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USING VISUAL INSPECTION NDT TO CHECK INTEGRITY OF TRIGA MARK I FUEL RODS

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ABSTRACT

In more than 45 years of operation, CDTN´s TRIGA IPR-R1 reactor may be considered a very safe nuclear research installation. As recommended by national and international regulatory organizations, all research and maintenance activities ever conducted have been continuously monitored. By the end of year 2000, a lot of actions and experimental jobs were established, concerning to its power increment to 250 kW. This paper describes the application of visual inspection non destructive tests in all fuel elements installed in that reactor. The electronic instrumentation and procedures applied to perform that task, as well as the operating details of the specially designed and constructed tools, which allowed an adequate handling of the fuel rods, are described. Furthermore, a set of photographs, digitally grabbed from the recorded data is presented. Additionally, some results obtained using an ordinary low cost water resistant surveillance camera are presented. A discussion, concerning to the actual integrity state of all installed fuel elements and the efficacy and limitations of such method to verify the occurrence of flaws is made. Finally, the authors suggest the application of other non destructive methods, such as sipping and eddy current tests, as complementary inspection alternatives.

1. INTRODUCTION

Working continuously for more than 45 years, IPR-R1 TRIGA Mark I nuclear research reactor is one of the more important facilities used to develop nuclear researches in CDTN. Due to its project, construction techniques and employed materials, this 250 kW installation can be considered intrinsically safe [1]. Under normal operating conditions, there are no heavy loading or large thermal excursions, if compared to those ones found in BWR or PWR plants. However, some long term degrading agents do really exist, and can act on the structural and core components or even the fuel rods. A typical example, recently studied [2], is related to the cooling water chemistry and the corrosion processes effects that can occur in the materials used in some of the reactor components. Additionally, during fuel manipulation or maintenance activities, accidents may occur. In October 2000, the application of structural integrity evaluation methods for IPR-R1 reactor was proposed [3]. From then on, two visual inspection tests were performed in this installation. The first inspection was done in September 2000 and was conducted by a team formed by researchers and technicians of IPEN and CDTN [4] [5]. All electronic instrumentation employed in that activity belong to IPEN. The specially developed tools, used to manipulate fuels and to support the video camera, belong to CDTN.

At that time, the acquisition, by CDTN, of a visual inspection system had been considered, but the cost of a complete professional system, including the water proof and radiation resistant camera, exceeded U$ 35,000. By other hand, many ordinary CCD technology and water proof surveillance video cameras became common in the market, as well as low cost good quality PC video capture boards and image processing software. So, a camera and a capture board were purchased for tests and evaluation, in terms of image quality, CCD sensor radiation resistance and gamma radiation interference on the video signals. After some *in-situ* experiments, the functionality of the camera and the image quality were considered good. In this scenario, a simple visual inspection system was implemented, simply joining that surveillance video camera and the low cost capture board. In May 2006, a second visual inspection reactor was performed in IPR-R1 reactor using this system. In this paper are presented: the electronic instrumentation used to do the jobs, the specially designed fuel handling tool and the procedures applied to perform both inspections. Finally, some photographs digitally grabbed from the recorded images are showed.

2. CONSTRUCTIVE ASPECTS OF IPR-R1 TRIGA MARK I REACTOR

The fuels installed in IPR-R1 reactor have aluminum or inox steel cladding. In Fig. 1 some constructive details of a typical fuel rod are showed. From left to right can be seen: the external aspect, the main dimensions and the internal parts.

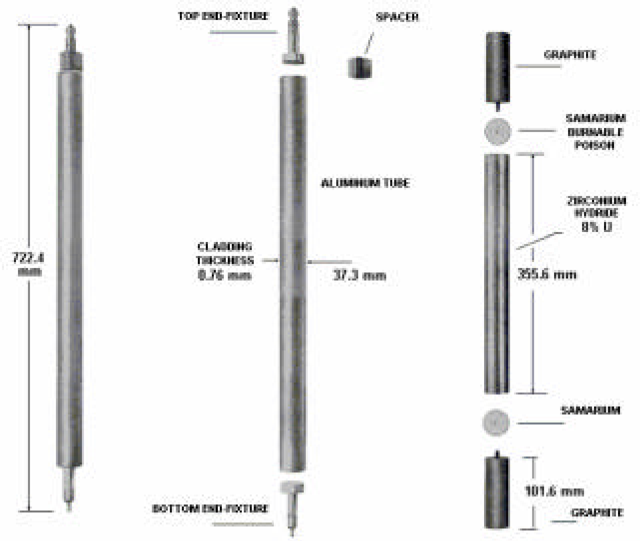

Figure 1. Constructive details of a typical fuel rod.

