The Irradiated Elements Cell at PHENIX

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Abstract

The Irradiated Elements Cell (IEC), one of the hot cells at PHENIX, became operational in 1974 at the same time as the PHENIX reactor. The purposes of the IEC are to verify the irradiated fuel in the PHENIX reactor, to study its behaviour and to dismantle core elements for subsequent reprocessing of the fuel pins.

This paper presents the Dismantling and the Non-Destructive Testing Facilities in the IEC at PHENIX.

Keywords

PHENIX, Irradiated Elements Cell, sub-assembly dismantling, Non-destructive Tests.

1. Introduction

Located on the banks of the Rhone river, PHENIX, an integral part of the Marcoule nuclear site in the Gard, is a prototype sodium fast breeder reactor (FBR). First divergence took place in 1973, and PHENIX delivered its first kilowatt-hours in December 1973. The objectives for this prototype were to demonstrate that the FBR is a safe reactor, that it produces electricity efficiently, that it is capable of serving as a breeder reactor, and that it can serve as a tool for increased understanding and further development of this reactor type and of future reactors. Recent years were marked by significant renovation work following several safety re-evaluations, and power operation resumed in 2003. Current objectives are to carry out a program of experimental irradiations over a period of six cycles in the field of transmutation and nuclear waste management, and to provide support for studies on future nuclear reactors.

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2. Sub-assembly dismantling

The IEC (cf. fig. 1) is 14 m long, 6.5 m wide and 9 m high. The concrete walls are 1.20 m thick and the inner liner is made of stainless steel. IEC atmosphere is kept in nitrogen with less than 2 % of oxygen to prevent the risk of sodium fires. Operations are conducted from the corridors located around the cells with remote manipulators and cranes and the operators monitor through the windows.

The IEC partially faces the fuel storage drum which enables the two be connected. The drum, filled with sodium, is storage in which the irradiated sub-assemblies are cooled after their extraction from the reactor vessel. The connections between the IEC and the storage drum consist of two channels which feed the two sub-assembly storage rings in the storage drum. The channel consists of a sleeve which is integral with the storage drum tank roof. A gas-tight valve equips the upper part. A removable sleeve is positioned inside the channel and serves to unlock the sub-assembly grab clamp and stop any potential sub-assembly pot from rising into the cell.

Once the sub-assemblies have been removed from the storage drum, they are washed to eliminate any residual sodium. The washing process consists of gradually transforming the sodium into soda and carbonate by circulating inert wet gas (nitrogen) then water. The sub-assemblies are rinsed then nitrogen-dried to avoid ingress of any water into the cell. The washing pit is a 250-mm diameter channel which can hold one entire sub-assembly or a basket holding pins or structures. The top of the pit, equipped with an airtight valve, comes out in the IEC. The pit itself, equipped with the nozzles required for the process (inert gas, water, ventilation, effluents) is located in a separate room located under the IEC.

