# LEAK TESTING OF WWER-440 FUEL ASSEMBLIES IN SLOVAK WET INTERIM SPENT FUEL STORAGE FACILITY

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## ABSTRACT

Nuclear fuel tightness is one of the most important things to keep the operational safety on high level. Untight fuel causes frequent operational layoffs, which are not advantageous for NPPs, and operation with such fuel increase the possibility of fission product release to the environment. Hence, it is very important to monitor fuel elements condition. An accelerated monitoring system designed for the Slovak wet interim spent fuel storage facility in NPP Jaslovské Bohunice based on the new designed "cesium detectors" is presented in the paper. Since 1999, leak tests of WWER-440 fuel assemblies are provided by special leak tightness detection system "Sipping in Pool" delivered by Framatome-anp with external heating for the precise defects determination. Although, this system seems to be very effective, the detection time of all fuel assemblies in one storage pool is too long. Therefore, a new "on-line" detection system, based on new sorbent NIFSIL for effective cesium activity was developed. Design of this detection system and its application possibility in Slovak wet interim spent fuel storage facility as well as the first results are presented.

## 1. INTODUCTION

The best way how to keep the fission products inside the fuel elements and to keep the environment safe is the high leak tightness of fuel elements. Hence, it is really important to make this cladding resistant towards many influences, which have negative effects on their damage. The leak tightness of fuel cladding plays important role in the reactor operational safety, fuel transportation and also in storage of burnt nuclear fuel [1, 2]. Therefore, the serious research of these materials is necessary. There exist several systems for the proper monitoring of leak tightness of fuel assemblies. The use of them is mostly for the monitoring at reactor.

In Slovak NPP's conditions, the Siemens-KWU "Sipping in core system" is used since 1986 [3]. The interim spent fuel storage facility in NPP Jaslovské Bohunice is a wet kind of interim storage facility, which use 3 pools for the storage of in total 14 112 fuel elements for 50 years (at this time only a half of the capacity is used). For monitoring of the fuel cladding leak tightness the "Sipping in pool" system with external heating was implemented in 1999.

The detection ability of leakages in fuel cladding by the "Sipping in pool" system is excellent, but it took too much time. Although, testing of one fuel assembly takes of about 30 minutes only, there was not any possibility how to identify were the leaking fuel assembly was located in the storage pool. So the time for finding one of fuel assembly with leaking element between of about 5000 in the pool, where the increased water activity was identified, could takes many months of testing. Thence, a faster pre-selection system was developed. This detection system use a special sorbent called NIFSIL, which has high effective cross-section for cesium capture. The advantages of these detection system based on gamma-activity measurement of NIFSIL are its easy and cheap manufacturing, easy and quick manipulation with samples handling, accessibility of NIFSIL holders to all places in the storage pool as well as clear and fast evaluation process.

## 2. FUEL CLADDING MONITORING AT SLOVAK WET INTERIM SPENT FUEL STORAGE FACILITY

It is necessary to keep the concentration of fission products in storage pools on the low level for assurance of acceptable activity of the coolant. This can be done with periodical monitoring of the fuel elements condition, leakages identification and closing of leaking elements in special hermetic caskets. That was the main reason for including not only "*Sipping in pool*" (Fig.1) system, but also the just presented monitoring system based on NIFSIL sorbent to the fuel control system at the Slovak burnt fuel interim storage in Jaslovské Bohunice [4].

