stage I and II vault are able to accommodate 450 fuel assemblies while the stage III vault modules can each accommodate 527 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 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 spent fuel assemblies are taken out from the reactor and are stored for a minimum of three years at the adjacent decay pool. The fuel assemblies are then transported to the MVDS from the at-reactor pool using the C-30 transfer cask and its railway wagon. The fuel assemblies are under water in the cask during the transportation.

The transfer cask is received in the TCRB where it is removed from the 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 individually 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 storage tube is connected to the built-in nitrogen system that monitors the storage environment of the spent fuel assemblies.

CONSTRUCTION AND EXTENSIONS

Due to its modular nature the Paks MVDS has been constructed according to the operational needs of the Paks NPP. The TCRB and the first three storage vaults (first module) were constructed in 1996. Commissioning of the store took place in 1997 by filling the first storage vault with 450 spent fuel assemblies.

The total capacity of fully extended ISFSI is currently planned to be 33 vaults. Due to developments of the nuclear fuel assemblies the total number of the spent fuel assemblies generated during the 30 years of the NPP lifetime is going to be decreased. Accordingly, the total number of the vaults needed to store the spent fuel reduces too. However, as part of the ongoing NPP life time extension program, spent fuel generation could continue for 20 more years, and that will make it necessary to use the total storage capacity or even to extend it further.

The complete construction of the storage facility is planned in three separate stages. The first stage covered the first three vault modules that accommodated a total of 4,950 storage positions in 11 vaults. This capacity was based upon the amount of the spent fuel arising from the four Paks reactors over an operating period of 10 years. Construction of the second and third vault modules, each with four storage vaults was finished in 1999 and 2002, respectively.

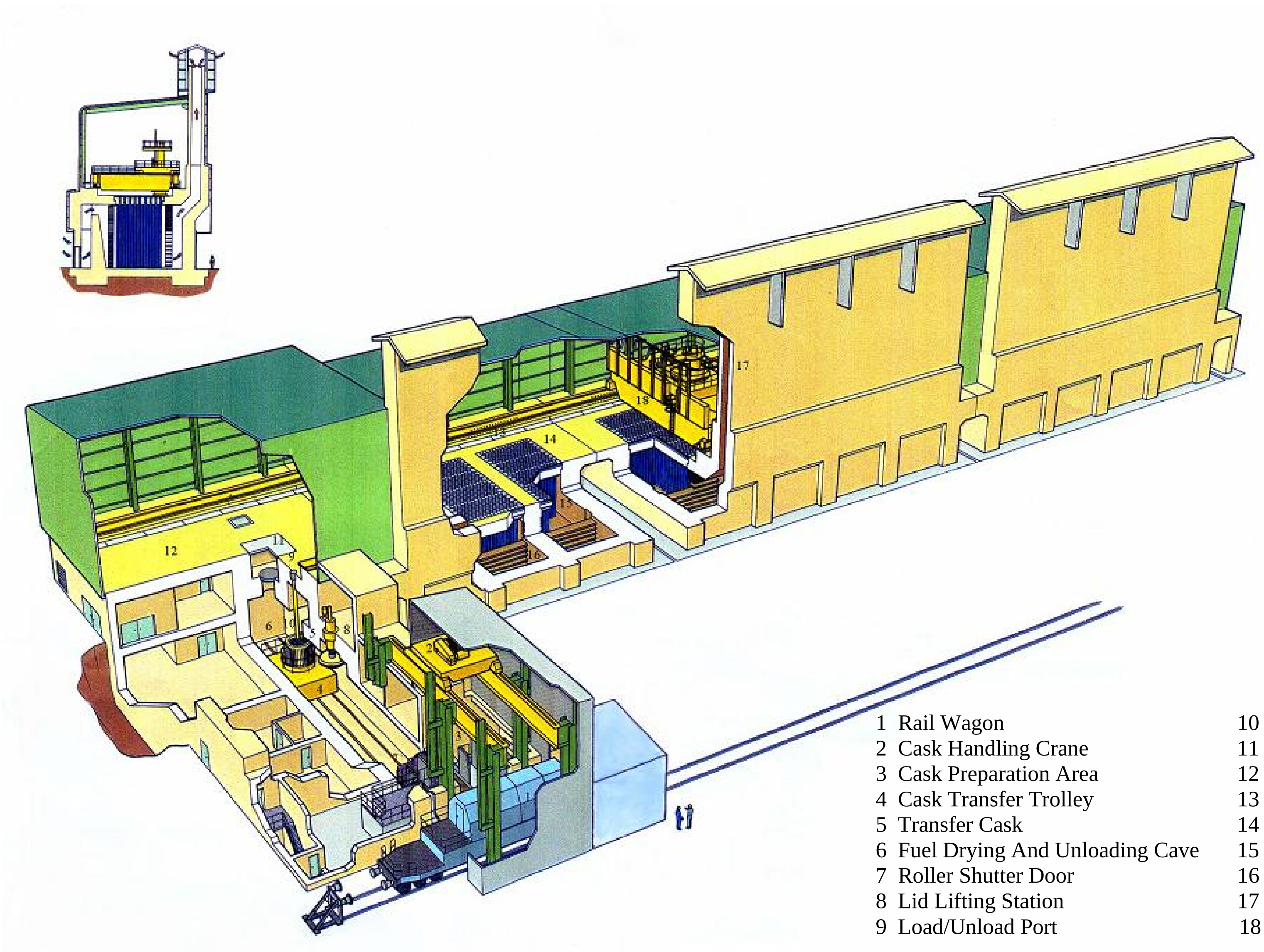
Having constructed the TCRB and the first 11 vault a new licensing process was necessary for the further enlargement in 2004. Based on the existing operational experience and cost reduction targets, with the cooperation of the original designer of the facility (Babcock International Group, Nuclear Division) some technical modifications were proposed, although the basis of the storage technology has not changed from MVDS. The modifications were:

