Implementation of a cabin X-rays in hot cell

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Abstract

The Fabrice process for the reconstituated short length irradiated rods in a hot cell was developed by the CEA, especially for power ramp testing. This technique requires intricate operations in a hot cell with specially adapted equipment and great skill people :

An end plug is inserted under pressure and fitted to the opening end of a cladding tube. The meeting surfaces of the end plug and the opening end are welded by a TIG (tungsten inert gas) process.
Experimental work to optimize the welding parameters of TIG method was achieved.

Nevertheless, some predominate defects may occur in the end plug weld joints, such as lack of penetration and cavity. So, particular attention must be paid to non-destructive examination in particular X-ray control of welding areas.

A radioscopy technique has been applied to the control of TIG welds of the end plugs to rod assemblies in a hot cell mock-up to be tested under realistic geometric conditions. This X-rays method enables immediate monitoring of any welding defaults on a TV screen.

A remote positioning system for the Fabrice rod is being developed to position fuel rods below a X-ray source. Radioscopy pictures will be recorded during remote positioning of the rod movement.

This document presents the modifications achieved by the constructor in cooperation with our laboratory staff, concerning the nuclearization of the apparatus as well as its implementation in the shielded hot cell n°2 of the CEA-DEC/SLS/LECA Laboratory in Cadarache. Hot operation of the rod positioner is planned for september 2022 because of recent refurbishing works in the plant.

Keywords : Rods positioner in a hot cell, X rays cabin, welding end-plugs, X-ray tube, Fabrice rods

1. Motivations and Objectives

In order to ensure the high reliability of Fabrice rods, it is necessary to apply a systematic control of the quality of weld end-plugs and to further improve the equipment, including radioscopy inspection.

The Fabrice process consists in the « hot cell refabrication » of short length rods cut-out from long irradiated fuel rods. Non destructive tests are carried out systematically, and these are indispensable to guarantee the remanufactured rod, in particular welding cycle inspection : any anomaly detected during

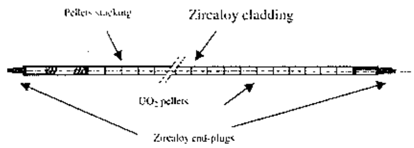

Figure 1 Fabrice rod

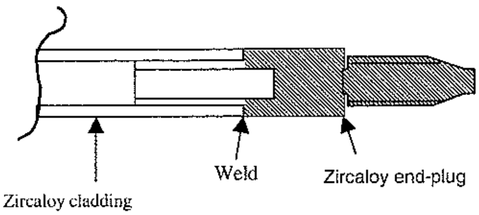

Figure 2 Weld Zircaloy end-plug

welding implies the possible presence of unacceptable defects.

This operation includes a pin seal test : a Fabrice rod will be called sealed if no anomaly is observed during visual and after result of the helium test. Photographs are often taken of welds on upper and lower end plugs. At the present time, Radioscopy inspection is carried out in an other Laboratory, and rod transport takes much time, that's the reason why we plan to implement a radioscopy equipment in **LECA** (the **LECA** Laboratory for the Examination of Active Fuels and a dismantling installation for big irradiated objects).

Discussed are the lessons learned during the project implementation in a hot cell in our laboratory, and identifies key points of the current strategy that should be maintained for any new design of X-rays device.

2. Process fabrice

The **Fabrice** process for the "hot cell remanufacturing" of shortrods made in a hot laboratory from long fuel rods was developed by the **CEA** to allow parametic studies of the irradiation behavior of pins from nuclear power plants.

An experimental rod, of 450 to 650 mm overall length, is reconstructed by using a part of an irradiated, 4 meter long PWR fuel element. It includes(inclusing Fig 1):

- the oxyde and clad of the initial rod,
- New components : insulating pellets, plug, spring

The Fabrice rod is ready for re-irradiation, once all the necessary steps are carried out during refabrication in particular quality radioscopy inspection of the weld zircaloy end-plug (**Figure 2**).

2.1. Existing X-rays cabin:

The X rays tube is located inside a lead cabin (inclosed Figure 3) where active fuel elements will have to be X-rays examined. The X rays source is provided with a standard collimator 0.2 mm, a X-rays detector and a supervisory control and data acquisition.

The source of the system is a 225 kV X-ray tube. This radioscopic system is designed for the inspection of welding areas and further cladding.

The laboratory **LECA** provides a hot cell mockup to check equipment for functional and remote operation, and provides actual hands-on training for operators. The facility arrangement is flexible and assists in solving potential problems in a nonradioactive environment.