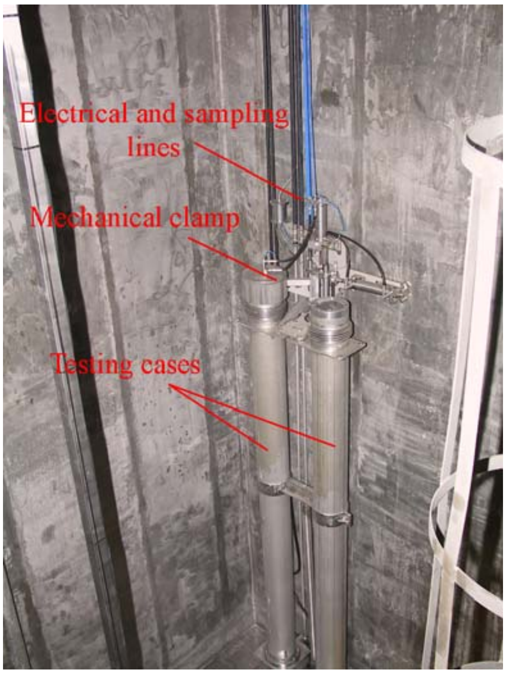

Fig 1. Sipping in pool

System "Sipping in pool" was designed by Framatome-anp for monitoring of the spent fuel from WWER-440 reactors. The fuel assembly was inserted into the special casket, which was electrical heated by three electrical heaters (5kW). After closing of the upper end of the casket, the temperature inside increases. If there are any leakages, they start to open themselves due to a higher temperature and the fission product will flow out from the element. Then, the wet sample from the casket is taken and evaluated. The sample is analyzed by gamma spectroscopy (the most important nuclides are $^{134}Cs$ and $^{137}Cs$). If this test proves that there are any leakages on the fuel element cladding, the defected fuel assembly is closed into a special hermetic casket (T-13).

## 3. ACCELERATION OF DEFECTS IDENTIFICATION OF WWER-440 FUEL AT THE WET INTERIM SPENT FUEL STORAGE FACILITY

For the acceleration of defects identification a quicker detection system was designed. The pre-selection of high probably defect fuel assembly is connected to the symmetrical distribution of NIFSIL holders in spent fuel storage pools. NIFSIL is a new type of composite sorbent based on potassium nickel ferrocyanide incorporated in silica gel matrix (prepared by sol-gel method) and it is indissoluble in water [5]. It is made in spherical shape with diameter 0,5 - 1 mm. The sorption capacity for cesium corresponds to the total amount of ferrocyanide in the sorbent. The dependence of $K_d$ (distribution coefficient) at the initial cesium concentration $5.10^{-4}$M on the amount of ferrocyanide in composite sorbent is almost linear (Fig.2).

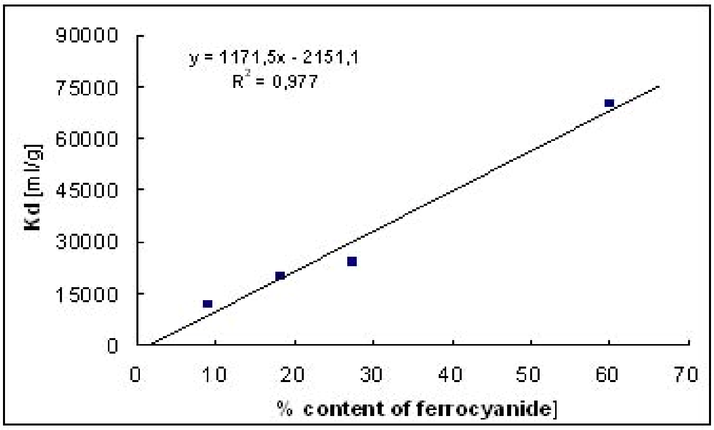


Fig 2. The distribution coefficient $K_d$ of cesium vs. total amount of ferrocyanide in sorbent

The experiments from 2005 (Figure 3, Table 1) showed that NISFIL is great sorbent for cesium ($^{134}Cs$, $^{137}Cs$). Three types of samples were taken:
OV57 – water sample from primary circuit of NPP V-1 in Jaslovské Bohunice,
OV57R – diluted water sample from primary circuit (NPP-SE EBO) in rate 1:5,
OV77 – water sample from wet interim spent fuel storage facility (pool 116/1).

Five measurements were made:
1 – water samples (OV57, OV57R, OV77) without NIFSIL. After these reference measurement NISFIL was filled into water samples,
2 – water samples with NIFSIL, measured after 3 days,
3 – water samples with NIFSIL, measured after next 7 days,
4 – only NIFSIL, measured after next 12 days,
5 – only water sample, measured after next 24 days.

