Advanced Dismantling Techniques Applied in an Industrial Project for the Dismantling of Highly Activated Equipment – 15446

Maxime Michel-Noel (ONET Technologies), Olivier Calixte (ONET Technologies), Cyril Moitrier (CEA), Samuel Blanchard (CEA), Julien Bani (CEA), Philippe Girones (CEA), Renaud Bourdy (CYBERNETIX), Gilbert Terry (CYBERNETIX)

ABSTRACT

Commissioned in 1958 on the CEA nuclear site of Marcoule (France) and shut down in 1997, the former UP1 plant was dedicated to reprocess the spent fuel from G1, G2 and G3 GCR reactors. Since 1998, a wide program for cleaning-up and dismantling the plant has been developed in order to dismantle the process equipment, eliminate any radiological risk in all buildings concerned and remove all the resulting waste. Major technical challenges are related to the wide range of complex components and equipment in the facilities such as chemical dissolvers, extractor batteries, evaporators, tanks; and to a high risk of exposure, due to the presence of fission products.

To address these challenges, CEA led R&D programs to develop advanced tools for complex dismantling projects: immersive virtual reality, laser cutting techniques, special remote-controlled arms combining dexterity and high resistance to irradiation

The purpose of this paper is to provide an overview of a practical implementation and to show first results of these advanced techniques on a real case: the dismantling of dissolver's equipment from the dissolution workshop of UP1 plant. ONET Technologies has been chosen by CEA to design, build and operate the overall dismantling and waste treatment system for this project.

ONET Technologies designed two main subsystems to meet all the requirements for this project: first, the "Remotely-Operated Handling and Cutting Unit" and second the "Waste Extraction and Conditioning Unit" and the combining innovative technologies. During the design phase, the "Immersive Virtual Reality" has been used to qualify the kinematics in the final environment and the preliminary dismantling scenario.

Following a first R&D program of CEA regarding the laser cutting technique applied to nuclear decommissioning, ONET Technologies and CEA realized elementary inactive tests based on a 6 kW Nd-Yag laser source to qualify the cutting performance according to material and thickness. Main objective was to meet the safety criteria and to check the physical characteristics of waste resulting from the laser cutting operation.

The Remotely-Operated Handling and Cutting Unit was equipped with a MAESTRO manipulator, resulting from ten years of research and development cooperation between CEA and Cybernetix. This manipulator, a 6 axis hydraulic manipulator-arm specifically designed to work in harsh environment, entered in its industrial phase. ONET Technologies was responsible for the overall system integration, confinement and performance.

A comprehensive qualification program in real conditions has been driven during 2014. The dismantling scenario was tested with a mockup at a full scale of dissolver equipment and confirmed at this stage the expected level of performance and safety.

INTRODUCTION

Commissioned in 1958 on the CEA nuclear site of Marcoule (France) and shut down in 1997, the former UP1 plant was dedicated to reprocess the spent fuel from G1, G2 and G3 GCR reactors. Since 1998, a wide program for cleaning-up and dismantling the plant has been engaged in order to dismantle the process equipment, eliminate any potential radiological risks in all concerned buildings (e.g.; 20 000 m^2, 14 workshops, around thousand rooms and cells) and remove safely all the resulting waste.
Major technical challenges are related to the wide range of complex components and equipment in the facilities such as chemical dissolvers, extractor batteries, evaporators, tanks, and to the ~~a~~ high risk of exposure, due to the presence of fission products.

The MAR200 facility (for Marcoule fuel reprocessing plant) contains blind cells equipped with tanks and pipe networks which were formerly used for chemical processing operations on nuclear fuel. Due to the high level of radiations present and to the necessary use of very special materials for the dismantling equipment (large thickness of Uranus stainless steel), these dismantling operations have to be partially performed by remote machines, and notably by using a laser cutting tool. The CEA has entrusted ONET Technologies to define the best way to dismantle these blind cells through remote operations. ONET Technologies will thus have to use its own remote robots and tools to dismantle the two main cells of MAR200 facility.