An artistic representation of the reactor, showing its main components and systems can be seen in Fig. 2. The configuration map, showing the 63 fuel elements installed in the core, can be observed in Fig. 3

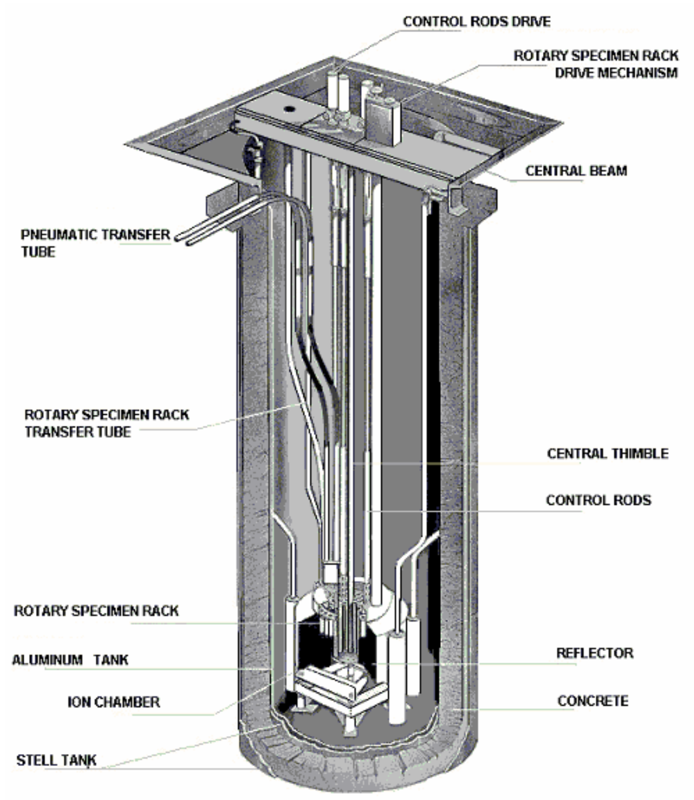

Figure 2. Main components and systems of IPR-R1 reactor.

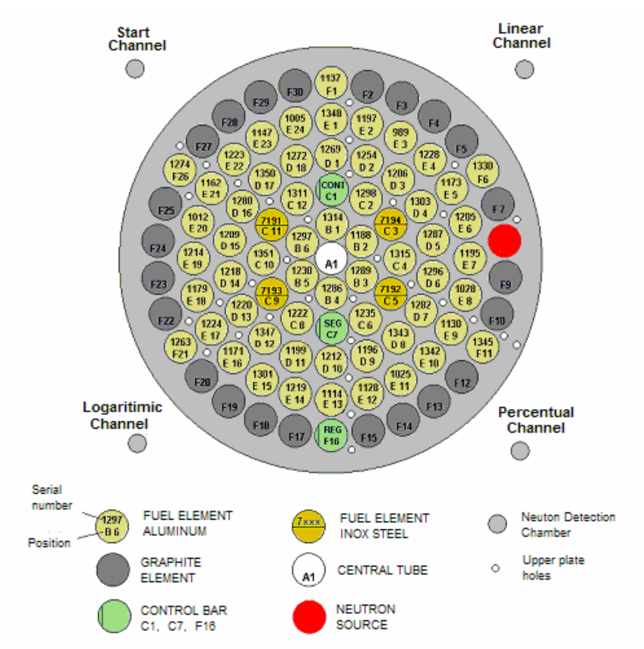

Figure 3. IPR-R1 core configuration map.

3. INSTRUMENTATION AND PROCEDURES

The instrumentation used in the first inspection, was constituted by the following devices:

- Water and radiation resistant, remote controlled, back & white video camera (IST);
- Illumination system with two independent dicroic light sources (ROS);
- Camera controller allowing remote moving (pan & tilt), focusing and zooming (ROS);
- Illumination system dimmers (ROS);
- 12” back & white video monitor (Samsung);
- Video cassette recorder (Panasonic AG 1980P);
- Video controller and characters generator (IST ETV 1258);
- Video printer (Sony – UP 880).

The electronic instrumentation was placed on a table, close to the reactor pool, and interconnected. The video camera and illumination system were attached to the lower end of a holding stick and immersed into the reactor pool (4 to 6 meters below the top), as presented in Fig. 4. The inspection of structural components was performed positioning the camera close to them. When necessary, some pan, tilt or zoom were applied. For fuel inspection, a special handling tool, which allows to pick and move safely each rod was used. The aspect of its lower end is shown in Fig. 5. To minimize the radiation damage, the camera was kept by one meter away from each examined fuel rod. All images were recorded in VCR tapes.

