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CHARACTERIZATION OF SPENT FUEL ELEMENTS STORED AT IEA-R1 RESEARCH REACTOR BASED ON VISUAL INSPECTIONS AND SIPPING TESTS

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ABSTRACT

Aluminum spent nuclear fuels are susceptible to corrosion attack, or mechanical damage from improper handling, while in pool reactor storage. Storage practices have been modified to reduce the potential for damage, based on recommendations presented at 2nd WS on Spent Fuel Characterization, promoted by IAEA [1]. In this work, we present the inspection program proposed to the IEA-R1 stored spent fuel elements, in order to provide information on the physical condition during the interim storage time under wet condition at the reactor pool. The inspection program is based on non-destructive tests results (visual inspection and sipping tests) already periodically performed to exam the IEA-R1 stored spent fuel and fuel elements from the core reactor.
To record the available information and examination results it was elaborated a document in the format of a catalogue containing the proposed inspection program for the IEA-R1 stored spent fuel, the description of the visual inspection and sipping tests systems, a compilation of information and images result from the tests performed for all stored standard spent fuel element and, in annexes, copies of the reference documents. That document constitutes an important step of the effective implementation of the referred IEA-R1 spent fuel inspection program and can be used to address regulatory and operational needs for the demonstration, for example, of safe storage throughout the pool storage period.

1. INTRODUCTION

IEA-R1 is a MTR (Material Test Reactor) open pool nuclear research reactor located at IPEN, in the campus of São Paulo University, in São Paulo City. The fuel elements (FE) that assemblies the core reactor are composed by metallic dispersion of U_3O_8-Al or U_3Si_2-Al with aluminum cladding. After the irradiation time of the fuel elements in the reactor core, the interim storage of that spent fuels is done under wet condition inside the pool storage racks.

Aluminum spent nuclear fuels are susceptible to corrosion attack, or mechanical damage from improper handling, while in pool reactor storage. Storage practices have been modified to reduce the potential for damage, based on recommendations presented at 2nd WS on Spent Fuel Characterization, promoted by IAEA, in 2002 [1]. To attend those recommendations, an inspection program was proposed for characterization of the IEA-R1 stored spent FE, in order to provide information on the physical condition during the interim storage time inside the reactor pool.

Experience has shown that video imaging can provide information on general fuel structural condition nature or type of fuel damage, and an estimate of breached cladding or exposed fuel meat [1]. Since the country have not yet a permanent irradiated nuclear material repository, the spent fuel elements need to stay stored during interim time inside the reactor pool, at storage racks. Then, the inspections shall be performed until the fuel is removed from the reactor pool to permanent repository for ultimate disposition.

As proposed at the inspection program, the examination results from visual inspections and sipping tests performed and also available information of all stored spent standard FE were compiled in a data-book titled "Catalogue of the IEA-R1 Research Reactor Spent Fuel". Additional images and information can be added to the actual content of the catalogue as result of the periodical visual inspections and sipping tests that will be performed during the interim storage time. This information will be especially important to address regulatory and operational needs for the demonstration, for example, of safe storage throughout the wet storage period at the reactor pool.

2. VISUAL INSPECTION AND SIPPING TEST SYSTEMS DESCRIPTION

2.1. Visual Inspection System

Spent fuel elements have been visually inspected by an underwater radiation resistant video camera system, inside the IEA-R1 reactor pool, to verify its integrity and its general surfaces conditions. This system has been used also to visually examine reactor core components like graphite or beryllium reflector elements, control rods, reactor core matrix plate and others.

2.1.1. Equipment

The actual visual inspection system for exam the spent fuels at IEA-R1 is composed by an underwater radiation resistant video camera IST – Color Underwater Outstation – model R982, equipped with a 13 inches Sony color monitor. The color camera is equipped with an auto focus system that allows a sharper focusing, thus improving the image quality. Imaging recording is made through a videocassette recorder Panasonic model AG-1980P. The images can be transferred to a digital file using a VITRA VGA+TV Combo Board.

