Improving of spent fuel monitoring in condition of Slovak wet interim spent fuel storage facility

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Abstract

Monitoring of VVER fuel assemblies condition in Slovakia is presented in the paper. The leak tightness results of fuel assemblies used in Slovak VVER units in last 20 years are presented analyzed. Good experiences with the “Sipping system” are described.

The Slovak wet interim spent fuel storage facility in NPP Jaslovské Bohunice was build and put in operation in 1986. Since 1999, leak tests of WWER-440 fuel assemblies are provided by special leak tightness detection system “Sipping in Pool” delivered by Framatome-anp facility with external heating for the precise detection of active specimens. Another system for monitoring of fuel assemblies condition was implemented in December 2006 under the name “SVYPP-440”. First non-active tests started at February 2007 and are described in the paper.

Although those systems seems to be very effective, the detection time of all fuel assemblies in one storage pool is too long (several months). Therefore, a new “on-line” detection system, based on new sorbent KNiFC-PAN for effective ^{134}Cs and ^{137}Cs activity was developed. This sorbent was compared with another type of sorbent NIFSIL and results are presented in the paper. The design of this detection system and its possible application in the Slovak wet spent fuel storage facility is discussed in this paper. For completeness, the initial results of the new system are also presented.

Keywords:

Fuel assemblies condition, Spent fuel storage, Fission product release, Safety operation, Sipping control, WWER-440 fuel

1. Introduction

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 during spent fuel storage [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 [3-6]. The use of them is mostly for the monitoring at reactor. In Slovak conditions, the Siemens-KWU “Sipping in core system” is used since 1986. This system showed very good results in monitoring of the fuel assemblies condition and for the NPP’s in Slovakia is the best monitoring system at the reactor.

For the storage facility, another monitoring systems are in use. Slovakia has only one interim spent fuel storage facility for high radioactive waste. It is placed near NPP in Jaslovské Bohunice as a wet kind of interim storage facility, which use 4 pools (3 active pools, 1 passive pool) for the storage of in total 14 112 fuel elements for 50 years (at this time only a half of the capacity is used) [1, 2].

2. Spent fuel condition monitoring at the 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 assemblies condition, leakages identification and closing of leaking assemblies in special hermetic containers. This is the main reason for including several monitoring systems at the Slovak spent fuel interim storage in Jaslovské Bohunice.

First system "Sipping in pool" (Fig.1) was designed by Framatome-anp for monitoring of the spent fuel from VVER-440 reactors. It was build and implemented to the special small pool at storage facility in 1999 and practice showed great results during measuring. This system contain from 4 main parts:

- 2 electrical heated cylindrical caskets,
- mechanical clamp,
- electrical and sampling lines,
- controlling and bleeding panel.

The fuel assembly is inserting into the special case which is electrical heated by three electrical heaters (5kW). After closing of the upper end of the case by the clamp, the temperature inside increase. If there are any leakages, they start to open themselves due to thermal expansion and the fission product escapes out from the element. Also because of increasing the temperature the pressure inside assembly increase too, so the fission products are treading out through even small leakages. Then, the liquid sample from the case is taken and evaluated. The sample is analyzed by gamma spectroscopy (Table1). If this test proves that there are any leakages on the fuel element cladding, the defected fuel assembly is closed into a special hermetic container (T-13).