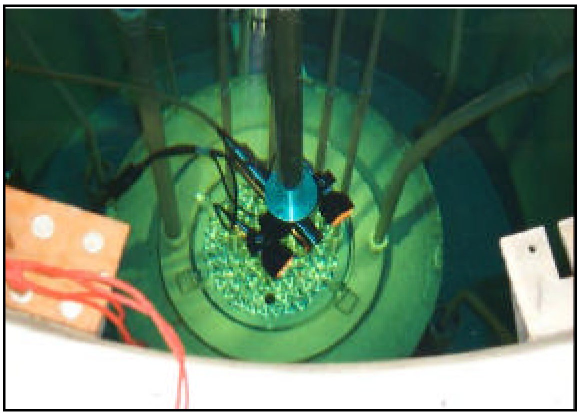

Figure 4. Camera immersed in the pool.

Figure 5. Handling tool lower end.

The instrumentation used in the second inspection, was constituted by the following devices:

- 0.05 Lux, CCD type, 560 x 420 pixels, fixed focus, water resistant video camera (SURNET TS506-PSC);
- 14” Video monitor (Toshiba - 14NL XH);
- Video capture board (Pinnacle – Studio Deluxe);
- Pentium III - 650 MHz PC, running MS-Windows XP Professional;
- 19” PC Video monitor (Samsung Syncmaster 997-DF);
- Image acquisition/edition software (Pinnacle - Studio 9.0);
- Image snapshot capture software (IrfanView 3.70).

The procedure was somehow similar to that adopted in first inspection, but due to the high sensitivity of the camera, no special illumination system was used. The camera was attached to the lower end of a holding stick and immersed into the reactor pool, 4 to 6 meter below the top. In the fuels inspection, the handling tool was employed. As the system does not have any panning or zooming resources, a 15 cm distance from the camera to fuels (still with good focus) was established. All images were recorded as digital (*mpg)* video files.

4. RESULTS

Within the limits of the method, the first inspection showed that all structural components, the core and the tank of the reactor were in good conditions. Concerning to the fuels, seven indications were pointed, as presented in Table 1. In the second inspection, the structural components, the core, the tank of the reactor and the fuels listed in Table 1 were re-examined. After 6 years of operation, none severe changing was verified. Six representative images, taken from the recorded video files, are presented in Fig. 6 to Fig. 11.

Table 1. Fuels with noticeable indications pointed in first visual inspection

Fuel Identification	Position in the core	Indicação
1179	E-18	Deformation (kneading) in the lower termination pin
1314	B-1	Deformation (bending) in lower termination pin
1199	D-11	Corrosion pit
1220	D-13	Oxide film color difference in the active/inactive zone
1147	E-23	Oxide film color difference in the active/inactive zone
1188	B-2	Corrosion pits
1205	E-6	Deformation (kneading) in the lower termination pin

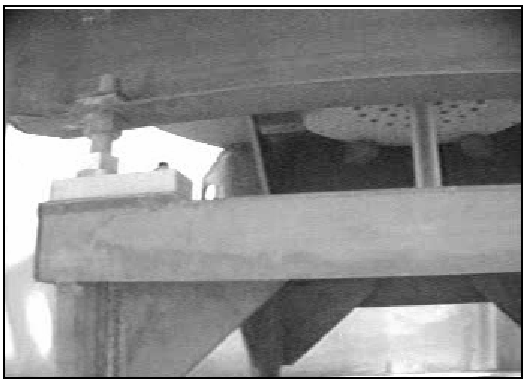

Figure 6. View of the reactor structure.

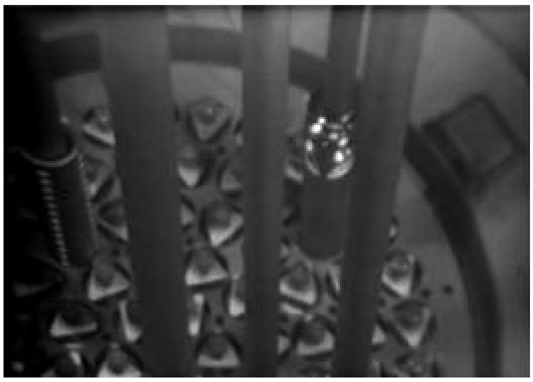

Figure 7. Fuel being taken for inspection.

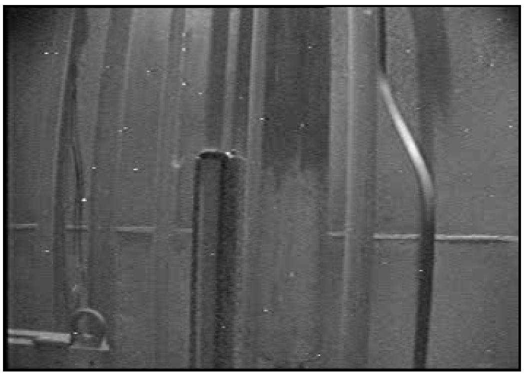

Figure 8. Fuel 1220 color difference.

