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FUEL ASSEMBLY RECONSTITUTION

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ABSTRACT

Fuel failures have been happened in Nuclear Power Plants worldwide, without lost of integrity and safety, mainly for the public, environment and power plants workers. The most common causes of these events are corrosion (CRUD), fretting and pellet cladding interaction. These failures are identified by increasing the activity of fission products, verified by chemical analyses of reactor coolant. Through these analyses, during the fourth operation cycle of Angra 2 Nuclear Power Plant, was possible to observe fuel failure indication. This indication was confirmed in the end of the cycle during the unloading of reactor core through leakage tests of fuel assembly, using the equipments called “In Mast Sipping” and “Box Sipping”. After confirmed, the fuel assembly reconstitution was scheduled, and happened in April, 2007, where was indentified the cause and the fuel rod failure, which was substitute by dummy rods (zircaloy). The cause was fretting by “debris”. The actions to avoid and prevent fuel assemblies failures are important. The goals of this work are to describe the methodology of fuel assembly reconstitution using the FARE (Fuel Assembly Reconstitution Equipment) system, to describe the results of this task in economic and security factors of the company and show how the fuel assembly failures are identified during operation and during the outage.

1. INTRODUCTION

Searching continuous the safety for the public, the environment and the workers, the Nuclear Power Plants around the world hopes to reach high reliability index of fuel assembly, this way is possible to guarantee the preservation of the fuel assembly integrity, which is the first barrier against external release of fission products. These failures causes’ bad effects in nuclear power plant performance, in operations coast and contributes with a little decreasing in safety without release of radioactivity or contamination for the environment and general public.

The chemical analysis of coolant reactor is used to determine the reliability index of fuel assembly in Nuclear Power Plants as PWR. Then, the concentration values of fission products are measured and this way is possible to determine this index. This parameter is continuous monitored during plant operation and it is characteristic of each nuclear design. The most used fission products to determine the reliability index are I-133 and Xe-135. From these chemical results, theoretical and computational methods are used to predict and to available, identified the presence of fuel assembly failed, the numbers of rods failure and also how big it is [1]. During the outage for refueling, the monitoring is done through leak test of fuel assembly, where the measured activity of radionuclides, emitting beta particles and gamma spectrometry using the equipments “In Mast-Sipping” and “Box-Sipping”.

In Angra 2, during the cycle 4 were recorded increases activity levels of fission products in reactor coolant, giving an indication of fuel failed, which was confirmed by chemical sampling and evaluation methods from theoretical and computing [1].

The Figure 1 shows the evolution of failures indicators in terms of the power during cycle 4 operation, where can be observed an increasing Xe-133 activity, after start up and during variations of power.

The Figure 2 shows the result of rate Xe-133/I-131, where points were greater than values established.

The Figure 3 shows the behavior of the failures indicators in terms of Power during a cycle without failure.