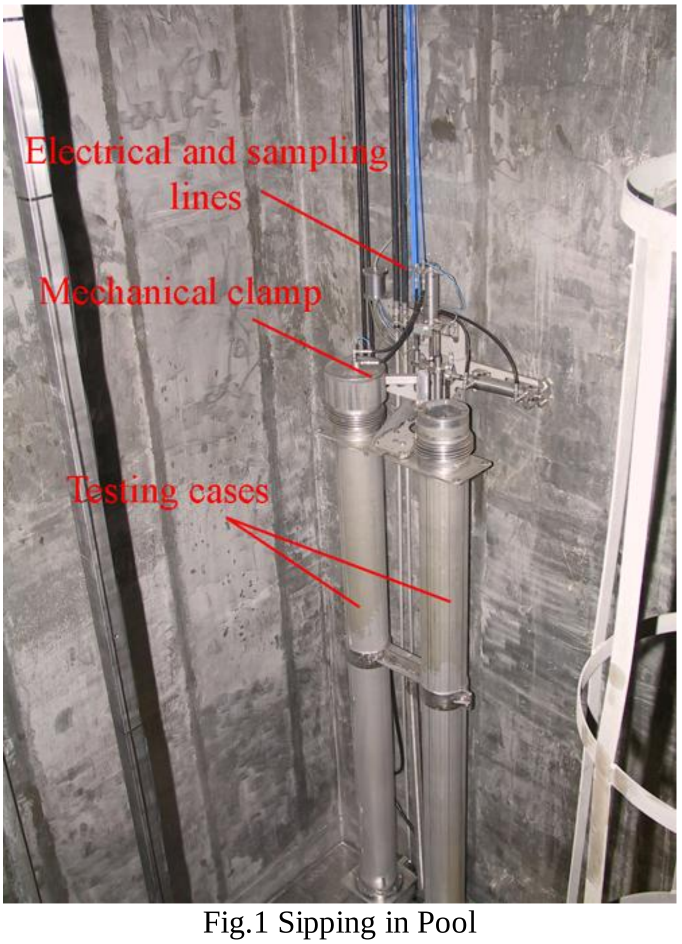

Fig.1 Sipping in Pool

Table1: Few results from measurements by Sipping in Pool [kBq/l]

Date	**Assembly**	^{131}**I**	^{54}**Mn**	^{60}**Co**	^{134}**Cs**	^{137}**Cs**
2.12.2002	13603900	< 8,45	<1,28.10^{1}	8,15.10^{2}	5,40.10^{1}	6,39.10^{2}
3.12.2003	13603900	<7,63	<9,64	7,47.10^{2}	3,84.10^{1}	4,84.10^{2}
9.12.2004	13603900	<9,79	1,13.10^{1}	8,06.10^{1}	5,81.10^{1}	3,72.10^{2}
22.8.2005	13603900	<1,13.10^{1}	<1,21.10^{1}	6,57.10^{1}	9,05.10^{1}	4,37.10^{2}

In December 2006, another system for monitoring VVER-440 fuel assemblies was implemented into the storage operation (Fig.2). Inspection stend "SVYP-440" it's a system for three main applications:

1. To find and examine fuel rod with leakage.
2. To determine extend of damage.
3. To store the rod with leakage in special container.

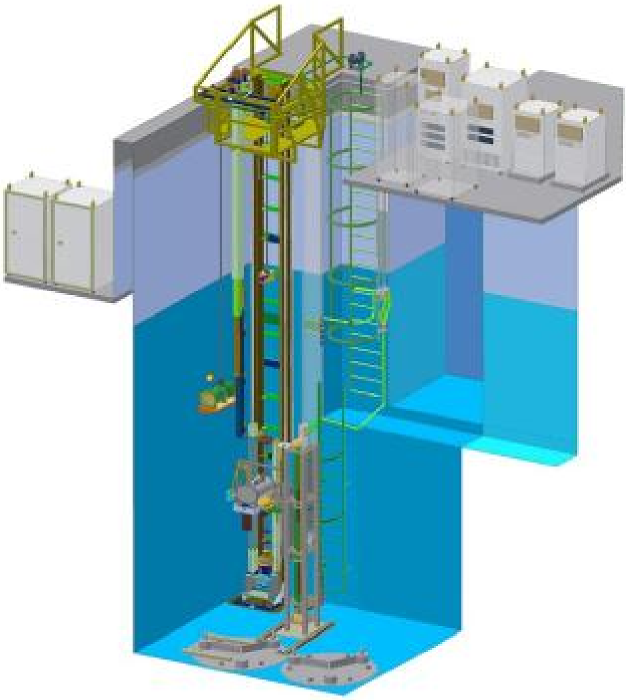

Fig.2 Inspection stend SVYP-440

This stend can open VVER-440 fuel assembly and examine all fuel rods which are inside by using different methods. The main of them are:

- Visual inspection.
- Ultrasound inspection.
- Turbulent flow inspection.
- Gama-spectroscopic inspection.

First non-active tests started at February 2007 and showed great results in manipulating with the fuel assembly (dummy).

3. Innovation of monitoring system

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

The pre-selection of high probably defect fuel assembly is connected to the symmetrical distribution of sorbent holders in spent fuel storage pools. Two types of composite sorbent based on potassium nickel ferrocyanide incorporated in different matrixes (prepared by different method) were used. The sorption capacity for cesium corresponds to the total amount of ferrocyanide (hexacyanoferrate) in the sorbent.

First type of sorbent was KNiFC-PAN (Potassium-nickel hexacyanoferrate incorporated in polyacrylonitrile organic matrix) [7], with three type of diameter: 0,3-0,6mm, 0,6-1,0mm and 1,0-1,4mm (A, B, C, Fig.3).

Fig.3 Different size of KNiFC-PAN sorbent

Second type of sorbent was Nifsil (composite sorbent based on potassium nickel ferrocyanide incorporated in silica gel (inorganic) matrix) with diameter 0,5-1,0mm (D, Fig4) [8].


