INTRODUCTION

The Phenix Irradiated Elements Cell has been operated since 1973. This cell was dedicated to the dismantling of the spent fuel sub-assemblies and the irradiation capsules, to the post-irradiated nondestructive examinations, and, in the early stage of operation, to the refabrication of new experimental irradiation sub-assemblies or capsules with irradiated pins. But, in 1981, the whole mechanical treatment processes of the sub-assemblies dismantling line were put in a new cell (Annexe Cell, cf. Figure 1). These processes were designed to assure the safety of the pins removal operation from the stainless steel hexagonal wrapper. The first operation of the dismantling process needs a sawing bench. After more than 35 years of operation and despite a corrective maintenance programme reinforced during the last decade some signs of obsolescence of the original saws had been appeared. Furthermore, the saws need to be decontaminated before their manual corrective maintenance carried out in a low level activity workshop. The decontamination procedures were becoming more and more complex due to the lowest efficiency of the decontamination products used considering the increasing quantity of sticky aggregates made of irradiated grease and activated stainless steel chips. For both reasons it was decided in the beginning of 2008 to start the refurbishment of the sawing bench. The purpose of this paper is to focus on this operation. After a presentation of the dismantling process of a Phenix fuel sub-assembly followed by a short description of the original saw that had been set up and operated since 1981, its main characteristics and operating principles, the necessity of a new design will be discussed and the upgraded design will be presented. Finally, the resumption of the dismantling operation with the upgraded sawing bench and the feedback will be presented.

Figure 1: General view of the Phenix hot cells.
DISMANTLING PROCESS OF A SUB-ASSEMBLY IN THE ANNEXE CELL

After moving to the Annexe Cell the spent fuel sub-assembly is laid down from vertical to horizontal position, then, with a sliding table, transferred on the sawing bench previously configured with the exact appropriate number of saws (2 or 3) according to the number of pins bundle embedded in the sub-assembly (1 or 2 respectively for a breeder or a fissile fuel sub-assembly). Then the sub-assembly is simultaneously cut in three (breeder) or four (fissile fuel) segments: the spike, the fuel or breeder pins bundle in its stainless steel hexagonal wrapper, the upper axial blanket pins bundle (for a fissile fuel sub-assembly) and the upper neutron shielding with the handling head. The Figure 2 shows the sawing locations for a fissile fuel sub-assembly.

Afterwards, for a fissile fuel sub-assembly, the pins bundle segment is grasped with an automatic gripper, handled with the overhead crane of the hot cell, and moved to the milling machine. Indeed, in such a sub-assembly, the stresses between the wrapper and the fissile fuel pins increase with the high cumulative dose rate. So it is absolutely necessary first to release them to secure the pins for the next operation. So, a first countersinking is made on one of the edges of the hexagonal wrapper to ablate about 50% of the thickness to weaken its mechanical resistance. Then the segment is turned over and a second countersinking is made on the opposite edge to open the hexagonal wrapper on about 66% of its length (cf. Figure 2).

Finally, the pins bundle segment is handled as previously described and moved to the extraction bench. First of all the claws of an opener machine are engaged in the opening previously made in the hexagonal wrapper with the milling machine to widen it, then the pins bundle is pushed out with an hydraulic jack into a special handling basket via a channel that holds back the wrapper during this operation (cf. Figure 2). Finally, the basket filled with the pins is moved to the conditioning workstation in the Irradiated Elements Cell and the structures of the sub-assembly (hexagonal wrapper, spike and neutron shielding) are cut in smaller pieces in order to optimise their conditioning in the waste container.

Figure 2 : Dismantling process of a Phenix standard spent fissile fuel sub-assembly.
ORIGINAL SAWING BENCH AND RELIABILITY PROBLEM

The sawing bench was equipped with two or three hydraulic power hacksaws. Based on a model commercially available in the 80's, five saws were supplied by BARRAS-PROVENCE Ltd which was in charge of their modifications for their appropriate remote handling and operating in the Annexe Cell environment (cf. Figure 3).