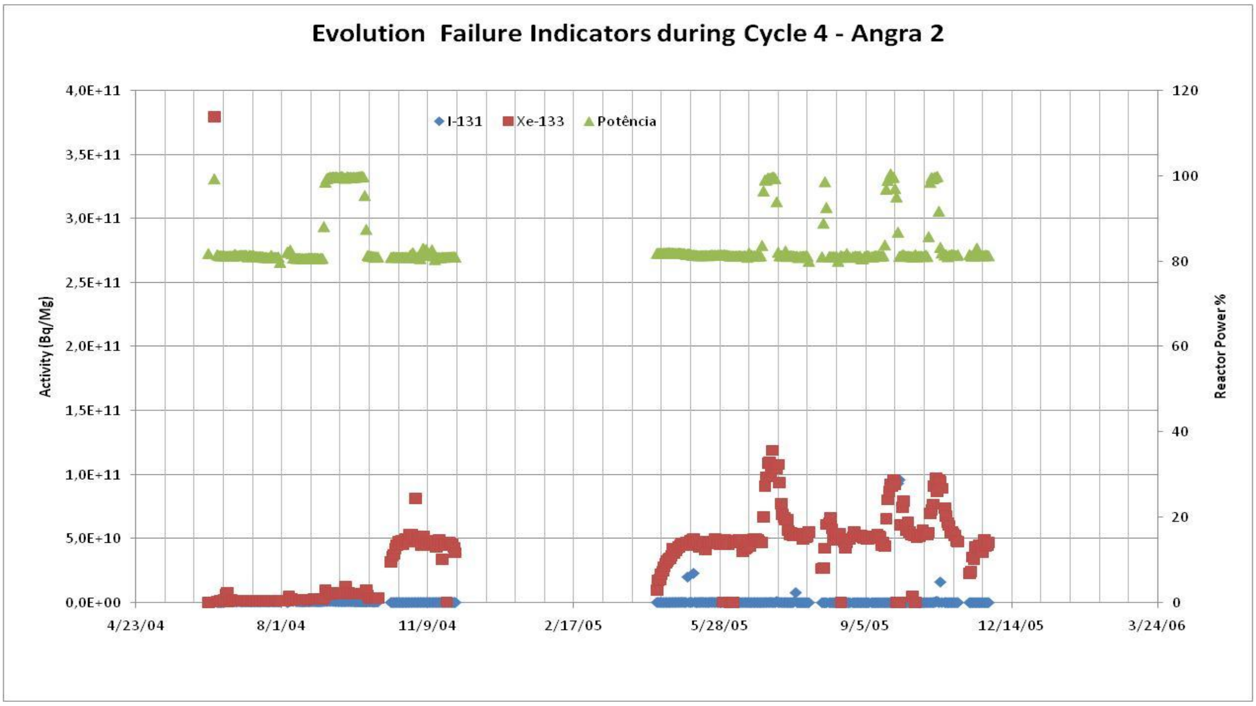

Figure 1. Evolution of Failures Indicators during the Cycle 4 with fuel assembly failed

