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VISUAL INSPECTION OF SPENT FUEL ELEMENTS FROM ININ TRIGA MARK III RESEARCH REACTOR

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ABSTRACT

International experience has shown that visual images may provide information on fuel structural conditions and of the type of existing damage of the irradiated fuel. Within the framework of the IAEA regional project RLA-4/018 – Management of Spent Fuel from Research Reactors, during the "3rd Workshop on Spent Fuel Characterization, Corrosion and Visual Inspection" - Mexico, 6-10 Dec/2004, a group of regional researchers together with the ININ TRIGA Mark III Reactor personnel performed the visual inspection of a set of irradiated fuel elements of that research reactor, as the starting point of a visual inspection campaign to be subsequently performed by the local personnel. The approach to perform the visual inspection involved adopting recommendations and procedures developed by the researchers' team in previous work, WS [1, 2]. In this present work, we discuss the adopted procedures for visual inspection of irradiated fuel at that reactor, describe the hardware and tools employed, present the inspection results and provide a preliminary interpretation of those results.

1. INTRODUCTION

International experience has shown that visual images provide information of fuel structural conditions and of the type of existing damage on irradiated fuel. Additionally, interpretation of the images provides an estimation of cladding leaking and fuel meat exposure.

A fuel inspection program provides information on the physical condition of the fuel. This information can be used to address regulatory and operational needs for the demonstration, for example, of safe storage throughout the basin storage period.

The ININ have taken the decision to carry out underwater NDT in 2004 of the TRIGA Mark III Reactor components, like the reactor liner (ultrasonic and visual inspections) and reactor fuel (visual inspection).

In the frame of the 3rd Workshop on Spent Fuel Characterization, Corrosion and Visual Inspection held at Mexico City, 6-10 Dec 2004, of the IAEA TC Project "Management of Spent Fuel from Research Reactors", a group of regional researchers together with the ININ TRIGA Mark III Reactor personnel performed the visual inspection of a small group of irradiated fuel elements, as the starting point of a visual inspection campaign to be subsequently performed by the local personnel. Hardware and tools were provided by the Reactor staff, as well as the monitoring system.

An inspection program of the TRIGA Mark I Reactor Fuel, at CDTN-Belo Horizonte, Brazil is being planned. This paper serves provides guidance for the inspection program plan, and inspection results and interpretation from a similar fuel type.

2. SOME CHARACTERISTICS OF THE TRIGA MARK-III REACTOR CORE

The ININ TRIGA Mark III reactor core is composed by 85 fuel rods, 4 control rods and 34 reflector elements of graphite. Some of the fuel element characteristics are:

- fuel rod full length: 722 mm, (active fuel length: 381 mm).
- fuel material: zirconium hydride 8,5% U, OD = 36,3 mm.
- cladding material: stainless steel (OD = 37,3 mm, thickness: 0,5 mm).
- top and bottom reflector block material/lengths: graphite, 87,4 mm and 88,1mm.
- top and bottom end caps and top spacer material: stainless steel.

3. VISUAL INSPECTION

2.1. Inspection Criteria

The following are the inspection method criteria adopted from protocols developed at WS [1] and [2]:

a) Underwater video equipment with recording video image capability.
b) Fuel stationary. Camera remotely moved.
c) Inspection areas on fuel are: fuel cladding 360º around, structural parts for fuel grappling and positioning and welding lines. Also ID number checking.
d) Minimum magnification 4X for fuel cladding and welding lines.

2.2. Monitoring System Description

The system has a high resolution camera Hydro-Technologie model VSLT 410N, showed in the Fig. 1, designed for underwater operation, until 30 m depth, environments temperatures of

0 ºC to 50 ºC and dose rates up to 50 rad/h, also a control unit, showed in the Fig. 2, that allows remote operation of the camera [3]. Other components used are:

- Illumination unit with intensity control independent of two halogen lights.
- AVERMEDIA External device Plug-and-play TV-USB, showed in the Fig. 3, with video-in that allows visualization of the picture in the personal computer screen, pictures and video capture in formats JPEG and RGB, with screen resolution of (320 x 240) pixels, shine, contrast, saturation and color adjusts, USB interface, supporting video formats NTSC, PAL-N and PAL-M.
- Digital video device, for video images recording.
- TV monitor.

