Monitoring and Leak testig of wwer-440 fuel assemblies in Slovak wet interim spent fuel storage facility

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Monitorovanie a únik testovanej WWER – 440 látky namočenej do vyčerpaného paliva zo skladu sústredenom na Slovensku

An accelerated monitoring system designed for the Slovak wet interim spent fuel storage facility in NPP Jaslovské Bohunice bases on the newly designed "cesium detectors" is presented in the paper. Since 1999, leak tests of WWER-440 fuel assemblies are provided by a special leak tightness detection system "Sipping in Pool" delivered by the 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 the new sorbent NIFSIL for an effective ^{134}Cs and ^{137}Cs activity was developed. The design of this detection system and its application possibility in Slovak wet interim spent fuel storage facility as well as preliminary results are presented.

Key words*: cesium detectors, Sipping in Pool, sorbent NIFSIL*

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 an important role in the reactor operational safety, fuel transportation and also in the storage of burnt nuclear fuel [1, 2]. Therefore, a serious research of these materials is necessary. Several systems for the proper monitoring of leak tightness of fuel assemblies exist. They are used mostly for monitoring in a reactor. In Slovak conditions, the Siemens-KWU "Sipping in core system" is used since 1986 [3].

The interim spent fuel storage facility in the NPP Jaslovské Bohunice is a wet kind of interim storage facility, which use 3 pools for the storage of 14 112 fuel elements in total 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 the fuel cladding by the "Sipping in pool" system is excellent, but it takes a lot of time. Although, the testing of one fuel assembly takes of about 30 minutes only, there was no possibility how to identify the location of leaking fuel assembly in the storage pool. So, the time for finding one of the fuel assembly with a leaking element between about 5000 in the pool, where the increased water activity was identified, would take many months of testing. Hence, a faster pre-selection system was developed. This detection system uses a special sorbent called NIFSIL, which has a high effective cross-section for ^{134}Cs and ^{137}Cs capture. An advantage of the system, based on the gamma-activity measurement of NIFSIL the 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 the clear and fast evaluation process.

The Monitoring of fuel cladding leak tightness at the Slovak wet interim spent fuel storage facility

It is necessary to keep the concentration of fission products in storage pools at a low level for assuring of acceptable activity of the coolant. This can be done with a 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 the "*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].

The system "Sipping in pool" was designed by the Framatome-anp for monitoring the spent fuel from the WWER-440 reactors. The fuel assembly was inserted into a special casket, which was electrical heated by three electrical heaters (5MW). After closing 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

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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).

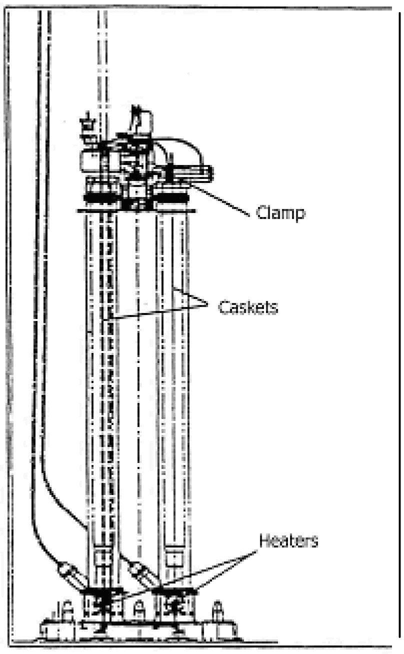


Fig. 1. Sipping in pool.

Aacceleration of defects identification of wwer-440 fuel at the wet interim spent fuel storage facility using "ON-LINE" detection

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 and it is insoluble in water [5]. It is made with a spherical shape and 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 the composite sorbent is almost linear (Fig. 2).

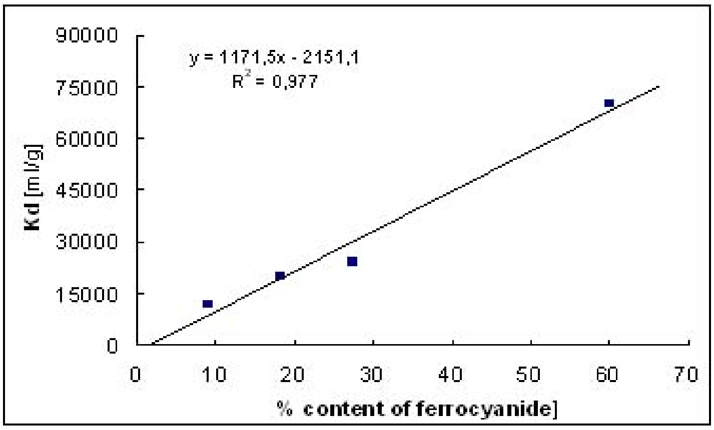


Fig. 2. Distribution coefficient K_d of cesium vs. the total amount of ferrocyanide in the sorbent