- The elastomer O-ring sealing of the storage tube lids was replaced by double metallic seal rings.
- The storage tube seal integrity monitoring system, which was previously continuously supplied with nitrogen, was simplified by coupling together the storage tube seal interspaces.
- As part of the storage capacity enlargement the number of the storage positions in the vaults starting from the vault 17 are to be increased. Instead of a triangular pitch pattern the tubes are arranged in a square pitch. This enables each vault to contain 527 storage tubes instead of 450 within the same plan area. With this modification the total storage capacity of the 33 vault ISFSI will increase from the original 14,850 storage positions to 16,159 fuel assemblies.

Replacement of the elastomer O-ring seals with metallic seal rings in the stage II and stage III modules eliminates the need to replace 11,209 pairs of seals at least once during the design life of 50 years of interim storage, as the lifetime of the elastomer seal rings are limited to 25 years. It also eliminates the need to conduct a regular monitoring of the seal degradation and lifetime surveillance program. Thus the metallic seal ring modification provides significant reduction in operational costs.

The implementation license was issued by the Hungarian Atomic Energy Authority. The construction of the Stage II vault module (vaults 12-16) was finished by 2007.

As of 2010 sixteen storage vaults are now in operation. In 2009 construction of a new module including the vaults 17-20 was started. Further extensions will be commenced in accordance with the NPP spent fuel generation which is roughly 360 spent fuel assemblies each year.



1 Rail Wagon
2 Cask Handling Crane
3 Cask Preparation Area
4 Cask Transfer Trolley
5 Transfer Cask
6 Fuel Drying And Unloading Cave
7 Roller Shutter Door
8 Lid Lifting Station
9 Load/Unload Port
10 Fuel drying tube
11 Maintenance Hatch
12 Charge Hall
13 Fuel Handling Machine Rail
14 Vault Modules
15 Storage Tubes
16 Collimators
17 Stack
18 Fuel Handling Machine

Fig. 1. Paks MVDS

OPERATION OF THE PAKS MVDS

The first license to operate the Paks MVDS was issued to the operator of the Paks NPP as the owner and licensee of the new IFSFI.

According to the modified Hungarian Atomic Energy Act that became effective parallel with the original commissioning of the ISFSI, a new agency called Public Agency for Radioactive Waste Management (PURAM) was established in 1998.

PURAM was designated to manage Hungary's radioactive wastes, including the interim storage of spent nuclear fuel. A multi-step take-over process was started following the establishment of PURAM.

In spite of the takeover of responsibility by PURAM, the NPP still has duties to perform at the facility. The NPP staff operate the ISFSI in a contractual arrangement with PURAM.

By the end of 2010 altogether 6,546 spent fuel assemblies are stored in the Paks MVDS.

RADIOLOGICAL CONDITIONS AND RELEASES

Radiation source terms of the Paks MVDS can be divided into the following groups:

- direct and scattered radiation from spent fuel assemblies
- release of crud
- release of cask water

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

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

The doses arising from the airborne releases and effluent are summarized in the Table 1. The dose restriction for the Paks MVDS is 10 microSv/year (1mRem/year) for the off-site doses.

In the environment there was no measurable 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.

The individual and collective doses of workers are shown in the Table 2.

The higher value in 2002 was partly due to the increased crud level on the fuel handling machine primary filter. A continuous activity monitor was subsequently installed on the filter to reduce the high dose rate from the filter exchange activity.