Fig.4 Nifsil

Water sample from spent fuel pool at NPP in Jaslovské Bohunice was used. Five gamma-spectroscopic measurements were made:

1. Water sample without any sorbent,
2. Water sample with different sorbents, measured after 1 day,
3. Water samples with different sorbents, measured after next 3 days,
4. Water samples with different sorbents, measured after next 3 days,
5. Water samples with different sorbents, measured after next 4 days.

Table2. Volume activity [kBq/l] of ^{137}Cs in different sorbents

^{137}**Cs**	1	2	3	4
A	18,1	1,17	0,21	0,11
B	22,16	1,6	0,2	0,036
C	23,17	1,96	0,33	0,092
D	18,14	5,35	2,35	1,23

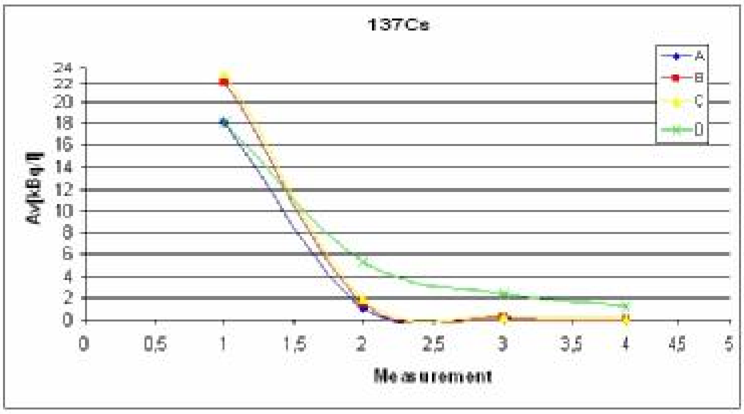

Fig.5 Decreasing of volume activity [kBq/l] of ^{137}Cs due to sorbent sorption

Table3. Volume activity [kBq/l] of ^{134}Cs in different sorbents

^{134}**Cs**	1	2	3	4
A	13,7	0,9	0,14	0,04
B	16,85	1,15	0,13	0
C	17,26	1,45	0,21	0
D	13,4	3,9	1,74	0,85

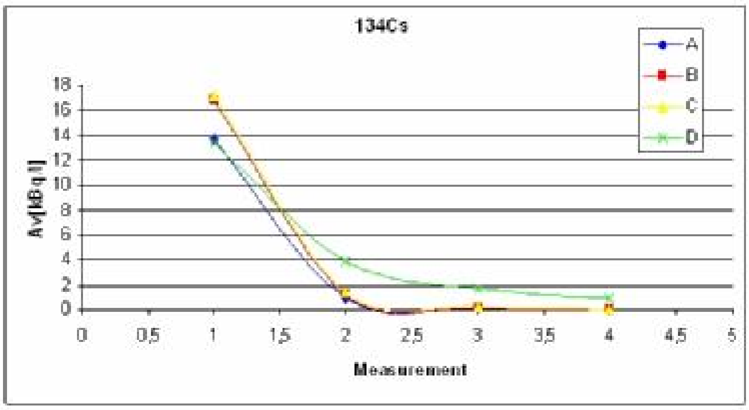

Fig.6 Decreasing of volume activity [kBq/l] of ^{134}Cs due to sorbent sorption

From the measurements is clear, that sorbent KNiFC-PAN has better sorption properties for cesium than Nifsil.

The detector has 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 type) and KZ-48 (the new type) have the same head, so the cesium detector is compatible for both. It consists of four main parts (Fig.7):

1. **Bayonet catch** – for manipulating with detector under water,
2. **Body** – for the detector placement on the head of storage container (Fig.8),
3. **Two strainers** – for sorbent deposition,
4. **Bayonet safety-pin** – for safety gripping.

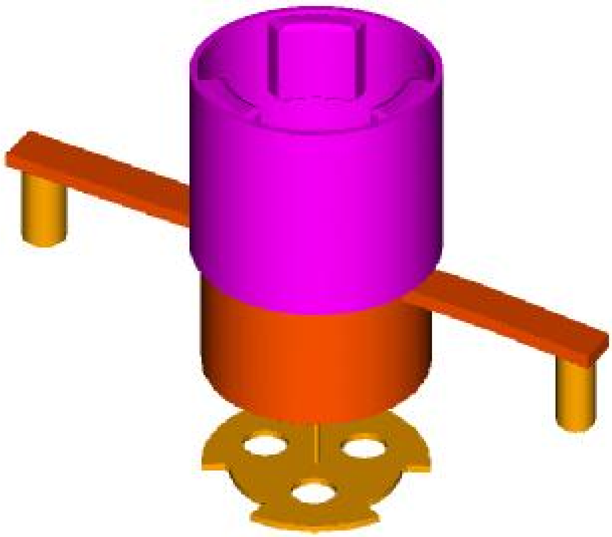

Fig.7 Cesium detector holder

The strainers are placed on the head of detector under 180^{o} angle and for the good contact between sorbent and water the holes diameter at the strainers are among 0,25 – 0,5 mm. Detectors are made from stainless steel.