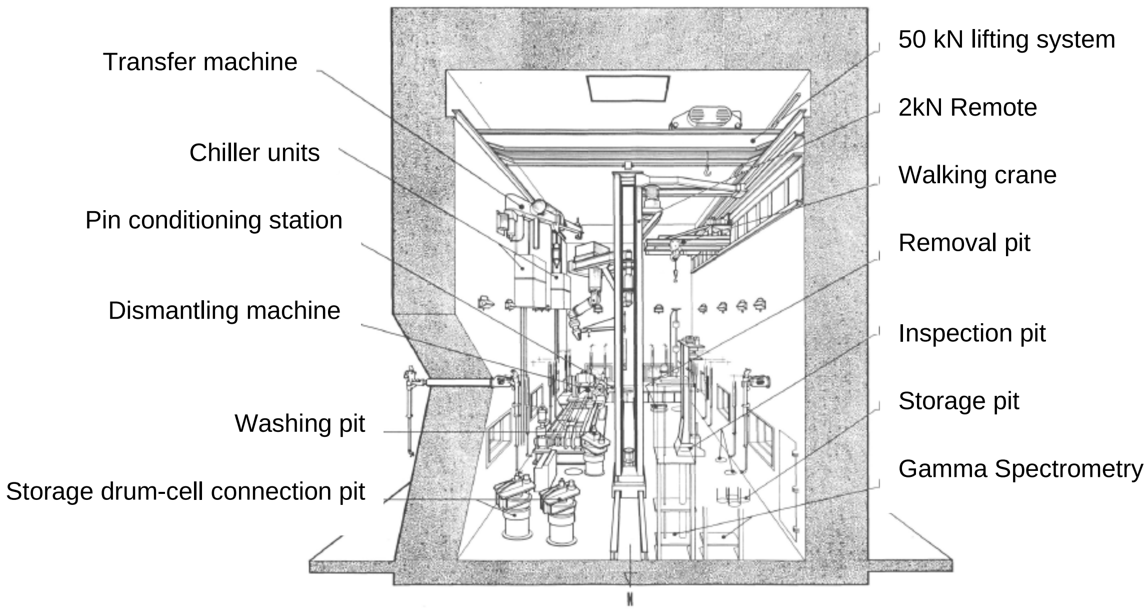

Fig.1: The Irradiated Elements Cell

The sub-assemblies are approximately 4 meters long with an average weight of 250 kg. After washing, they are transferred to the Annex Cell (AC) for dismantling. The sub-assemblies are handled with automatic inertia grab clamps, manually controlled handling rods and various lifting means.

The AC (Fig. 2) is 7 m long, 2.5 m wide and 7 m high. Like the IEC, the AC is kept under nitrogen atmosphere. The method used to dismantle the sub-assemblies in this cell consists of cutting them into 4 parts in order to isolate the part of the wrapper tube containing the pins. One edge of the tube undergoes weakening machining then through machining, followed by the opposite edge, in order to open the tube and extract the pin bundle.

The various machining operations (cf. Fig. 3) are performed by the usual machining processes at slow speed : reciprocating sawing and milling. Equipment includes a 4-saw line of saws. A milling machine machines the two edges. The machine has a cutter blade at the tip. A guide roller which rolls along the edge to be milled ahead of the miller cutter sets the depth of the cut. A power cylinder extracts the pin bundle in the wrapper tube through the extraction line partially opened with a retractor device and transfers it to the recovery container. The pin bundle is then transferred to the pin conditioning facility in the IEC. The metallic structures from the dismantled sub-assembly are then contained in metallic bins (approximately 2 sub-assemblies per metallic bin) and removed to the DIAM facility at Marcoule, where the metallic bins are stored for approximately 30 years for radioactive decay.