Figure 1 - Underwater Camera

Figure 2 – Camera control Unit

Figure 3 – External device Plug-and-play TV-USB

The design bases for the system were defined and included the need of performing underwater fuel inspection a minimum of 3 m below the pool surface to ensure safe handling of the spent fuel. The handling system was designed to maintain the fuel integrity of the spent fuel during the visual inspection operation and total access to the entire surface to be inspected.

2.3. Hardware and Handling Tools

A frame to position the camera and the illumination system was used. The system accommodates typical tools for fuel handling, and a special device for fuel positioning and rotation. A fuel positioning indicator system with a rule attached, allowed the fuel to be positioned and vertically oriented for visual inspection.

4. RESULTS

A total of eight fuel elements were inspected: one fresh fuel element (FLIP design), three spent fuel elements ("low-enriched" design) from the storage racks and four elements from the reactor core (two of the "low-enriched" design and two of the FLIP design).

The spent fuel cladding of all the elements inspected looked in very good condition. The features observed on the spent fuel did not show evidence of degradation of the cladding, including the weld regions, which would compromise the integrity of the cladding. There was no evidence of a cladding breach.

The fuel was of two basic designs, "low-enriched" design and the FLIP design. The low-enriched design itself was either a "5000-series" or a "7000-series" design. The full weld region that is comprised between the top end cap weld and bottom end cap weld, for the low-enriched design were not entirely visible due the fixture of the camera-holder system. However, a portion of this weld region was visible using the existing configuration of the camera system. Both the top and end cap weld regions, and the longitudinal weld in the tube of the FLIP design were visible with the existing configuration of the camera system. Table 1 summarizes the results of the inspection for each of the inspected elements. Still photographs are shown in Fig. 4 to 9.

Table 1. Inspection Results - Observations

Fuel ID Number	Fuel Design	Location	Inspection Results -Observations
883A (Fresh Fuel)	FLIP	Outside of pool	Fresh fuel placed underwater in holder for visual examination. 4x magnification shows minor surface bumps and scratches.
5079	Low-enriched fuel	Storage Rack	Dark orange-brown-blue region 38 mm in length. Scratches both circumferential and longitudinal. Debris both along lines and as separate particles were attached to cladding. The gas-fill port seal was observed on the lower end fitting.
5113	Low-enriched fuel	Storage Rack	Same general observations as for fuel ID 5079. In addition, a semi-shiny band about 3,1 mm wide and irregular was observed in the colored region. The band had several white deposits adjacent to it.
5056	Low-enriched fuel	Storage Rack	Same as for fuel ID 5079.
7126	Low-enriched fuel	Reactor Core	Same general features as for fuel ID 5079. In addition, a clear, sharp shiny-metal band approximately 6,3 mm wide and corresponding to 22,8 mm from the bottom of the fuel cylinder was observed within the colored region, showed in the fig. 4. Thin bands of dark and light colors within the colored region were observed. Debris and scratches were observed and appeared to be less in amount than element ID 5079.
7130	Low-enriched fuel	Reactor core	Same as fuel ID 7126, including the shiny-metal band. Not the same irregular clear region. A small black stain approximately 6,3 mm long was observed. A still photography of this fuel is showed in the Fig. 5.
8841		Reactor core	Same as fuel ID 7126 but with two shiny-metal bands, each approximately 6,3 mm wide. A still photography of this fuel is showed in the Fig. 6.
5107		Reactor core	Same as fuel ID 7126 but no shiny-metal bands. The bottom and top boundaries between the colored regions were not as distinct as the other element examined. Still photographs of this fuel are showed in the Fig. 7 to 9.