2.1.2. Methodology and procedure

The underwater camera is placed about 3-m deep, supported by a metallic tube, arrested at the pool reactor mobile bridge. Using the reactor crane, each fuel element is withdrawn from its position at the reactor core or from its storage rack and it is positioned about 0,7 to 2,5 m from the camera, in order to obtain the best images and to avoid damages in the camera due the FE radiation. The FE is maintained in a fixed position in front of the camera and the camera is moved by remote control using the pan and tilt system to perform the visual inspection along the complete FE length, as showed at figure 1.

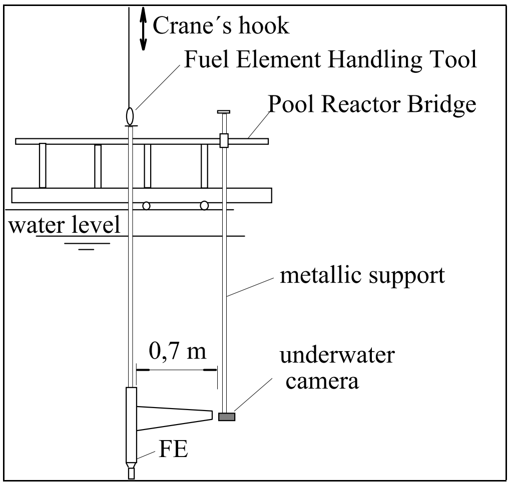

Figure 1 – Fuel inspection arrangement

The four FE lateral faces are observed attentively from the top to the bottom. If a visual occurrence is observed, the image is approximated by zoom for more detailed examination. A standard form containing the FE schemes is filed, annotating the FE Id number, date and hour of the inspection. Eventual visual occurrences during the inspection are annotated. The reactor radiological protection group must follow and monitor the visual inspections.

2.2. Sipping Test System

Sipping tests are performed to detect eventual defects in fuel elements. The operational procedures for the sipping tests performed at IEA-R1 reactor are defined in the Ref. [3].

2.2.1. Equipment

For gamma spectrometry the following equipments have been used: Pb shield, support for samples, liquid calibration source of ^{137}Cs, HPGe detector (model GEM-25185-P-PLUS, by EG&G/ORTEC), amplifier (model 973U, by EG&G/ORTEC), high tension source (model 659, by EG&G/ORTEC), BIN (4001C, by EG&G/ORTEC), multi-channel analyzer (model 921, by EG&G/ORTEC), coaxial cables, IBM compatible microcomputer, program for gamma spectra acquisition (MAESTRO II, by EG&G/ORTEC) and program for analysis for determination of the number of counts (area) under the photo-peak (IDEFIX).

2.2.2. Methodology and procedure

The sipping system is basically composed by an aluminum tube (12 cm inside diameter, 300-cm width) with its bottom extremity closed. This tube is maintained in vertical position. Both a FE and a ¾“ PVC tube are introduced into the sipping tube. The PVC tube is connected to the demineralyzed water circuit or compressed air system, depending on the operational phase. After that, the open tube extremity is elevated over the pool water level in order to maintain the tube internal water volume separated from the pool water volume. Then, an internal washing is promoted by ascendant circulation of fresh demineralyzed water, supplied by the PVC tube, to remove the eventual contaminants from the proper pool water or accumulated impurities during the storage time, as showed at figure 2.

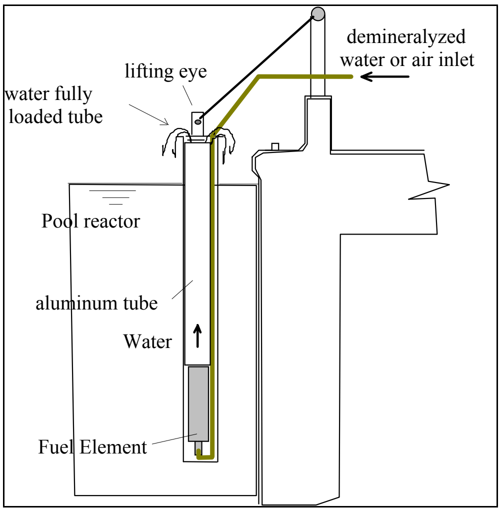

Figure 2- Fuel element position into the sipping tube.

