New Phenomena Observed during Fuel Assemblies Testing

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1. Introduction

The paper presents the results from fuel assemblies testing procedure just finished on Kozloduy NPP, Unit 4. The accent is not so on the fuel performance regarding fuel tightness, as on possibilities for performing reliable processing of the received results in the light of some difficulties due to unknown phenomena. Our experience includes fuel testing after nearly 70 fuel cycles of four "small" units (WWER-440) in Kozloduy NPP and such phenomena was observed for the first time. This work on this problem goes on.

2. Method of Fuel Tightness Control Used at Kozloduy NPP

The individual assembly control at Kozloduy NPP is performed by "wet canister" method. Essentially, the method is consisted in the isolation of every tested assembly in a can situated in the spent fuel pool, washing, followed by forced "pumping-out" of fission products from leaking rods by means of changes in system pressure. From every assembly two samples are taken. One – at the end of washing cycle, this is so called "background simple". This sample serves to show what is the activity of the water in the can before the real test. At the end of the procedure second water sample from the system is taken. In the case of leaking fuel assembly the growth of activity due to fission products is considerable. As indicators for leak ^{131}I, ^{134}Cs and ^{137}Cs are used and as an auxiliary tool – the growth coefficient. The specific activities of the above mentioned isotopes are measured directly in water samples. Assemblies with specific activities of the indicators in their water sample greater than $A_{average}+3\sigma$ are considered to be leaking.

3. Results

The Fuel testing was performed from 5-th to 28-th of September. Two schemes of fuel path are used:

- From the reactor core to the can;
- From the spent fuel pool to the can.

The first scheme was applied unloading of a fuel from reactor core – the assembly is put in the can and the time for testing is used for unloading of the next assembly, which is placed in the spent fuel pool. In this way after unloading of all FA from the reactor core, 180 of them passed through testing procedures. The rest – 169 assemblies were checked immediately after (without any delay) using the second scheme.

The borderline dividing all data in two regions is clearly seen and one with average specific activity of about $1\text{-}2\cdot10^{-5}$ Ci/l and another one with average specific activity of an order of magnitude lower-about $1\text{-}2\cdot10^{-6}$ Ci/l. It is obvious that in the first region there is no contrast at all and it is impossible to make any assessment of the fuel integrity.

At the same time the results based on cesium isotopes are contrast enough to give a good evaluation of the fuel state.

The borderline corresponds to assembly number 180, i.e. changing of the scheme of fuel path. Here is a place to say that in our practice we have used different scheme for fuel testing, including this one but never have received such a result.

4. The Hypothesis

Before the step in Iodine activity was reached we expected that this will be the value of average activity to the end of the testing – really too high, but could be explained by the fuel state or coolant state or another reason.

When the new activity value became stable and correspondence with changing in fuel path was found, the first assumption we made for the reason was is the different value of water activity in reactor core and spent fuel pool. Measurement of the samples from these places rejects this assumption – the both activities were much lower than average value of a first step.

This brought us to the suggestion that the volatile form of Iodine is carried by the gaseous bubbles covering the fuel rods. Such a model could be associated very well with fizzy water and a straw in it. The fuel rod serves as concentrator for the bubbles.

After putting the assembly in a can, the can is covered and the first step of the testing procedure starts – washing in open circuit. The washing water is drained permanently, but the bubbles couldn't be separated completely because drain line is located about 5 meters higher than the can – so the water in it is under pressure.

During the second step of the testing procedure (real test) the circuit is closed. Due to the pressure change the volatile Iodine is dissolved in water and

in this way the activity of the water at the end of the cycle increases. This process doesn't affect the activity of cesium isotopes, because at such temperatures and pressure cesium is always in dissolved ion from. This is the reason of uniform high Iodine activity.

This hypothesis explained other facts, which had no reasonable interpretation. For example: the existence of deviation in Iodine activity more than usual. It was found that for some technological reason just these assemblies were left in the can longer time – about 1-3 hours, of course with an open cover (usually there is no additional time). In this case the natural process of degassing is accelerated by even a minor temperature rising.

For the rest of the assemblies the relatively long period of staying in spent fuel pool at atmosphere pressure (about week) lead to bubble's degassing.

To confirm this hypothesis some of the assemblies were tested again including all leaking (assessed by cesium isotopes). The result concerning their tightness was completely confirmed.

We tried to find a connection with technology during shut down and cooling of the reactor. The minor changes were found within the allowed limits of the technological regimes. Probably there is a connection between the minimizing the gas effluents. There is no enough evidence for making final conclusion – work goes on.

5. Conclusions

- The observed phenomena give a new light on the processes during test procedures especially on behaviour of the referent isotopes;
- The use of the quantity criteria for fuel failure based on ^{131}I and binding it to the claim criteria has to be reconsidered;
- The use of ^{134}Cs and ^{137}Cs as stand-alone criteria is reasonable and gives more reliability;
- The minor changing in technology may have a great influence on different process. The absence of degassing may compromise the results from fuel testing, especially for sipping procedure.