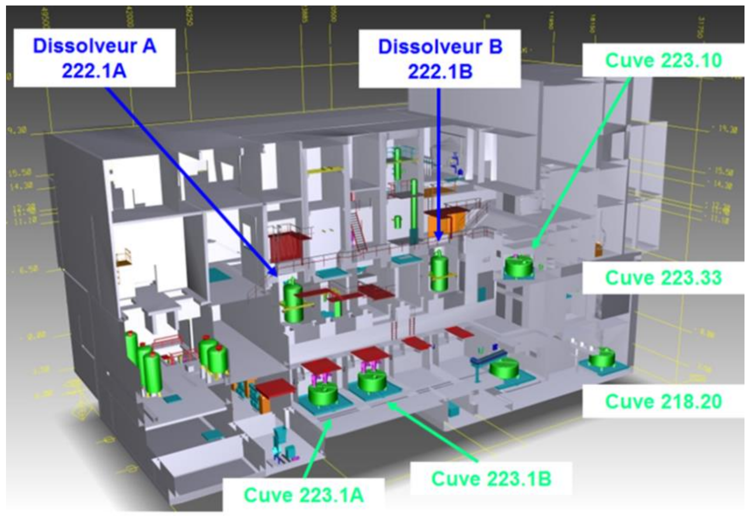


Figure 1. UP1 – MAR200 facility (CEA)

The final step will consist in emptying these cells completely and attaining a radiological environment compatible with a final manual on dismantling [1].

DESCRIPTION

Dissolver's equipment to dismantle: main features

The components to dismantle mainly consist of the process systems (dissolvers, pipe networks, tanks, etc.) contained in two blind cells of MAR200 facility. In their initial state, these systems have already been emptied and cleaned by high-pressure rinsing and lancing operations. Even though there are still some remaining nuclear materials (several grams) inside the networks, the "criticality" risk is considered as nil during the whole dismantling process. Approximately, 90% of the cell waste came from the dismantling of two tanks called "dissolvers" located in the core of both cells. These tanks are designed to be used for the dissolution of fuel rods from the UNGG industry. The dissolvers are made in Uranus 65 (special stainless steel with high corrosion resistance properties).

The dissolvers main dimensions and design characteristics are described below:

- Diameter : 1.9m;
- Height : 3.6m;
- Wall thickness : 12 to 18mm;
- Effective volume : 3.2m3;
- Mass : 4,600kg;
- Inlet and outlet pipe networks: diameters ranging from 20 to 160mm;
- Dissolver internal and external components: about 100m in developed length.

The radiological state of the dissolver varies according to the elevation considered. Although the ambient dose rate is moderate in its upper part (10 to 70mGy/h), it reaches 270mGy/h in its intermediate part, and even 1Gy/h around the most active parts of the lower bowl.

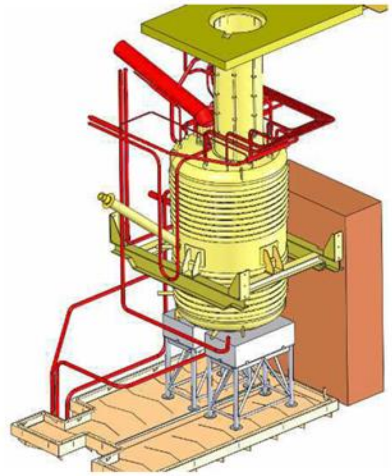


Figure 2. Dissolver in 3D view

ONET Technologies has been chosen by CEA to design, build and operate the overall dismantling and waste treatment system for this project (for the 2011 – 2018 period; 15,000 hours of engineering studies, 11 metric tons of primary waste, 60 metric tons of secondary wastes).

Dismantling Scenario Definition

The main constraints identified in relation to the physical environment, "waste" regulations, coactivity due to concomitant operations and specific operating and safety rules that will define a special framework for the dismantling scenarios. The detailed identification of the scope of work to be done will then allow development of one or several dismantling scenarios, to be compared with the abovementioned general constraints. Afterwards, one or several scenarios will thus be selected after a technical and economic cross-analysis is made based on standard criteria, such as:

- costs,
- lead times,
- operational accumulated dose,
- technical feasibility,
- existing feedback about the systems implemented,
- quantity and nature of the waste produced, and
- necessary adaptations before the dismantling operations,

A multi-criteria analysis will finally enable the selection of the reference dismantling scenario.