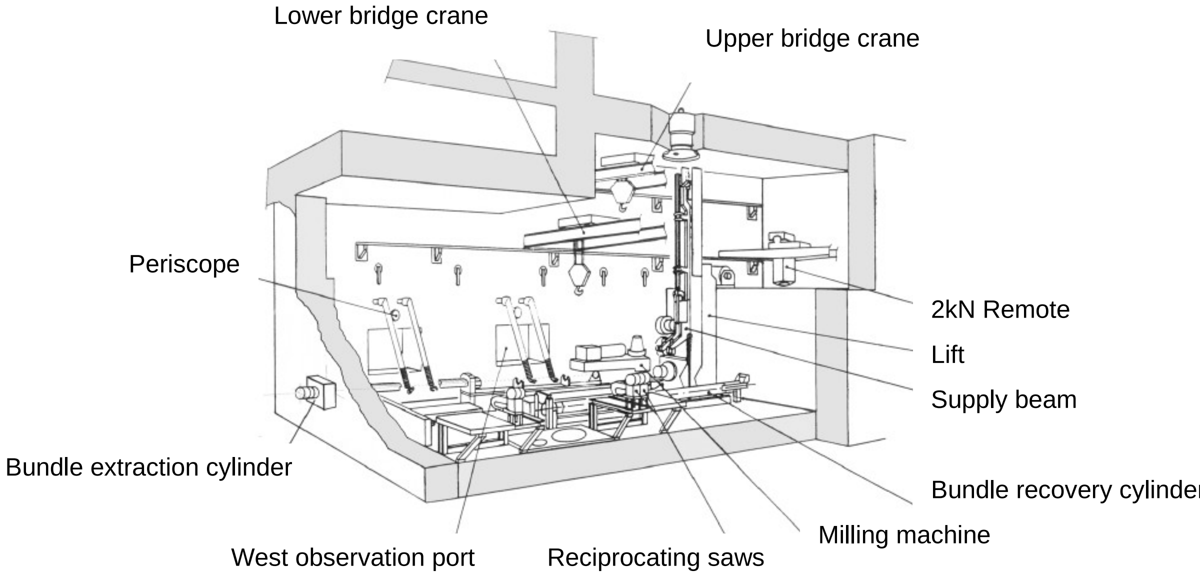

Fig.2: The Annex Cell

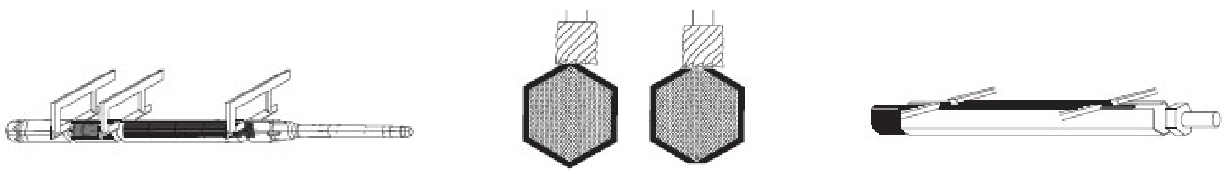

Fig.3: Sub-assembly dismantling in the Annex Cell

At the pin conditioning facility, (cf. Fig.4) the pins are separated from the support rails and placed in the sheath. Each sheath holds approximately one-half bundle. The facility includes a reception and spreading counter, one power cylinder for extracting the pin from the rail, and a welding machine to weld the sheath caps. Once the sheaths are filled with pins and capped, they are placed in a holder with room for up to eight sheaths. This holder is stored in shielded, cooled storage space for later shipment. To ship the pins, the holder is positioned in the transport packaging which docks under the IEC in a vertical position.

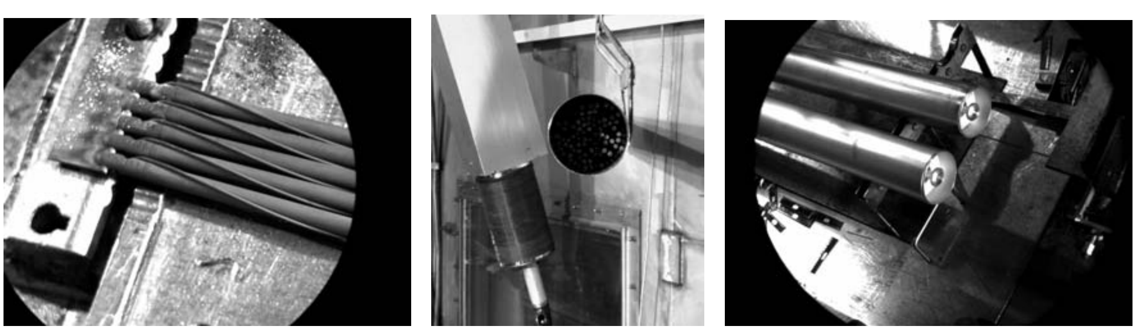

Fig.4: Pin conditioning facility

The sheaths of irradiated pins are removed 4 by 4 in transport cask to the APM storage facility at Marcoule, where they await later transport to La Hague for reprocessing. There is an average of two shipments per week (1 shipment of 4 sheaths of pins, and one transport of metallic bins).

The IEC provides for several different storage possibilities while awaiting this transportation. These include a ventilated pit able to hold the sub-assemblies which require cooling, two non-ventilated sub-assembly pits, one non-ventilated pit used to hold the pin-filled sheaths awaiting shipment. The Annex Cell itself has two pits able to hold one partially dismantled sub-assembly and one pin container, and one pit for metallic bins for structures being filled.

Two intervention cells connected to the IEC and the Annex Cell use remote disassembly operations to decontaminate and perform maintenance on the equipment removed from the cells. These cells are gas-tight metal chambers equipped with biological protection consisting of 10-cm thick lead brick external lining of the walls. The cells have workstations with observation windows and remote manipulators or telescopic nippers. They are in air atmosphere with slight overpressure with respect to the cell chamber and approximately 3-mbar negative pressure with respect to the operations corridors.