For example, as shown in Figure 3, some remote handling modifications are the following:

- The baseplate shows two V-shape cutouts to allow, at the rear, the positioning of the saw handled by the overhead crane guided by three locating pins welded on the bench (only the two pins on the sides are visible on the picture), and, at the front, the tightening of the saw with a locking pin.
- A pin force fit at one end of the blade makes easier its remote positioning in a groove milled in the holder screwed on the arm, and, a hex-head screw allows the stretching of the blade with a socket wrench.
- The cutting force is adjusted with a capstan-head screw acting on the hydraulic system.
- A T-shape telemanipulator handling is welded on the bottom jaws of the vice.
- All the electrical and pneumatic standard connectors were changed.

From the operational principles point of view the cutting results of two synchronised motions: The blade moves backwards and forwards driven by an electrical gear motor, tearing the material and removing the chips on the backwards stroke, whilst a pressure is applied on the cutting arm and the blade with a hydraulic pump. Only dry cuttings were performed (no coolant used) because of criticality risk.

Two or three saws were always being in operation in the hot cell while on the others a corrective maintenance and some qualification tests was being performed in a dedicated workshop beside. So, it was not being necessary to implement a preventive maintenance programme. Indeed, in that way there was always a saw in perfect working order available on the shelf.

But, after more than 35 years of operation of the Annexe Cell (i.e. 1300 sub-assemblies cut or less than 800 cuttings per saw) and despite this maintenance policy reinforced during the last decade some signs of an inexorable obsolescence of these saws had been appeared.

Furthermore, the saws needed to be decontaminated before a manual corrective maintenance be able to be performed in a low level activity workshop. Furthermore, the decontamination procedures were becoming more and more complex due to the lowest efficiency of the decontamination products used considering the increasing quantity of sticky aggregates made of irradiated grease (i.e. lubricant leaks from the hydraulic system) and highly activated stainless steel chips. Additionally, the impossibility to remove by a remote handling operation the electrical gear motor was making necessary to do this operation by hand previously directly in the decontamination box.
For both reasons it was decided in the beginning of 2008 to start the refurbishment of the sawing bench.

NEW SAWING BENCH

AEMCO Ltd was in charge of the design and the fabrication of a new-generation of saw with the following specifications:

- A higher reliability of the blade guidance, the deflection of the cutting being not tolerated because of the closeness of the pins, and more especially of the upper axial blanket pins,
- A performance of more than 1000 cuttings to avoid a preventive maintenance programme,
- A modular design to limit the decontamination operations to the only broken part of the saw, each unit having to be compatible with the top (Ø 590 mm) and bottom (700×1200 mm) openings of the Annex Cell,
- The compatibility with the remote handling apparatus (overhead crane, telemanipulators CRL J and M50 models) of the operational organs: valves, electrical and pneumatic connectors, blade, motors, …
- The compatibility with the unchanged existing baseplate fixing system,
- The necessary outline dimensions to put up two saws side by side for the fissile cutting configuration,
- The consideration of several years of corrective maintenance feedback,
- The use of a maximum standard spare parts available at retail,
- The limitation of the hydraulic fluid quantity according to the criticality rules of the cell.

After two years of design and development, few remote handling tests performed in an inactive hot cell mockup equipped of the whole remote handling apparatus (telemanipulators and crane), and many additional reliable and endurance tests, five saws were supplied on December 2012.

The global shape of the new saw is almost similar to the first-generation one (Figure 4) and the heart of this saw, the hydraulic unit, is still the same. The new saw is taller than the previous one for several reasons: first the modular design, secondly the compatibility with the hot cell rooftop opening (a 590 mm diameter tunnel) and third the short centre-to-centre distance (331 mm) between two adjacent saws.

Figure 4 : New design of a power hydraulic hacksaw by AEMCO Ltd
But, the main challenge of this new design is related to the necessity to keep an absolute control of the blade guidance during a cutting operation for safety reasons. First of all, the mechanical analysis about the stresses applied on the blade during a cutting operation concludes:

- The misalignment of the blade increases when its penetration into the material is progressing,
- The cutting forces highly stress the two linear guidance systems corresponding to the up-and-down and back-and-forth arm motions.