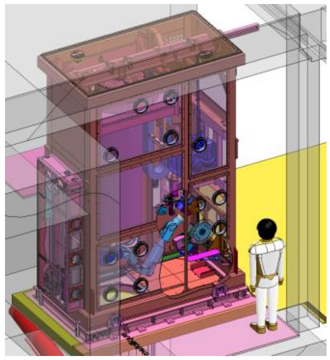
Dismantling system architecture

ONET Technologies designed two main subsystems to meet all requirements for this project:

Remotely-Operated Handling and Cutting Unit: the handling and cutting unit must thus be designed to face all the possible situations and comply with all the possible applications. This is the reason why the cutting tool holder is equipped with a far-reaching telescopic mast for an optimum accessibility and a MAESTRO-type 6-axis robotic arm for a maximum operators' dexterity.

Moreover, because of its force feedback system intended to the machine operator, this equipment limits the risk of breakage (traditionally associated with standard cutting devices) and minimizes the forces transmitted back to the robotic arm holder.

Figure3. Remotely-Operated Handling and Cutting Unit - 3D exploded view



In order to ensure containment of the dismantling operations and cutting systems, the mechanical assembly is integrated into a watertight containment which is positioned at the roof of the cell and moves inside the dissolver during the dismantling phases. The whole abovementioned equipment forms the remotely-operated containment.

The large thicknesses to be cut, and the abrasive nature of the dissolver materials (URANUS 65), led to the implementation of innovating cutting means, which had never been used on standard dismantling sites yet. Within this context, the **laser cutting method** was finally selected since it can cut large stainless steel thicknesses, even greater than 40 mm, in a very limited time. Even so standard cutting means (angle cutters, saber saws, nibblers, etc.) are not dismissed: they can be used during secondary phases or as emergency means in case of failure of the laser devices.

ONET Technologies and CEA have achieved elementary inactive tests based on a 6 kW Nd-Yag laser source to qualify the cutting performance according material and thickness, to meet the safety criteria and in order to check the physical characteristics of waste resulting from the laser cutting operation.
The application of these new technologies notably the fact that the laser is controlled by a robotic system, requires an additional approval with regard to the compliance of nuclear safety and security rules.

Therefore, to guarantee the control of laser firing, new measures must be taken, such as:

- an optimized human/machine interface for the robot control (reduction of human error risk);
- a reinforced training for the operators of the dismantling equipment;
- a management function of the fire- and no-fire areas integrated into the machine control system (program safety);
- fire-detection and fire-extinguishing means adapted to laser process;
- physical protection means for operators and facility components;
- a qualification program showing the reliability of the safety systems implemented.

The Remotely-Operated Handling and Cutting Unit were equipped with a **MAESTRO manipulator**.
Maestro System is the result of 10 years research cooperation between CEA and Cybernetix: a 6 axis, low encumbrance, rad-hard with heavy load capacity hydraulic arm.
Its design has been specifically adapted to work in nuclear environment, ensuring easy decontamination and enabling work in narrow space with high dexterity.
The end of the arm is equipped with a tool changer that assures connection to different tools and enables signal and electric power supply through the arm itself (up to 2kW) limiting the need for external umbilical when using electrical tools.
The heavy duty hydraulic rotating jack composing the 6

Figure 4. MAESTRO slave arm

axis of the arm and its subassemblies mainly made of titanium allows the use of high power mechanical cutting like 5kW Hydraulic grinder.

The Maestro system is mainly composed of 5 major sub-assemblies:

- the Slave arm and its tools, working in the hot cell
- the Hydraulic Power unit supplying the slave arm, that can be, depending on the project, inside or outside the hot cell
- the electric TAO control cabinet, in green area assuring the closed loop control of the arm
- the supervision software CyxPro®, assuring the Human Machine Interface (HMI)
- the master arm, at operator's desk

Depending on the project's requirement, Maestro system can be operated in both, robot mode, performing pre-programed operations and trajectories, and in force feedback remote handling mode.

Figure 5. Master arm

In this latest mode, operator uses a Master arm, installed in front of its control screens, to operate the Maestro slave arm which reproduces master arm's movement. The TAO advanced control system is employed for supervising equipment's operating, when grabbing a tool, its weight is automatically compensated and its manipulation is fully transparent to the operator.
CyxPro® is the supervision software enabling operator's interface with the system. Separated in 2 main screens, CyxPro® regroups all the necessary information and command to operate the system and offers a real time 3D display of the all Remotely-Operated Handling and Cutting Unit equipped with Maestro

ONET Technologies was responsible for the overall system integration, confinement and performance.