2.2. Fuel rod positioner

One access port in a wall structure of the enclosure allows to position fuel rods between the interior of the enclosure and the X-rays cabin. The hot-cell extension chamber provides a nominal diameter 20-cm

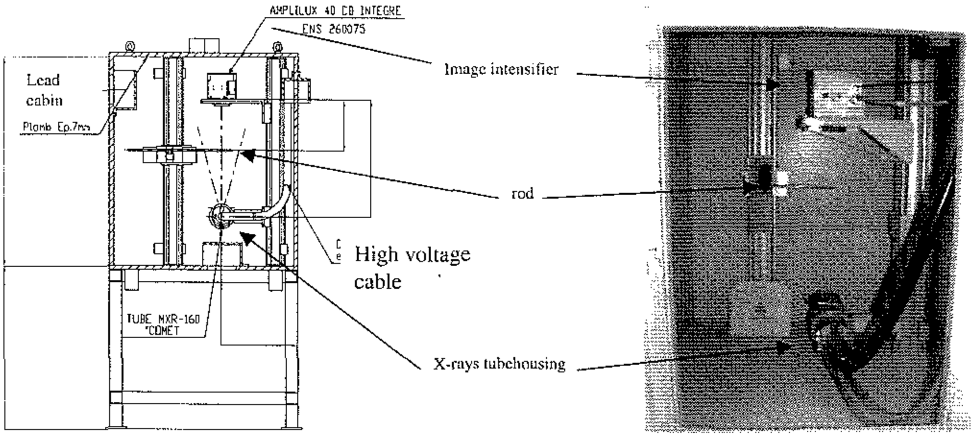

Figure 3 X-rays cabin

until the docking port of the X-ray cabin. So, fuel rods can be transferred into the cabin through the fuel rod positioner in the wall. The port are sealed by a protecting closed lead tube. A narrow aperture has been designed in optical alignment of the tube and X-rays detector. It is covered by an industrial foil. This device has been manufactured by recessing it into the wall from the inner hot cell.

The examination is carried out by translating the objects in front of x-rays beam from the hot cell n°2 through a containment and guide tube which is an integral part of the hot cell extending to the rear hot cell thus maintaining containment. This approach has many advantages, but it puts severe constraints on the design and safety aspects of x-rays radioscopy rig. A chucking grips the rod while a Trapezoidal screw sets it below the X-rays beam (one turn for 5 mm).

Remotely operated O-ring ethylene propylene seals (as EP 851) have been installed in the fuel rod positioner (inclosed Figure 4) to avoid the risk of contamination (radioactive dust) during transfers of highly alpha-contaminated rods from the hot cell to the rear X-rays cabin.

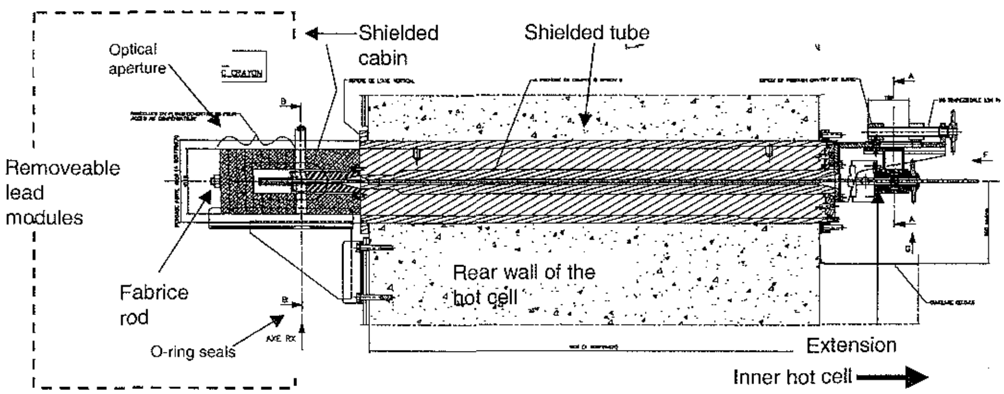

Figure 4 Layout of the fuel rod positioner

To reach the X-ray area, the sample will be mounted on an extension rod (Figure 4). The upper end has a gripping portion to be locked with the Fabrice rod.

The shielding protecting tube consists of lead modules assembled by screws (Figure 5). These components are mechanically attached and can be removed outside the hot cell in order to replace the

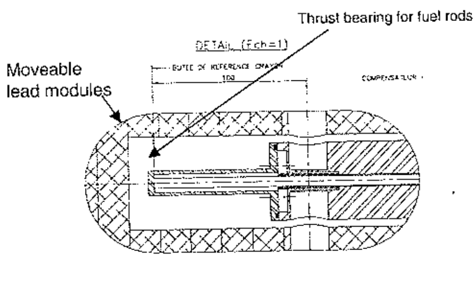

Figure 5 Stack of lead modules/shielding of the Fabrice rod

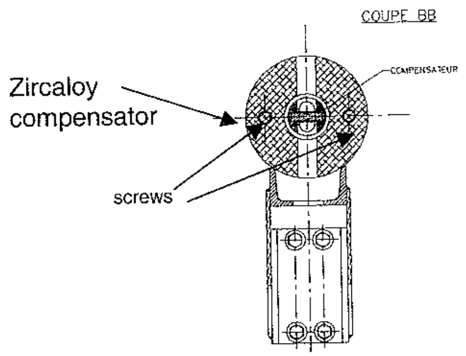

Figure 6 Zircaloy compensator

compensator.