And, hot cell environment constraints have to be taken into consideration in the reflection. It is not possible to lubricate the linear guidance systems because of possible leaks on the sub-assembly, and the pins as well. Additionally, it is not possible to use some specific materials that could be useful to solve the problem except that they lose their mechanical properties under high cumulative dose rates. Finally, a corrective maintenance is not easy and restricted in a hot cell.

To respect all these requirements and constraints the following technical solutions were implemented in the new saw design:

- The stiffness of the blade linear guidance systems was obtained first by a well design dimensioning of the bearing structure made of the base frame, the vice and arm guidance columns and their top flange plate.
- The whole parts related to the blade linear guidance systems exposed to a high mechanical stress were made in special steel grades having high elastic and mechanical resistance: 40CMD8 for the arm, DFO110 for the small guidance parts or the ball-bearings, 45CND16 for both arm and vice columns.
- All the parts related to the blade linear guidance systems were perfectly fit with less than few hundredth millimeter plays.
- A dry lubrication is performed with carbide inserts bronze plates (maintenance free) screwed on the rubbing surface areas (cf. Figure 5). These wear parts should be replaced outside of the hot cell. Additionally, ball-bearings equipped the moving parts of the guidance axes particularly exposed to high bending stresses (cf. Figure 6).

![Figure 5: Arm motion guidance lubrication carbide inserts bronze plates – (a, b) up-and-down motion; (c, d) back-and-forth motion.](image)

![Figure 6: Arm motion guidance ball-bearings – (a) back-and-forth motion; (b) up-and-down motion](image)
An example of the new designed sawing bench for a spent fissile fuel sub-assembly configuration is reported on the Figure 7.

Figure 7 : New sawing bench set-up for the dismantling of a fissile fuel sub-assembly.

SETTING UP AND FEEDBACK OF FEW WEEKS OF OPERATION

To set-up the new sawing bench it was first necessary to evacuate outside the cell the old highly irradiated saws due to the activated stainless steel chips sticky aggregates in a waste container. Each saw was handled with the overhead crane and then lifted down through the bottom opening directly in a waste container previously partially filled with other metallic low level activity wastes as an appropriate shield placed in the decontamination and easement cell underneath.

Then, after several inactive functioning tests had been performed outside, three new saws were conversely handled and put in the hot cell. The final qualification hot tests had been performed and the dismantling irradiated elements process was restarted on 20th December 2013 with the dismantling of an experimental capsule holder (cf. Figure 8).

Figure 8 : Experimental capsule holder dismantling operation on the new sawing bench.
During this operation two unexpected events happened:

- The cutting time was higher than expected according to the reference cutting times recorded during the endurance tests.
- The arm of one of the three saws jammed during the cutting.

The increasing of the cutting time was the consequence of the compressibility property modification of the hydraulic fluid due to several successive inappropriate inflating operations of the pressure accumulator.

The jamming of the arm was the consequence of an inappropriate handling operation. During the setting up of the new saws it was necessary to handle many times each saw from and to their cutting location. Due to a malfunction of the socket wrench the locking pins were not completely unlocked and the base plates not totally free and ready for handling. So, when the saws were lifted with the overhead crane they were put under strain leading to a plastic deformation of each hydraulic unit on which the handle is attached (Figure 4).

Additionally, recently, it was noticed that the vice tightening was not permanent during the cutting because the original design of the nitrogen distribution does not allow a permanent pressure on the jaws after releasing the pushbutton of the circuit actuator. The old saws were equipped with an oversized pneumatic tightening motor that allowed the pressure holding on the jaws even after the falling off the pressure in the circuit.

**CONCLUSION**

A new generation of saws was designed based on the original one that had been operated since 1981 and five saws were supplied in Phenix in 2012. The main improvements are about the reliability and the performance of the cutting guidance system and the remote operation. The new sawing bench was qualified and restarted on December 2013. The feedback of the first weeks of operation is not completely satisfactory and some additional modifications must still be performed before reaching optimal conditions of operation.