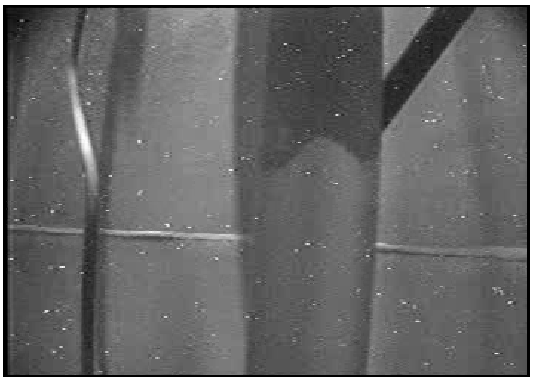

Figure 9. Fuel 1147 color difference.

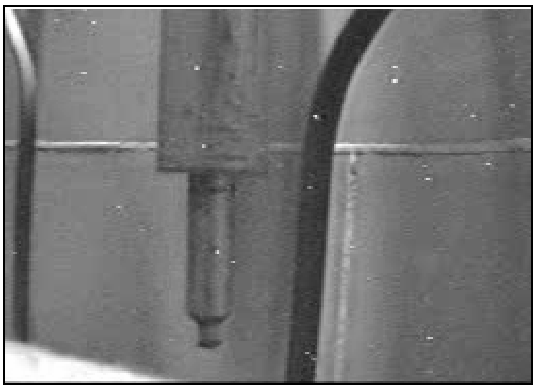

Figure 10. Fuel 1179 kneaded pin.

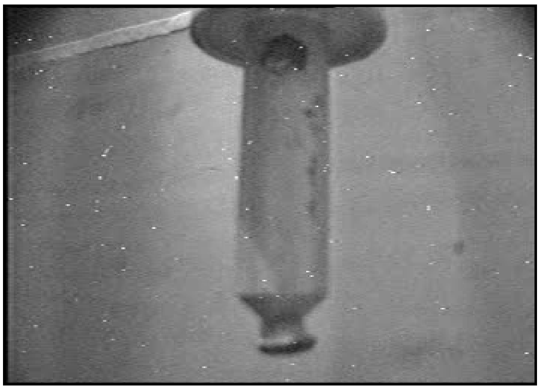

Figure 11. Fuel 1205 kneaded pin.

5. CONCLUSIONS

Remote visual inspections of the structural components, the tank, and the fuel rods of IPR-R1 reactor has been performed with good results. Most of the noticeable indications, found in two inspections performed in six years, are basically related to oxidation processes present in the cladding of some fuels. Other indications concern to handling operations, resulting in few cases of deformation (bending or kneading) mainly at the lower termination tips. Within the technical limits of the visual inspection method, the integrity of the whole installation can be considered good. The authors suggest the development and application of other inspection methods, such as sipping and eddy current tests, as complementary integrity evaluation processes.

REFERENCES

1. CDTN, *Relatório de Análise de Segurança do Reator TRIGA IPR-R1*, CDTN, Belo Horizonte, Brazil (2000).
2. C. F. C. NEVES, M. M. A. M. SCHVARTZMAN, W. R. C. CAMPOS, N. N. ATANAZIO FILHO, "Corrosion Monitoring of Aluminium Alloys in the TRIGA IPR-R1 Research Reactor", *Proceedings of Research Reactor Utilization, Safety, Decommissioning, Fuel and Waste Management Conference*, 10-14 Nov. 2003, in CD-ROM, Santiago, Chile (2003).
3. J. R. B. CRUZ, Z. ROCHA, A. Z. MESQUITA, P. F. OLIVEIRA, R. R. RODRIGUES, "Programa de Gestão de Envelhecimento para o Reator TRIGA IPR-R1". *Proceedings of XII Encontro Nacional de Física de Reatores,* 15-20 Oct. 2000, in CD-ROM, Rio de Janeiro, Brazil (2000).
4. A. T. SILVA, J. A. PERROTA, *Inspeção Visual dos Combustíveis do Reator IPR-R1 do CDTN*, IPEN, São Paulo, Brazil (2000).
5. D. A. ALENCAR, S. F. SILVA JÚNIOR, *Acompanhamento do Ensaio de Inspeção Visual nos Combustíveis do Reator IPR-R1*, CDTN, Belo Horizonte, Brazil (2000).