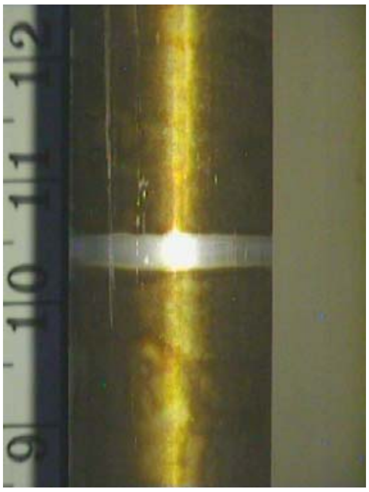

Figure 4 – FE # 7126

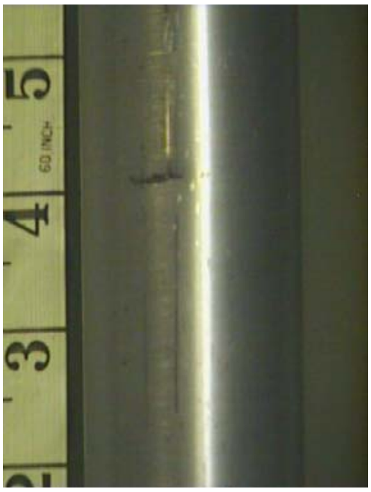

Figure 5 – FE # 7130

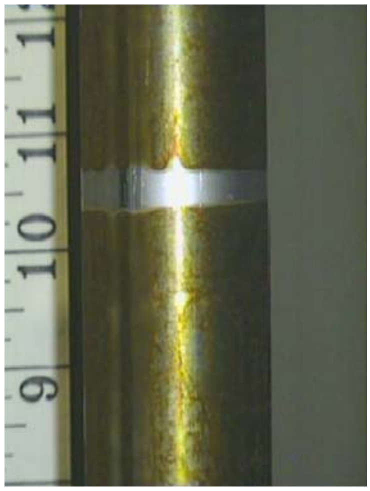

Figure 6 – FE # 8841

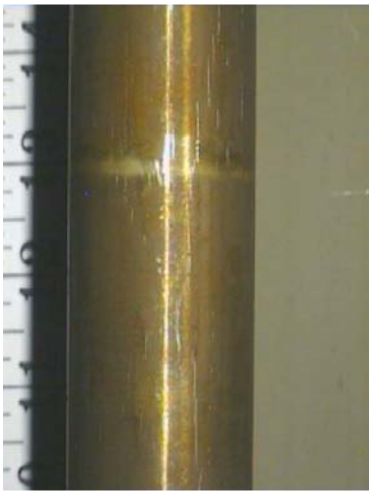

Figure 7 – FE # 5107

Figure 8 – FE # 5107

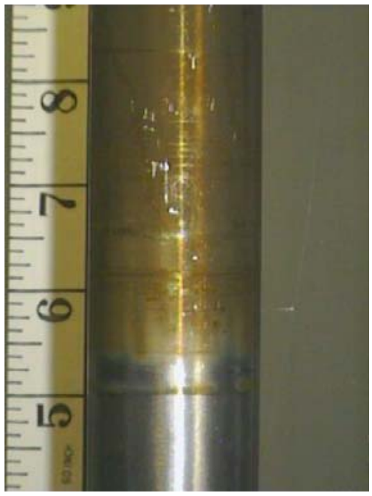

Figure 9 – FE # 5107

4.1. Preliminary Interpretation of Results

Enhanced thicknesses of oxide (Cr_2O_3) films, as evidenced by a strong orange-brown-blue color, were seen on the spent fuel cladding. This coloration corresponded to the fuel pellet locations beneath the 0,508 mm thick stainless steel cladding of the element. One or two bands that did not show this coloration, but were a shiny metal, oxide-free ring within the colored region were observed in one or two locations on several elements. This corresponded to pellet-to-pellet interface regions.

Scratches black, white, or bare metal coloring, were observed on the spent fuel claddings. These features are attributed to handling as the fuel is loaded/removed from the core and loaded/removed from the storage racks. The white scratches are attributed to aluminum oxide in a thin film that occurred when smeared aluminum metal from the storage rack would subsequently oxidize. The black scratches could also be aluminum-oxide or shadow-effects of deeper surface scratches in the stainless steel clad. One fuel that was loaded in the storage racks was observed to have a thin, irregular band of lighter color in the colored region, plus several deposits adjacent to this band. This is attributed to galvanic reactions of the stainless steel cladding with the aluminum storage rack. The deposits are suspected to be aluminum oxide and hydroxide. Additional small white deposits were observed on the fuel cladding, with a greater amount of this debris on the fuel from storage racks. These deposits are expected to be aluminum oxide and hydroxide.

5. CONCLUSIONS

The spent fuel cladding of all the elements inspected showed to be in very good condition. The features observed on the spent fuel did not show evidence of degradation of the cladding, which included the weld regions, which would compromise the integrity of the cladding. There was no evidence of a cladding breach. The aluminum oxide indications observed on the surface of the cladding were located at the position where the cladding contacted the aluminum racks, resulting in galvanic corrosion. Both the attack to the racks, and the deposits on the stailess steel cladding, are undesirable. To avoid the galvanic corrosion due the contact of two different materials, it was recommended to modify the rack holder contact region with ceramic insulator.

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