After the water homogenization, the first water sample collection is done in plastic flasks. This sample will be characterized as background (BG) level. The FE stays in rest, inside the sipping tube, during an established time (four hours). In this condition the tube entrance is about 15 cm over the water level. After the rest time, the compressed air system is connected to the PVC tube. Compressed air is injected during 2 minutes to promote a new water homogenization. The second water sample is collected and characterized as the "sipping sample for that in test FE".

Additional data collection are: water temperature from inside the sipping tube, the sample collection time and the reactor power during the sipping test; as well the demineralyzed water characteristics used in the washing (pH, conductivity, chlorides). Radiochemistry analyses are made on the collected samples. The presence of chemical elements of fission products at the samples indicates the existence of some defective part in the FE cladding. The reactor radiological protection group must monitor the sipping test operation.

3. INSPECTION PROGRAM FOR IEA-R1 SPENT FUEL

The proposed "Inspection Program for IEA-R1 Spent Fuel" /2/ contains guidelines for characterization of the IEA-R1 stored spent fuel elements, in order to provide information on the physical condition during the interim storage time inside the reactor pool. This inspection program is based on non-destructive tests results (visual inspection and sipping tests) that have been periodically performed at the IEA-R1 to exam the general fuel conditions of the stored spent fuel and also the FE from the reactor core.

The main topics specified on the inspection program are: i) Scope of Inspection Program; ii) Examination Methods; iii) Examination Requirements; iv) Frequency of Examination; v) Catalogue of Examination Results; vi) Categorization of Fuel Damage.

4. EXAMINATION RESULTS

During 2004, all stored standards spent fuel element were sip tested. Also, in November-2004, it was performed a campaign for visually inspect all stored spent fuel at the IEA-R1 storage pool. It was inspected twenty-nine (29) standard FE. The six stored controls fuel elements (CFE) and the standard one (IEA 156) failed in 2001 were not inspected.

The design of the control fuel elements did not permit a view of any internal fuel plate. Therefore, those CFE shall be inspected, as established in the scope of the inspection program. Visual inspection of all stored control fuel elements at IEA-R1 shall be scheduled.

The examination results and information of all stored spent standard fuel assemblies were compiled and catalogued. Each fuel element has the proper datasheet and when necessary to show eventual visual occurrence additional pages are added to the main initial page. The table 1 presents the categorization criteria for damage index, specified at the inspection program /2/ and used to characterization of the inspected fuel elements.

Table 1- Categorization criteria for damage index /2/.

Visual Inspection Categorization		Sipping Test Categorization	
Class	Total Active Area Exposed (cm^2)		
V0	Fuel Element without nodules or corrosion in general	**S0**	No leakage
V1	$< 0,5\ cm^2$	**S1**	Leakage occurrence
V2	$\geq 0,5\ cm^2$ to $< 1,0\ cm^2$		
V3	$\geq 1\ cm^2$		

The visual inspections and sipping test results for the IEA-R1 stored spent fuel, performed until November 2004 are presented in the table 2.

Table 2- Visual inspections and sipping tests results for IEA-R1 stored spent fuel (Until November, 2004)

Visual Inspection Categorization	**Sipping Test** Categorization	**Fuel Element Identification Number**
V0	**S0**	128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 140, 141, 143, 144, 145, 148, 149, 150, 151, 152, 153, 154, 155, 157, 158, 159, 160, 161, 162
V1	**S1**	156
V2		
V3		

3. CONCLUSIONS

It is presented, in general lines, the proposed inspection program of the IEA-R1 stored spent fuel elements. An important step for effective implantation of that program was the elaboration of the "Catalogue of the IEA-R1 Research Reactor Spent Fuel", that consists in a compilation of information and images result from the visual inspections and sipping tests performed for all stored standard spent fuel elements. That document will be received and maintained by the IEA-R1 reactor operator and constitutes an important step of the effective implementation of the referred IEA-R1 spent fuel inspection program and can be used to address regulatory and operational needs for the demonstration, for example, of safe storage throughout the pool storage period.

For future work, we present the following suggestions:

- Visual inspection of all stored control fuel elements;
- Establishment of additional intermediate categorization index, inside the visual inspection V0 index, to make a differentiation on the general aspect of the spent fuel element cladding surfaces;
- Permanent implementation of the images catalogue, adding information and images results from visual inspections.

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