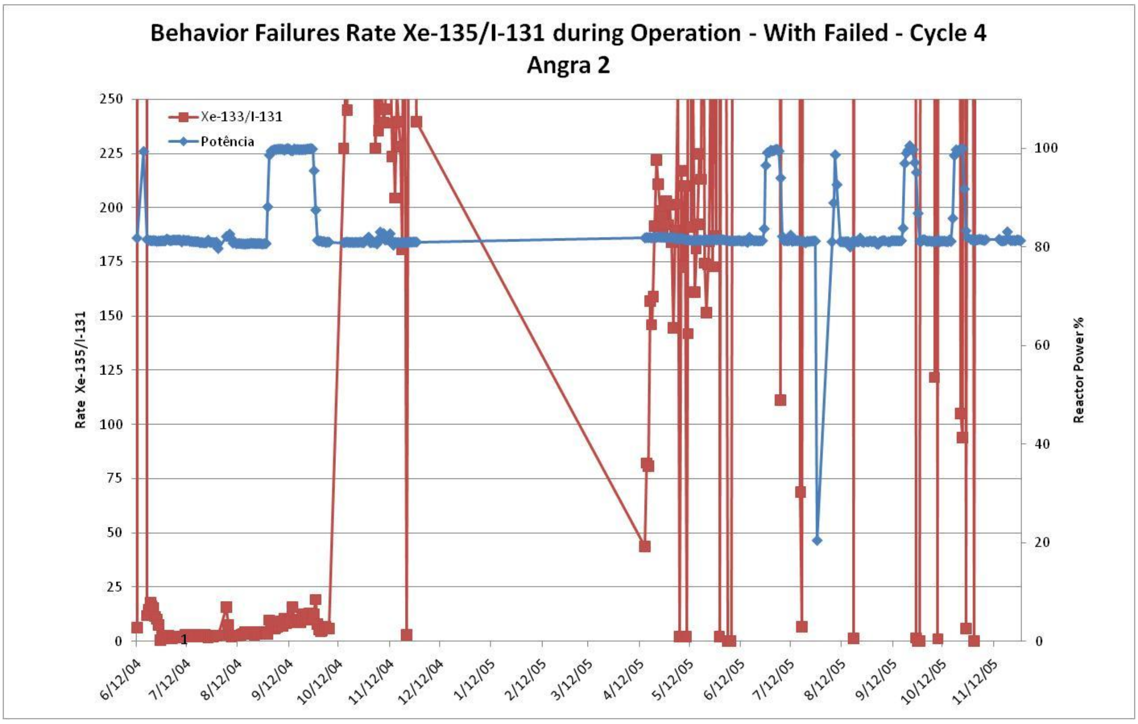

Figure 2. Behavior of failure indicator, Rate Xe-133/I-131, during Cycle 4 with an indication of fuel assembly failed in Angra 2.

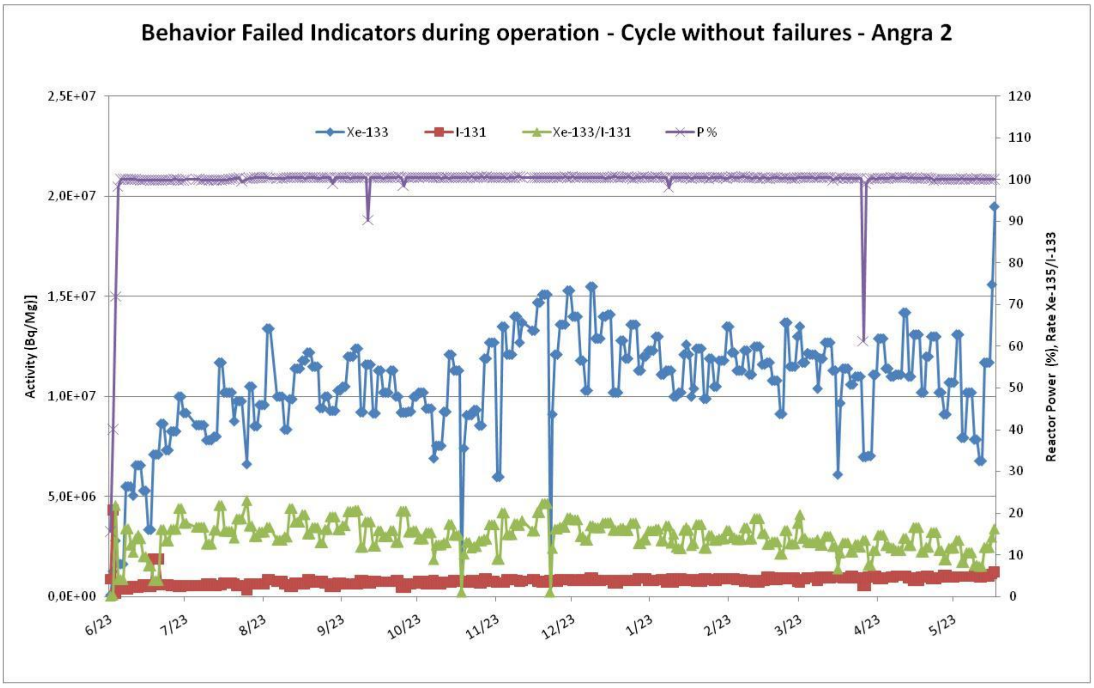

Figure 3. Behavior of failure indicators during a cycle with no indication of fuel assembly failed in Angra 2.

During the refueling outage 2P4, performed at the end of Cycle 4, the step of unloading the core, the "In-Mast Sipping" test recorded for the fuel C033 an activity from fission products greater than the average recorded for all other unloaded fuel assembly, Figure 4 [2]. Subsequently, an indication of failure observed during the cycle and recorded "In-Mast-Sipping" test and it was confirmed using "Box-Sipping" test, which also indicated an increase level of fission products in the water sample taken during the implementation of the test. After, the fuel C033 was confirmed as failed, a visual inspection was done on it, however had no evidence of defective in external fuel rods or spacer grid. During the visual inspection, were also inspected the top and bottom nozzle of fuel rods searching failures evidence in especially in solders. The fuel C033 Visual Inspection showed normal appearance to the residence time in the reactor, a cycle. After, it was stored in the pool spent fuel to wait the planning of repair, using the FARE (Reconstitution Fuel Assembly Equipment) system.