3. Non-destructive experiments

The IEC has also very comprehensive equipment to conduct the Non-destructive Post Irradiated Experiments to quickly obtain early data on the behaviour of the experiments after their irradiation in the reactor.

3.1. Objects examined

The experimental objects which are examined are as follows:

- Standard geometry sub-assemblies containing experimental pins (composition of the cladding, type of fuel, geometry, irradiation conditions …),
- Rig containing experimental pins or baskets holding structure elements or materials samples. For irradiation purposes, these rigs are placed in carrier sub-assemblies (cf. Fig.5).

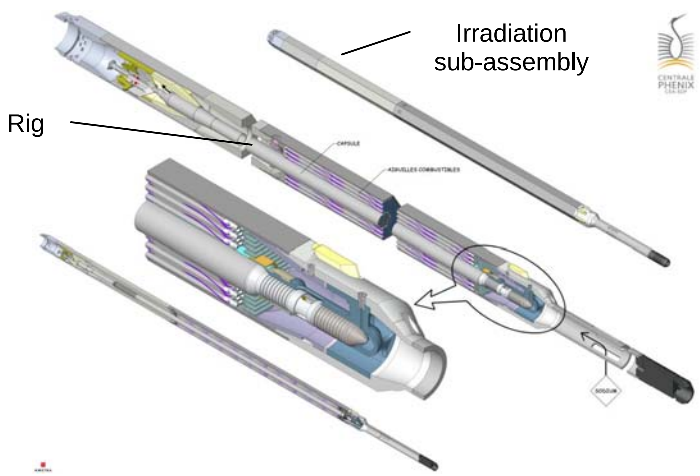

Fig.5: Rig inside a carrier

3.2. Resources

3.2.1. Visual inspections

The object is run before the periscope to obtain a digital video recording. These analysis tools verify the absence of any major deformation of the rig or the pin.
When pins are equipped with spacer wires, inspection takes place before and after removal.

3.2.2. Length measurements

Length measurements are taken on the rigs and on the pins using a mechanical comparator to 1/100th of a millimetre. The measurement reference is a measuring rod which is specific to each object to be analysed.

3.2.3. Rig diameter and sag measurements

Diameter and sag are measured on a horizontal beam equipped with a moving carriage. The rig measurement bench uses two LVDT sensors (diameter and sag). With respect to the pins, measurement of the diameter and deformation due to the spacer wire is performed using laser shadowscopy (cf. Fig. 6).