Volume activity $A_v$[kBq/l] of all types of nuclides were spotted, but only $^{134}Cs$ and $^{137}Cs$ have had the highest values.

| Volume activity $A_v$[kBq/l] in 5 measurement conditions | | | | | |
|---|---|---|---|---|---|
| **Nuclides** | **1** | **2** | **3** | **4** | **5** |
| Mn-54 | 16 | 13 | 10 | 2 290 | 10 |
| Co-58 | 14 | 10 | 5 | 3 467 | 2 |
| Co-60 | 3 | 2 | 1 | 765 | 0 |
| Ag-110m | 4 | 3 | 1 | 1 080 | 0 |
| Cs-134 | 100 | 49 | 13 | **26 626** | 9 |
| Cs-137 | 129 | 63 | 17 | **36 088** | 12 |

Tab 1: Volume activities $A_v$[kBq/l] of OV77 sample

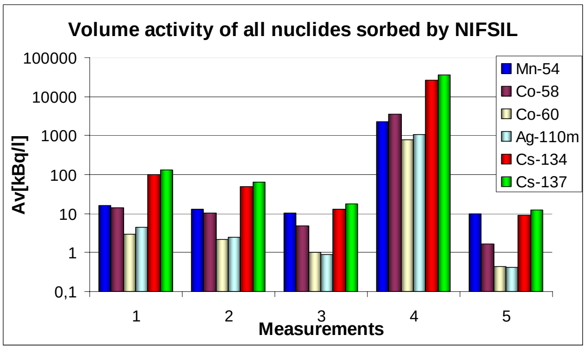


Fig 3. Volume activities of OV77 sample

The highest values are in fourth measurement. It means that NIFSIL is a great sorbent for fission products. It absorbs not only cesium isotopes, but also the other nuclides.
The NIFSIL holders have cylindrical shape, so it can be placed right on the head of storage containers in the pools. Both used storage containers T-12 (the old one) and KZ-48 (the new one) have the same head, so the "cesium detector" is compatible. It consists of four main parts (Figure 4):
**Bayonet catch** – for manipulating with detector under water,
**Body** – for the detector placement on the head of storage container (Figure 5),
**Two strainers** – for NIFSIL deposition,
**Bayonet safety-pin** – for safety gripping.