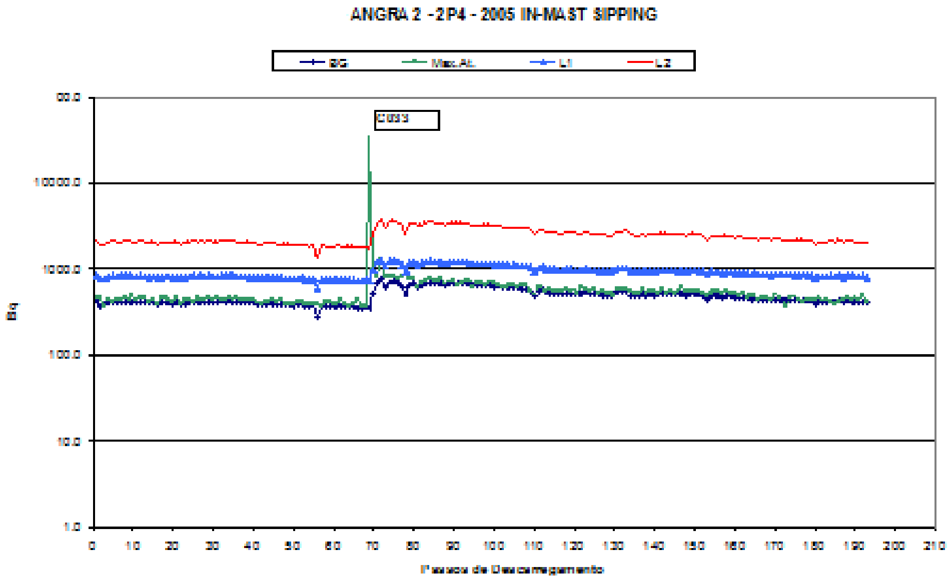

Figure 4. Analysis of the beta activity of fuel during unloading.

1.1. In-Mast Sipping

The "In-Mast-Sipping" test works using the principle the analysis of gases dissolved in reactor coolant, determining the activity of fission products released by fuel rods failed. The release of gases from interior of failed rods to the reactor coolant is facilitated by the decrease in pressure of water (range of depth), when the fuel is lifted from the core to the inside of the mast guide of refueling machine, which is used to move the fuels. The procedure for measuring the gases activity is made by collecting a sample of water and also through the registration of beta activity, measured by the detectors of the "In-Mast-Sipping.

During all the time that the fuel remains inside mast guide of refueling machine, the activity and the average maximum activity are recorded for each scintillator detector. The maximum

activity values are used for the analysis of failure. This process is repeated for each fuel removed from the reactor core after a cycle of operation to be stored in the spent fuel pool.
The water samples collected were analyzed by gamma spectrometry equipment to identify radionuclides, fission products such as Kr-85, Xe-133, Xe-135, Cs-137, Cs-134, I-131, I-133, Ba-140 [3].

1.2. Box-Sipping

The "Box-Sipping" test, also work using the principle the analysis of gases dissolved in water. But, the leak of fuel is checked in a box, located inside the pool spent fuel. Then, this box is closed making it a closed refrigeration circuit, where the water is recirculated and heated, stimulating the release gas of fuel rod failed. At this point, using a closed circuit sampling, a sample of the water box is collected and sent for gamma spectrometric analysis to identify radionuclides, fission products. These values are compared with preliminary analysis of the water from fuel without failure, called the background. The fuel is considerate as failed if after gamma spectrometric the sample to indicate an activity of fission products greater than 10 times the background activity.