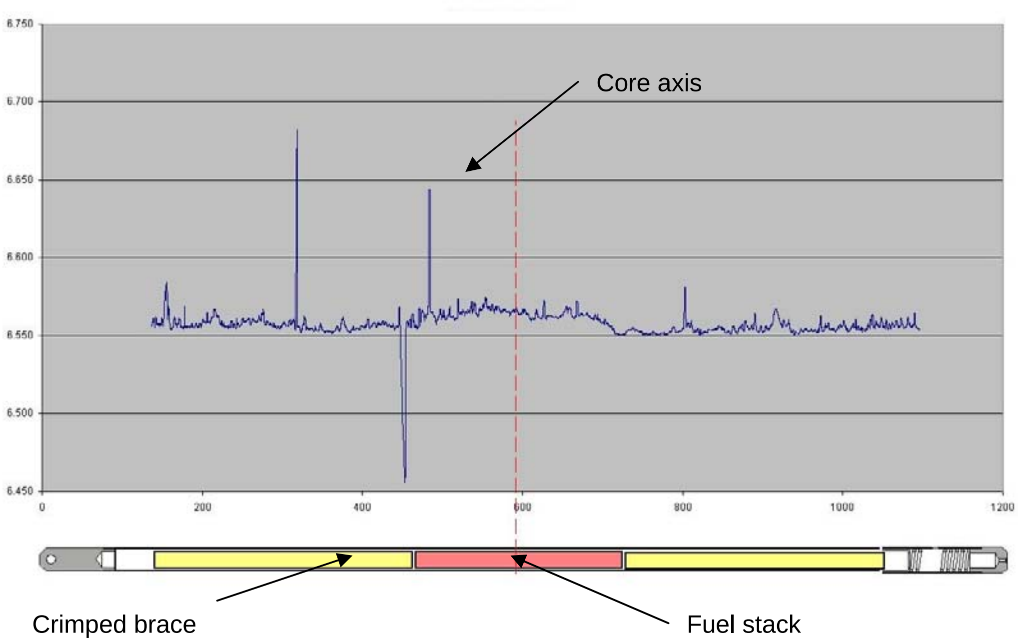

Fig. 6: Pin diameter measurement

3.2.4. Eddy currents

This diagnostic tool is currently being renovated. Its purpose is to control pin clad condition and detect any clad – oxide interactions.

3.2.5. Gamma spectrometry

Measurement is taken with a millimetric graduated scale when the pin runs in front of the detector. This examination determines production and migration of the γ emitters in the pin by analysing the profiles of the different radio-elements (cf. Fig. 7).

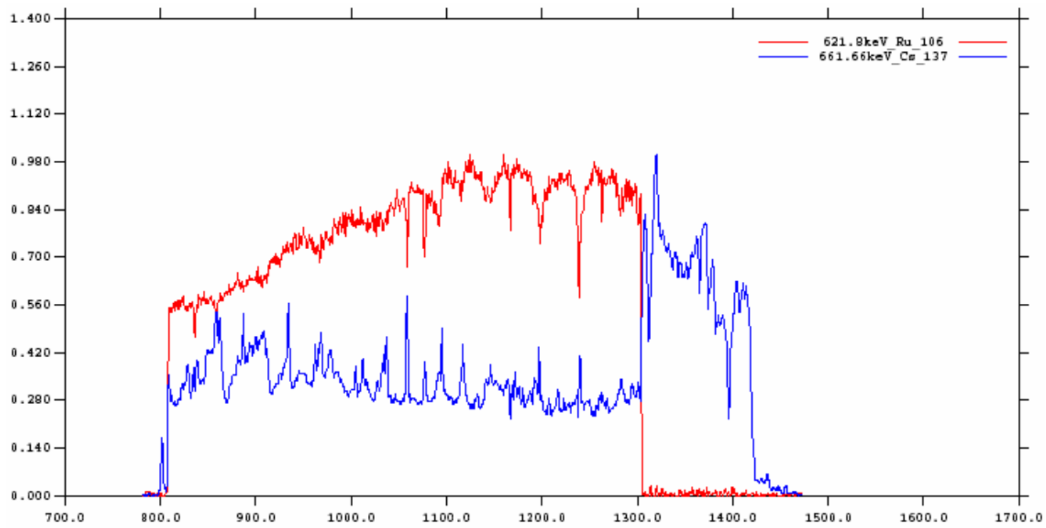

Fig. 7: Spectrometry for one pin

3.2.6. Neutron radiography

The neutron radiography has power of 5.1015 fissions/s (approximately 170 kW). It is used to imprint photographic film by activating an indium plate (cf. Fig. 8).

This process is used to obtain an image of the fuel pellet column inside the pin and to detect any changes (for example, reaction of a central hole or pellet fracturing).

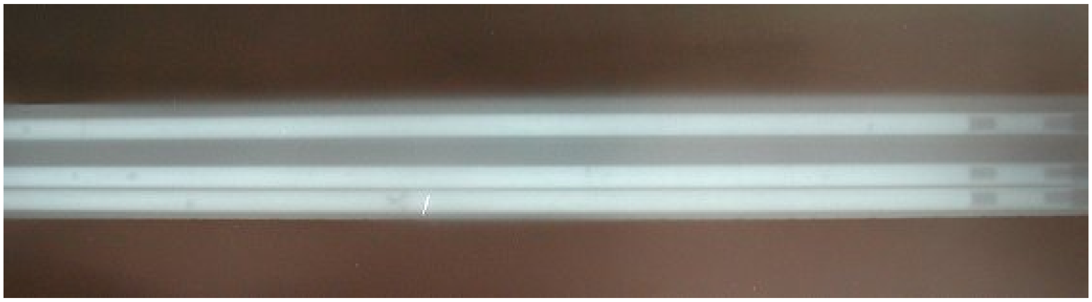

Fig. 8: Image obtained using neutron graphy