The experiments in 2005 (Figs. 3-5, Tables 1-3) showed that NISFIL is a great sorbent for cesium (^{134}Cs, ^{137}Cs). Three types of samples were taken:
OV57 – water sample from the primary circuit of NPP V-1 in Jaslovské Bohunice,
OV57R – diluted water sample from the primary circuit (NPP-SE EBO) in the 1:5 ratio,
OV77 – water sample from the wet interim spent fuel storage facility (pool 116/1).
Five measurements were made:
1 – water samples (OV57, OV57R, OV77) without NIFSIL. After these reference measurements 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.

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

Tab. 1 Volume activities A_v[kBq/l] of the OV57 sample.

Volume activity A_v [kBq/l] 5 measurement conditions					
Nuclides	1	2	3	4	5
Co-58	41	2	1	167	1
I-131	102	95	88	398	89
Cs-134	184	146	44	54 463	21
Cs-137	210	180	53	65 500	24

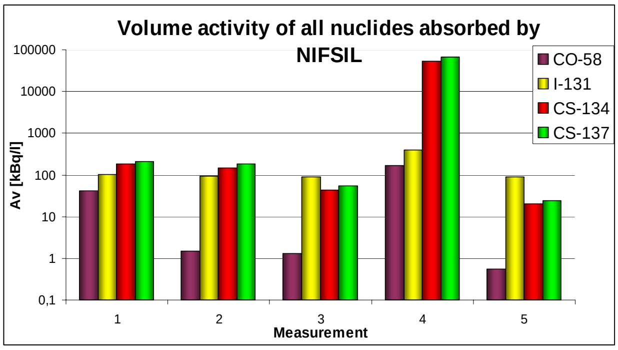


Fig. 3. Volume activities of the OV57 sample.

Tab. 2. Volume activities A_v [kBq/l] of the OV57R sample.

Volume activity A_v[kBq/l] 5 measurement conditions					
Nuclides	1	2	3	4	5
Co-58	13	1	1	44	0
Co-60	2	1	2	14	0
Nb-95	7	1	1	18	0
I-131	15	14	13	32	15
Cs-134	26	16	12	6 489	9
Cs-137	31	21	14	7 845	10

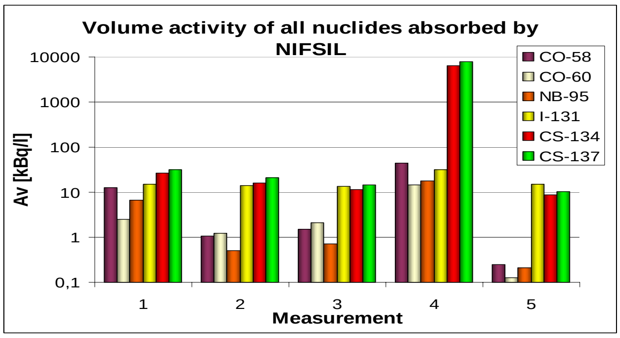


Fig. 4. Volume activities of the OV57R sample.

The highest values are in fourth measurement. It means that NIFSIL absorbs not only cesium isotopes, but also other nuclides.

Tab. 3. Volume activities A_v[kBq/l] of the OV77 sample.

Volume activity A_v[kBq/l] 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

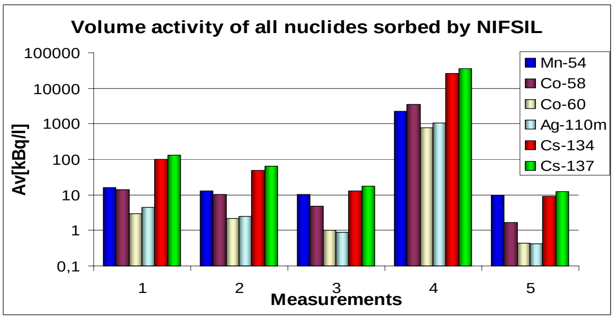


Fig. 5. Volume activities of the OV77 sample.