2. FUEL ASSEMBLY RECONSTITUTION EQUIPMENT (FARE)

The FARE aims to repair spent irradiated fuel assemblies in the spent fuel pool, through the use of tools, electronic equipment, motors, vacuum pumps, hoses, compressed-air system, visual inspection system, test "Box Sipping”, and others items. The repair of irradiated fuel assembly consists basically of three main stages: eddy current test, replacement of failed fuel rods and leak test – Box Sipping [4].

2.1. Eddy Current Test

For non-destructive verification of the integrity of fuel rods cladding, during repair of irradiated fuel is used the method Eddy Current Test. The goal of test is to identify each fuel rod of the fuel, identifying and characterizing the defective rod and the kind of damage.

For this, the fuel rods are removed individually from spent fuel, using a tool itself, which automatically makes the Eddy Current Test. In the same tool there is a circular probe and a sensor that checks the diameter of the rod throughout its length to guarantee the correct setting near the spacer grid.

2.2.Replacement of failed fuel rods

When the failure rod is identified, it is placed into the “canister”, equipment for storage of damaged rods in the spent fuel pool. However, before it, the rod was inspected using Underwater Visual Inspection System with recorder media and the final position into “canister” was recorder with double check. After storage of failed fuel rod inside the “canister”, a solid Zircaloy rod was placed in the fuel rod position of the irradiated fuel. The undamaged fuel rods were reinsertion in their position.

After the conclusion of a campaign to repair one or more elements of spent fuel, the “canister” is closed and sealed with a lid, which prevents access to the rods but not impossible its cooling. Finally, the canister was deposited in a cell for storage of fuel in the pool spent fuel. Each year, exceptionally, this “canister” is open to be inspected by international organizations (International Atomic Energy Agency - IAEA and Brazilian-Argentine Agency for Accounting and Control of Nuclear Material - ABACC) to guarantee non-infringement, or the misappropriation of nuclear material deposited there.

2.3.Leakage Test – Box Sipping

After repair of spent fuel and before be used again, it is tested using the Box-Sipping equipment to verify that the repair was effective. From the results of the sipping test it can be concluded that the assemblies do not contain anymore failed rods rods and are thus cleared for further operation. Then, the fuel was inspected visually, using the Visual Inspection System with Underwater cameras with recording media. If "Box-Sipping" results indicated failure, the fuel must be back to the FARE system and the procedure described above will be realized again.

2. FUEL ASSEMBLY RECONSTITUION – C033

The fuel C033 was identified as failed, after one cycle of operation, when Angra 2 was in the 4th cycle, during the outage 2P5, in 2005, through "In-Mast-Sipping" test and confirmed by "Box-Sipping”. On 04/26/07, before start fuel repair, the "Box-Sipping” test was done again and the failure indication was checked again.

After “Box-Sipping” test, the Visual Inspection in fuel C033 was executed again, using the Visual Inspection System with Underwater Cameras, where was observed a “blister” (secondary located in fuel rod pellet damage caused by swelling) in column "P" (from 0 º / 360 º), in first three fuel rods (VC). This observation indicated the need another test called Eddy-Current Test. The diagram used as a guide for the identification of fuel rods (VC), tubes Guides (TG) and identifies fuel rods failed (F) is shown in Figure 5.

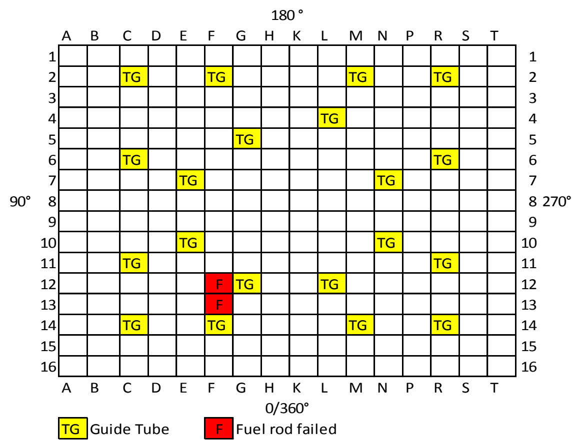

Figure 5 – Scheme alpha numeric identification of fuel rods in fuel assembly.