Waste Extraction and Conditioning Unit: once the dissolver elements have been cut, the parts which may have fallen inside the dissolver or on the floor must be picked up by the lifting clamp of the robotic arm and placed in a transfer conveyor towards the waste outlet unit located on one side of the cell. This waste outlet unit is used to build up finished packages which are ready to be sent to waste storage centers (ANDRA, the French National Radioactive Waste Agency). Apart from its mechanical kinematic functions, the Waste Extraction and Conditioning Unit includes all the necessary radiological measuring devices to characterize the waste and then allow its disposal.

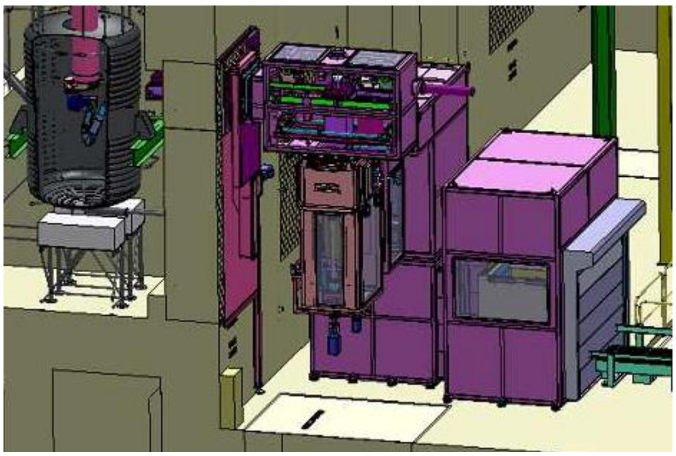


Figure 6. Waste Extraction and Conditioning Unit

The Remotely-Operated Handling and Cutting Unit and the Waste Extraction and Conditioning Unit are remotely controlled by a control unit located outside the facility and equipped with all the human/machine interfaces (master arm of the robotic arm, control PC, video control room, alarm management, etc.) needed for the conduct of the dismantling Operations.

Immersive Virtual Reality

Figure 7. CEA immersive room

Different software and hardware tools based on Virtual Reality technologies are developed by the CEA. Simulation is a good mean to meet the dismantling challenge for nuclear companies for understanding and visualizing constraints, testing different alternatives and training workers to interventions. In this context, Virtual Reality allows a user to interact with a computer-simulated environment, whether that environment is a simulation of the real world or an imaginary world. Virtual reality environments, mostly based on The CEA immersive room, displayed either on a computer screen or through stereoscopic displays, can also include additional sensory information, such as sound or touch mechanism [2].

During the design phase, Virtual Reality has been used to qualify the kinematics in the final environment and the preliminary dismantling scenarios. The Remotely-Operated Handling and Cutting Unit, including the Maestro slave arm, has been coupled with the haptic interface and to force feedback and visual immersion, accessibility; operational trajectories and maintainability on the carrier that have been verified. If some problems were found, updates of the carrier design were made before manufacturing the carrier to guarantee the good working conditions of the system.

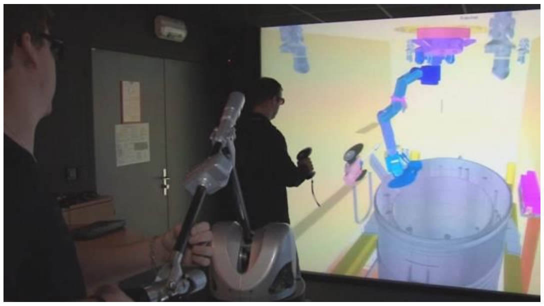


Figure 8. ONET Technologies testing virtual reality

These simulations are extremely efficient. They notably revealed that the equipment design had to be modified to facilitate its use, that the layout initially planned for the cameras had to be changed too and that the cutting scenario could be optimized to reduce the overall dismantling duration. These lessons learnt at a very early stage of the project contributed to secure and enhance the design and the future dismantling operations.
Finally, this step allowed operators to be familiar with the system before the first inactive test.

Inactive Tests

A comprehensive qualification program in real conditions has been completed during 2014.The dismantling scenario has been tested with a mockup at full scale of a dissolver equipment.