The NIFSIL holders have a 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 that the "cesium detector" is compatible. It consists of four main parts (Fig. 6):

- **Bayonet catch** – for manipulating with the detector under water,
- **Body** – for the detector placement on the head of storage container (Fig. 7),
- **Two strainers** – for the NIFSIL deposition,
- **Bayonet safety-pin** – for the safety gripping.

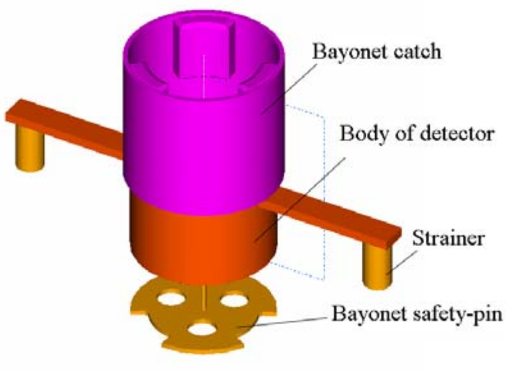
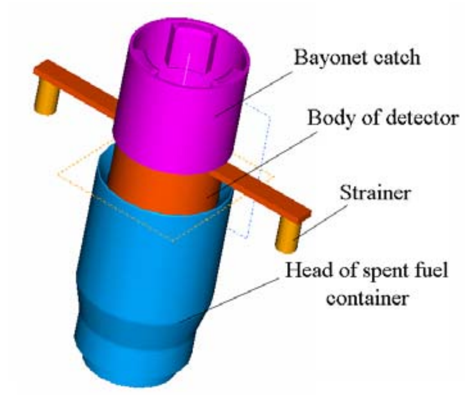


Fig. 6. Cesium detector holder .



The strainers are placed on the head of detector under 120° angle and the holes diameter is 0,25 – 0,5 mm the detectors are made from stainless steel.

Fig. 7. Detector shoulder on the head of storage container.

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 is taken separately. The evaluation by 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, detectors are taken out and send to the radiochemical laboratory for an evaluation by gamma spectroscopy. The evaluation will show us the place (eventually the storage container), where the highest activity of cesium occurred (Figs. 8, 9). So, we can at a high probably find a container, which contains the damage fuel element (assembly). This storage container is send for the sipping control by system "Sipping in Pool", where the damage assembly will be found. Then, the damage fuel assembly is hermetically stored in a special storage container T-13.

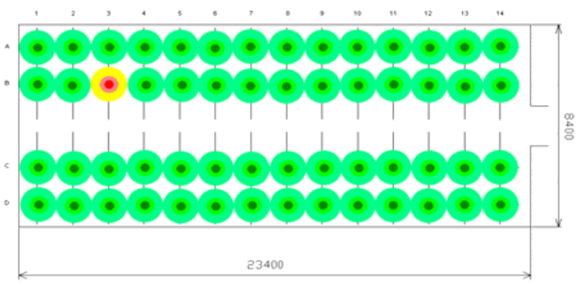


Fig. 8. Former distribution of storage containers T-12 with 1680 fuel assemblies in pool.

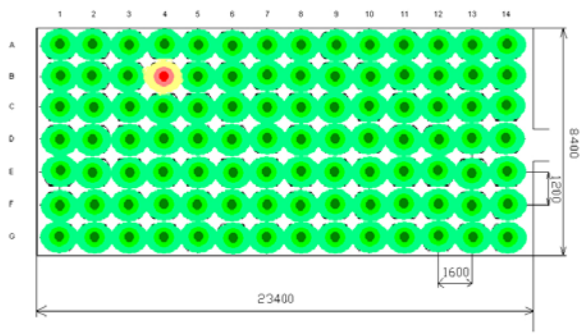


Fig. 9. Actual distribution of storage container KZ-48 with 4704 fuel assemblies in the pool.

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 the environment not only during the 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 a high effective equipment for the fuel cladding defects detection. However, the time for finding the defects could be too long. The "On-line" detection system for determining the water activity, which was proposed, provides us with a possibility to accelerate the identification of a most probable place of the damaged fuel elements. Measurements with NIFSIL showed that it is a great absorber for cesium and other important nuclides. Therefore, it was chosen as the main component for this detection system. An optimal use of the "On-line" detection system requires to construct and test it in practical contious.

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