Then, after Visual Inspection, before of repair process, the bottom nozzle was removed and "debris" was located between the rods E12, E13, F12 and F13 against 1st spacer grid as can be seen in Figure 6. After removal of the “debris”, the fuel rods in position F12 and F13 were identified as failed by "Eddy-Current” test and confirmed by visual inspection.

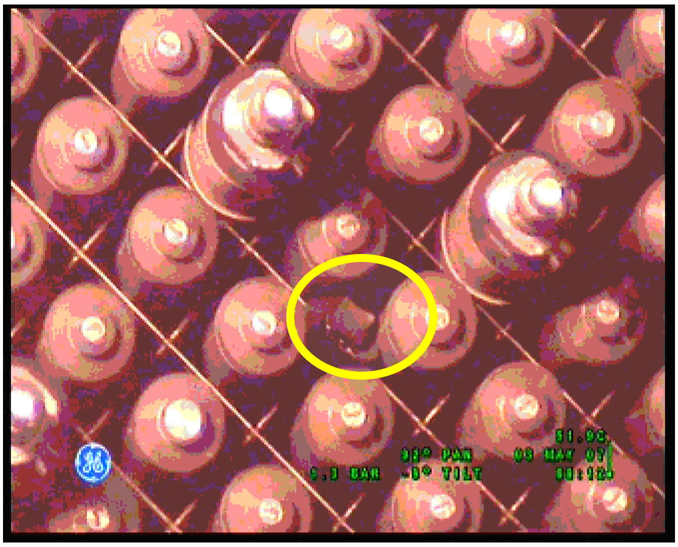

Figure 6 . “Debris” located between the fuel rods of positions E12/E13/F12/F13.

The VC F12 was noticed a failure in region near the spacer grid caused by "Debris" and another failure secondary, "Blister", near center of the VC. The VC was removed and placed in the “Canister”, the special place where is possible to put failed rod fuel in pool spent fuel. This VC was replaced by Dummy rod (Mass of Zircaloy rod).

The VC F13, during the visual inspection was noticed a failure in region near spacer grid caused by “Debris” and other secondary failures - "Blister", near center of VC. The VC was replaced by P12 position VC, which had burn up value close VC removed.

The VC P12 rod was moved to position F13 to avoid that more than two rods dummy in neighboring positions in fuel element. This point is important because of the "Debri" was between four fuel rods that also were neighbors of the two guides tube.

The VC P12 was also tested by “Eddy Current” test and wasn´t detected failure. In place of this rod (position transferred to F13), was placed a rod "Dummy" (Mass of Zircaloy rod).

After checked the integrity each fuel rod, the leak test of the fuel was checked again through "Box-Sipping” test and other Visual Inspection was performed using Underwater Camera. The result of “Box Sipping” test and Visual Inspection showed that the fuel assembly was intact and free of debris.

4. CONCLUSIONS

The Angra 2 Power Plant fixed the fuel assembly C033 successfully. In the 6^{th} cycle, the fuel C033 and their counterpart fuel (fuel diametrically opposite) returned to the reactor core. The continuous monitoring of the failures indicators adopted by plant, Xe-133/I-131 rate, proved to be efficient and enables the rapid detection of fuel failure during operation of the plant. The equipment of the fuel leak test was very effective. The equipment for reconstitution of fuel assembly allows the repair of fuel, accurate detection of failed rods in fuel, enabling the continuity of generation of energy such as your original design and avoided the storage of defective fuel in pool spent fuel. The Angra 2 Power Plant improved through processes and procedures, the rigid control of access to areas where there could be intrusion of foreign material ("debris") in the reactor cooling, such as spent fuel pool and equipment of the primary circuit, with the objective to achieve zero fuel failure.

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