The Zircaloy compensator (Figure 6) is used to compensate the shape of the rod in order to avoid contrast variations.

Circumferential weld is inspected by radioscopy at various incidences (60°). The method consists in carrying out several transversal scans of the fuel rod from different view angles (typically 6 scans) (Figure 7).

The X-rays source and detector will be driven by a motor on a stroke of 150 mm.

Next operation will consist to drill a port through the lead cabin between the X-rays tube and detector. It permits to insert the lead protected tube (Figure 8). His position is function of the geometric blurring.

2.2.1. Geometric blurring

The port position on the X-rays cabin will be worked out for improving accuracy. Indeed, the distance between the X-rays detector and the controlled object has an effect on the contrast of the image of the flaw under conditions of slight geometric blurring. In any case, the fuel rod will have to be closer to the X-ray image intensifier. For this reason, the diameter of the protected tube has been evaluated to be smaller as possible (the useful distance source/ X-rays detector is 90 mm).

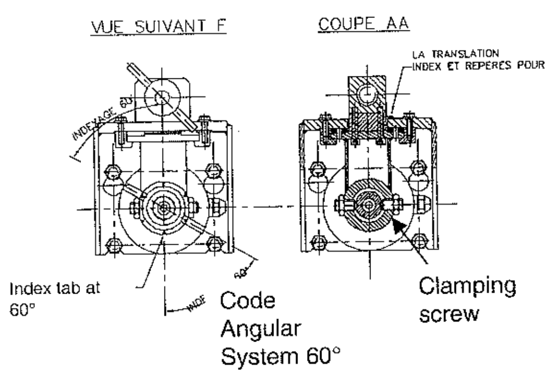

Figure 7 : Front Layout of the fuel rod positioner

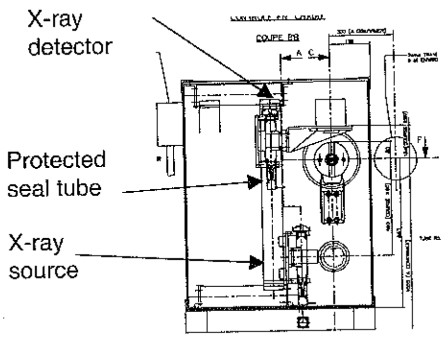

Figure 8 : Layout of the future cabin

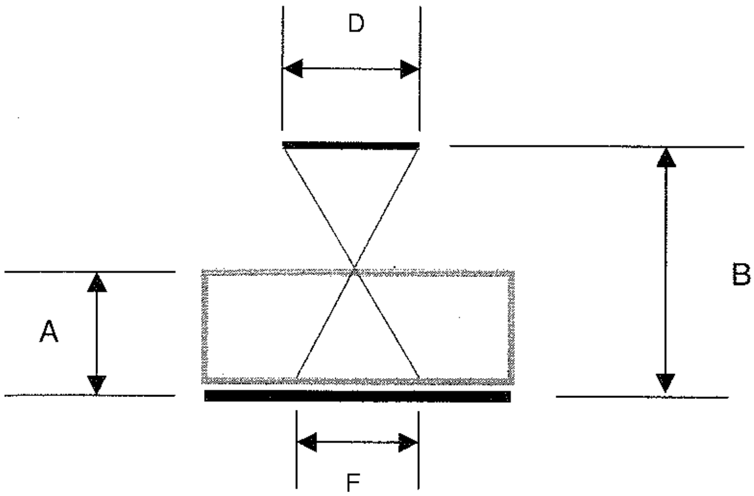

Figure 9 geometric blurring

It represents the dark area around a X-ray radioscopied object. Its origin comes from the source size.

It's function of the following parameters:

$$F = \frac{DxA}{B - A}$$

F = geometric blurring

D = size source

A = distance between incidence face of the object and the X-ray detector

B = distance source/detector

Commissioning for hot operation will be around September 2002 because of recent refurbishing works in the plant. To demonstrate the feasibility of the position operations, and to optimise the maintenance scenario and the handling equipment design, a test facility will be set-up in a full size mockup that will allow to simulate all handling operations inside hot cell.