Fig.8 Detector 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 liquid 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 sent 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 (Fig.9). So with high probability we can find the container, which contains fuel element (assembly) with leakage. This container is sending for the sipping control by system "Sipping in Pool", where the damaged assembly will be found. After the fuel assembly with leakage is sending for inspection by "SVYP-440" and the defective fuel rod is examine and stored in special hermetic container. The fuel assembly without any leakages is tag together and returns to the container into its place in the storage pool.

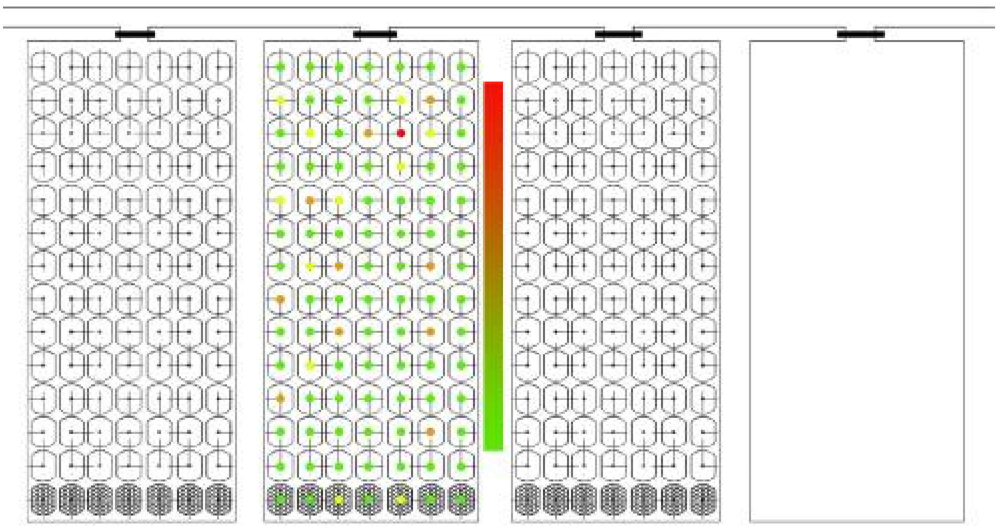

Fig.9 Monitoring by cesium detectors

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 spent 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 sorbents showed, that KNiFC-PAN has better sorption properties for cesium than Nifsil. 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.

Improvement of monitoring at the storage facility is in conjunction with all three monitoring systems: On-line detection system, Sipping in Pool and SVYP-440.

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References

[1] K.FUKUDA and col.: IAEA overview of global spent fuel storage, Proceedings from International Conference, 2-6 June 2003 in Vienna, IAEA-CN-102/60.

[2] J.VÁCLAV: Power reactors spent fuel storage in Slovakia, Proceedings from International Conference, 2-6 June 2003 in Vienna, IAEA-CN-102/44.

[3] V. SLUGEŇ, I. Smieško, Atomwirtschaft-Atomtechnik 38, 1993, p.375-378 (in German).

[4] A.DELFIN, R.MAZÓN: *Visual inspection system and sipping design for spent fuel at Triga Mark III Reactor of Mexico*, ININ Mexico 2002, [on line] 7/6/2004 at < http://www.rertr.anl.gov/Web2002/2003%20Web/Mazon.html >.

[5] J.A.PERROTTA, L.A.A. TERREMOTO and C.A.ZEITUNI: *Experience on Wet Storage Spent Fuel Sipping at IEA-R1 Brazilian Research Reactor*, Annals of Nuclear Energy, Volume 25, Issues 4-5, March 1998, Pages 237-258.

[6] *Telescope sipping — pinpointing leaking fuel bundles*, Fuel and Energy Abstracts, Volume 36, Issue 1, January 1995, Page 25.

[7] F.ŠEBESTA, J.John, A.Motl, Development of composite ion-exchangers and their use in treatment of liquid radioactive, Final Report of the research contract No.7381/RB between IAEA and Czech Technical University in Prague, 1993.

[8] P.RAJEC, J. Orechovská, I. Novák: *Nifsil a new composite sorbent for cesium*, January. 1999, Journal of Radioanalytical and Nuclear Chemistry, Vol.245, No.2 (2000) 317-321.