The collective dose from 2003 shows a significant increase compared to the values corresponding to the first operational years of the Paks MVDS. This increase is due to the increased crud amount on the fuel assemblies and the accident that happened in 2003 at the NPP. The accident occurred at unit 2, when thirty irradiated fuel assemblies were damaged during a cleaning process. The fuel assemblies were not inside the reactor, but in a separate tank within the adjacent fuel decay pool. As a result of this accident, contamination from the badly damaged fuel assemblies spread to the decay pool water and also became deposited onto the surface of spent fuel assemblies within the decay pool.

Table 1, Used percentage of the dose restriction

Year	Effluents		Airborne releases		Summary	
	nSv	%	nSv	%	nSv	%
1998	0.11	0.0011	0.12	0.0012	0.23	0.0023
1999	0.04	0.0004	0.06	0.0006	0.10	0.0010
2000	0.17	0.0017	0.10	0.0010	0.27	0.0027
2001	0.10	0.0010	0.11	0.0011	0.21	0.0021
2002	0.14	0.0014	0.08	0.0008	0.22	0.0022
2003	0.08	0.0008	0.09	0.0009	0.17	0.0017
2004	0.05	0.0005	0.07	0.0007	0.12	0.0012
2005	0.13	0.0013	0.20	0.0020	0.33	0.0033
2006	0.54	0.0054	0.44	0.0044	0.98	0.0098
2007	0.28	0.0028	0.68	0.0068	0.96	0.0096
2008	0.93	0.0093	1.84	0.0184	2.77	0.0277
2009	0.90	0.0090	1.38	0.0138	2.28	0.0228

Table 2, Radiation exposure of workers

Year	No. of loaded fuel assembly	Number of entries oper./main. (person)	Collective dose (man* mSv)+	Average individual dose (mSv)	Highest individual dose (mSv)
2000	500	834/253	2.4(1.0/1.4)	0.002	0.071
2001	750	1113/262	2.1(1.4/0.7)	0.002	0.035
2002	420	804/433	8.6(5.6/3.0)	0.007	0.582
2003	480	775/236	6.3(5.1/1.2)	0.006	0.849
2004	270	724/644	3.7(1.0/2.7)	0.003	0.168
2005	500	1103/343	6.3(1.8/4.5)	0.004	0.298
2006	480	1120/432	7.6(2.8/4.8)	0.005	0.198
2007	360	950/447	6.6(3.1/3.5)	0.005	0.203
2008	480	1385/249	9.6(7.1/2.5)	0.006	0.220
2009	480	1412/322	8.3(5.1/3.2)	0.005	0.260

+Operation/Maintenance contribution

On the basis of the design assessments and measurement of the results during the fuel transfer operations, it was shown that radiological activity values increased as a consequence but these levels did not compromise the release and dose limits for the fuel storage facility.

Due to the increased surface contamination on the spent fuel assemblies the off-site dose rate increased almost 27 times compared to the least annual value, but still less than 0.03 percent of the allowed dose restriction.

OPERATIONAL EXPERIENCE

During the 13 years of operation of the facility there have been only a few technical difficulties. Since 2003 the increased level of the crud on the fuel assemblies transferred from the reactors results in more frequent HEPA filter exchange in the Transfer Cask Reception Building ventilation system. The doses of the workers and the off-site doses are increased, too.

In spite of this difficulty the evaluations of the operation through the radiation protection program show good results. Both the radiation releases and the personal exposures are still low compared to the radiation protection limits (as shown by the percentage values).

The periodical review of the operational experiences and a 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 a fan belt in the ventilation system

Accordingly, 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 was carried out.

The general review of the system failures revealed in 2004 that the majority of the problem was associated with the fuel handling machine seismic restraints. The drives of the system were redesigned and replaced in 2006-2007.

In 2008 a new inflatable seal was developed by a new manufacturer to replace the seal at the spent fuel drying system. The new seals operate according to the design intent.

In 2009 a periodic review revealed that the environment of the Fuel Storage Tubes in the vaults 1-11 contain a slightly increased level of oxygen and water compared to specified values in the Technical Specification. As part of the review it was identified that the Technical Specification values were derived only taking into consideration the oxygen and water content of the gas bottles used to provide the nitrogen storage environment.

An extensive measurement and evaluation program has been initiated. As from the preliminary results it can be seen that the oxygen and water content values are still low, and do not increase to an unacceptable level. The oxygen content is 10-20 ppm, while the water content is 1,000-5,000 ppm. Further measurement and evaluation are in progress to redefine more accurate Technical Specification values.

In spite of above detailed operational difficulties more than 6,500 spent fuel assemblies were handled one by one and stored safely in the facility.