Due to safety conditions in the industrial testing facility, all trajectories have been checked with the LASER source switched off. A separate qualification program has been conducted in CEA facility in order to establish the cutting parameters and the physical characteristics of waste resulting from the laser cutting operation.

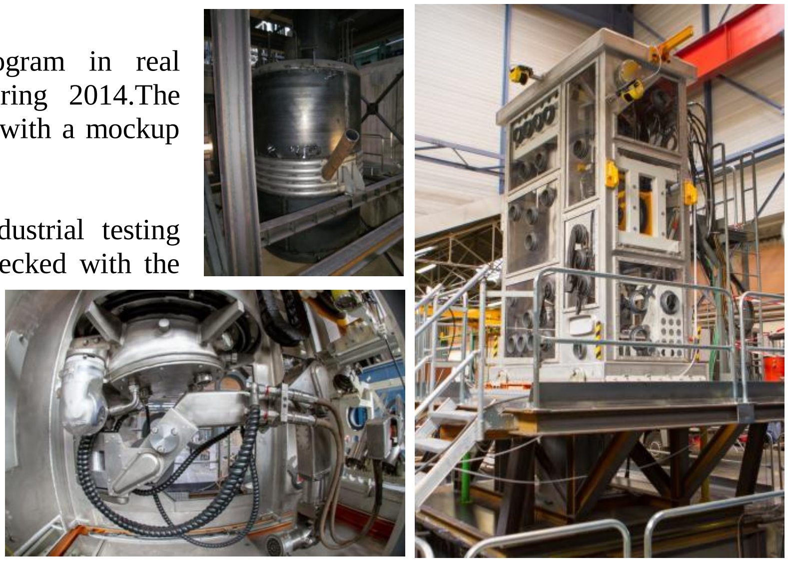


Figure 9. Inactive tests (full scale) on realistic mockup

The inactive qualification phase enabled the following conclusions:

- The ability of the system to ensure the whole dismantling scenario exactly as it was designed,
- The operating time in line with the expectation from the virtual simulation
- The capacity to ensure the dismantling operation with a rescue mode based on conventional tool (grinder), however, the stress release in the dissolver material caused several jamming and breakage of the tool.
- The maintenance operations and procedures have been tested

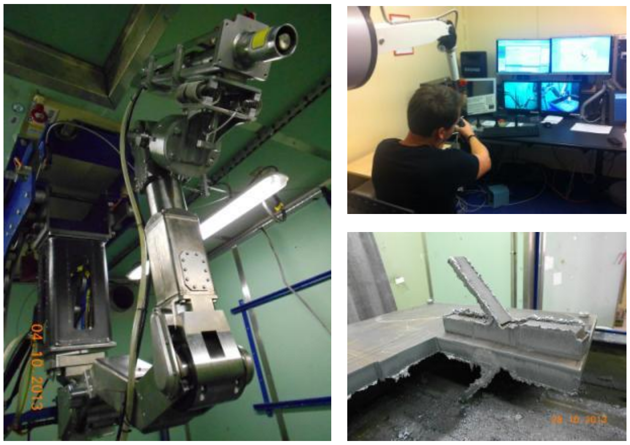


Figure 10. LASER preliminary tests

The whole advanced dismantling system is now ready to be transferred in its final destination at the CEA site of Marcoule in order to achieve its on-site qualification tests in 2015 and first dismantling operation in 2016.

CONCLUSION

The former fuel reprocessing plants or nuclear plants after a severe nuclear accident (eg Fukushima) are facing a very complex dismantling due to high activity, high risk of dissemination combined with a lack of information regarding their physical and radiological characterization for older plants.
Based on R&D programs lead by CEA, new industrial technology (MAESTRO) was developed by Cybernetix and ONET Technologies engineering. In addition, based on its work experience in decontamination and decommissioning projects, we designed and built a comprehensive system with the most advanced techniques for nuclear dismantling projects in order to meet both to performance and safety.

REFERENCE

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2. “VR technologies, a way to verify dismantling operations - First application case in APM cell 414”; Caroline CHABAL, Jean-François MANTE, Jean-Marc IDASIAK – CEA - 4th International Conference on Advances in Computer-Human Interactions 2011