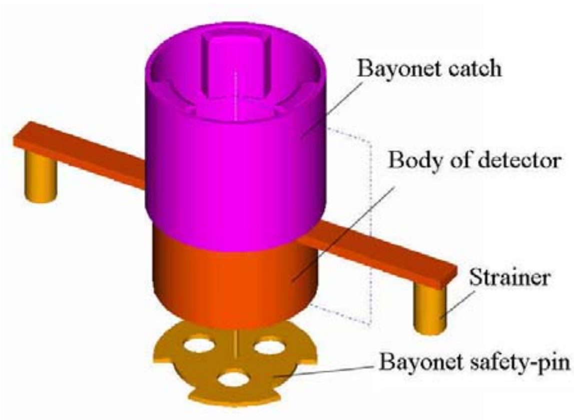


Fig 4. Cesium detector holder

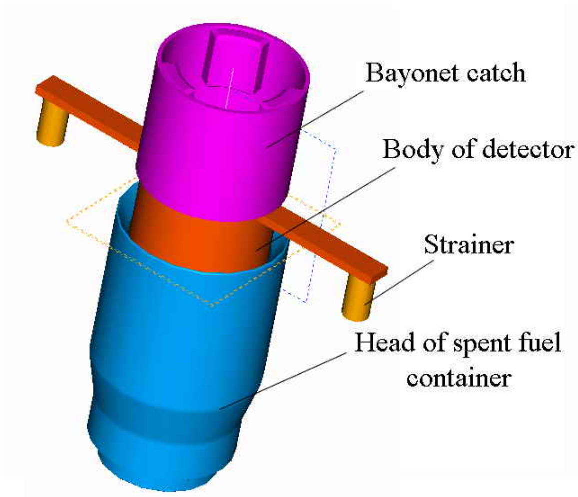


Fig 5. Detector shoulder on the head of storage container

The strainers are placed on the head of detector under 180° angle and the holes diameter is 0,25 – 0,5 mm. Detectors are made from stainless steel. If the activity of nuclides (mostly $^{134}Cs$ and $^{137}Cs$), measured on-line in the pools, exceeds the nominal rate, the pools are closed and wet sample from each pool separately is taken. Evaluation using precise gamma spectroscopy will show us, which pool has the highest activity (in that pool is also the highest probability of leaking fuel element). Then Cs detectors are inserted to the pool and gripped on every storage container. After few days are detectors taken out and send to the radiochemical laboratory for evaluation by gamma spectroscopy. Evaluation will show us the place (eventually the storage container), where the highest activity of cesium occurred (Figure 6). So we can high probably find the container, which contains damage fuel element (assembly). This storage container is sending for the sipping control by system "Sipping in Pool", where the damage assembly will be found. Then is the damage fuel assembly hermetic stored in the special storage container T-13.

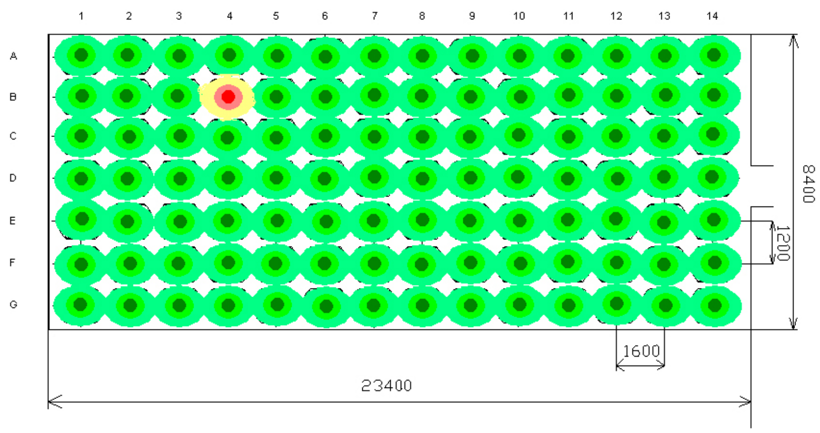


Fig 6. Actual distribution of storage container KZ-48 with 4704 fuel assemblies in pool.

## 4. CONCLUSION

From the nuclear safety point of view, it is necessary to keep the fission products inside the fuel elements and to prevent their escape into environment not only during reactor operation or fuel transport, but also during the long term storage of burnt nuclear fuel. Therefore, the effective leak tightness monitoring system at all fuel interim storages is necessary. The designed system from 80-ies at the Slovak wet interim storage facility didn't assure this task at the desired level, so the system "Sipping in Pool" was implemented in 1999. After several years of its operation, performed measurements showed, that this system is high effective equipment for fuel cladding defects detection. However, the time for defects finding could be too long. "On-line" detection system for determine the water activity, which was proposed, provides us with possibility to accelerate identification of most probably place of damaged fuel elements. Measurements with NIFSIL showed that it is great absorber for cesium and other important nuclides. Therefore, it was chosen as the main component for this detection system. Optimal use of "On-line" detection system needs to construct it and to test it in practice.

## 5. REFERENCES


[1] IAEA: *Long term storage of spent nuclear fuel – Survey and recommendations*, Final report of the Coordinated research project (1994 – 1997), May 2002.

[2] IAEA: *Storage of spent fuel from power reactors*, Proceedings from International Conference, 2-6 June 2003 in Vienna.
[3] Slugeň V., Smieško I.: *Atomwirtschaft-Atomtechnik* 38, 1993, p.375-378 (in German).
[4] Mikloš M.: *Monitoring of the fuel elements condition in a burnt fuel interim storage at the NPP SE-EBO*, Diploma thesis, FEI STU, 2005 (in Slovak).
[5] Rajec P., Orechovská J., Novák I.: *Nifsil a new composite sorbent for cesium*, January. 1999, Journal of Radioanalytical and Nuclear Chemistry , Vol.245, No.2 (2000) 317-321.