SURVEILLANCE PROGRAMS

During operation of the Paks MVDS three major periodical examinations have been performed. One is for the fuel storage tubes material behaviour. The other two are connected with the leak tightness of the storage tubes. These surveillance programs are performed in order to check the corrosion mechanism of the fuel storage tubes, to predict the fatigue life of the elastomer sealing rings of the fuel storage tube installed with such seals, and the leak tightness of the storage tube equipped with metal seals.

Corrosion coupon examinations

In order to examine the corrosion mechanisms of the fuel storage tubes strings of corrosion coupons are located in the storage vaults. The corrosion coupons are samples cut out of material of the fuel storage tubes and are sprayed with an aluminium coating the same as that used at the fuel storage tubes. The strings penetrate into the air-space of the vault via the charge face steel structure.. Consequently the corrosion coupons are installed into the same environment as the fuel storage tubes and are subject to the same environmental effects as the fuel storage tubes.

The corrosion coupons are subject to a visual inspection and a metallographic examination. The examination period is five years after filling-up of each vault. The visual inspection and the metallographic examination confirm that the containment function of the fuel storage tube is not endangered by unexpected or unpredictable external corrosion mechanisms.

After commissioning of the Modular Vault Dry Storage (MVDS) in 1997 the first inspection of the corrosion coupons was performed in 2003. On the basis of the continuous enlargement of the facility and loading rate of the vaults, a corrosion coupon inspection was performed in every year starting from the year of 2003. For the corrosion coupons of the vaults previously already examined a repeated examination was performed during the period of 2007 - 2009. Accordingly 11 pairs out of the 22 total pairs of corrosion coupons have been inspected up to now in the facility.

The results of the examinations that have been performed up to now show that condition of the metalized coating of the corrosion coupons is acceptable, no deteriorating effect of corrosion processes can be detected, and the adhesion layer thickness and surface appearance of the coating comply with the requirements. A continuous transition between the coating layer and the base metal is demonstrated by micro examinations.

Shield plug elastomer seals examinations

The fuel storage tube shield plugs are located within the head of the fuel storage tubes. At the vaults 1-16 closure of the fuel storage tubes are provided by the deadweight of the shield plugs. Leak tightness of the fuel storage tubes is ensured by two elastomer seals on the shield plug. The design lifetime of the elastomer seal of the fuel storage tube is 25 years. Consequently a seal replacement has to be performed at least once at all fuel storage tubes having elastomer seals during the planned 50-years lifetime of the Paks MVDS.

Fatigue of the elastomer seal of the fuel storage tube shield plug arises from reduction of its elasticity caused by effects of temperature changes, humidity and radiation. If its value does not meet the acceptability limit value then it indicates a significant decrease in effectiveness of the seal. The examination period of the elastomer seals is five years after loading of the vault.

The first inspection for elastomer seals of the shield plug was performed in 2003. Considering the continuous enlargement of the storage facility and the loading rate of the vaults, a program of elastomer seals elasticity reduction inspection has to be performed in every year starting from the year 2003. For elastomer seals of the vaults previously examined a repeated examination was performed during the period 2007-2009. The inspection program examines the elastomer seals of eight shield plugs per vault. More than 190 elastomer seals have been inspected up to now within the seal inspection program.

According to the experience gained during the examinations that have been performed so far it can be concluded that the lifetime of the elastomer seals will comply with the design intent.

Shield plug elastomer seals examinations

Starting from Stage II (vault 12) of the facility the fuel storage tubes are equipped with dual metal seal instead of the elastomer seals. The fuel storage tube is closed by a bolted connection. Spaces between the dual seals of the fuel storage tubes are connected into groups. This solution increases the sealing integrity and makes it unnecessary to replace the seal every 25 years contrary to the elastomer sealing rings where it is necessary.

The connected pressure volume of the metal sealed fuel storage tubes is continuously monitored by a pressure monitoring system. In the period after commissioning of the system the pressure in inter-stage spaces of some of the fuel storage tubes decreased to an extent slightly greater than the planned one. After detecting the cause of the leakage and repairing it there is now no excessive leakage indicated, showing that the system is performing correctly.

FUTURE PLANS

Prior to the relicensing in the mid of 2000s PURAM initiated a two-step re-selection process 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 a 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 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 (vault 12-16) in accordance with original plan to extend the Paks MVDS. The ongoing construction of the module including the vaults 17-20 is expected to be in operation by the end of 2011.

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

Further extensions to the storage facility are planned according to the operational needs of the Paks NPP. The total licensed capacity of the fully extended ISFSI is currently 33 vaults. However, due to the ongoing NPP life time extension program further vault constructions could be necessary up to 37 vaults.