COGEMA EXPERIENCE ON DECONTAMINATION AND UNDERWATER AUTOMATICALLY REMOTE CUTTING USING ULTRA HIGH PRESSURE WATER DURING NUCLEAR DECOMMISSIONING OPERATIONS
THE AQUARAD ROBOT

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ABSTRACT

Reprocessing operations on gas cooled French reactor spent fuel included a mechanical operation called decladding, (i.e., stripping the fuel rod from its magnesium metal cladding). After this operation shut down, COGEMA started a D and D project on the decladding building where specific equipment was stored under water. COGEMA then developed and operated a process to decontaminate and cut metallic structures remotely, using ultra-high-pressure water mixed with sand (3600 bar).

This paper describes the experience gained, since the start up of this operation in 1994, discusses resulting dosimetry and waste produced, during decontamination and underwater cutting of high active large metallic structures including some with 200 mm thick steel plates.

This process results in significantly lower exposures to workers involved in the D and D operations. In addition, the work was carried out in an environmentally safe manner with reasonable financial costs.

INTRODUCTION

A number of nuclear installations throughout the world are reaching the end of their life and will, at some point, have to be dismantled. Removing some units inside these installations is anticipated and the main concern will be to keep as radiation exposures to D and D staff low as reasonably achievable (ALARA).

At the end of operational life of the gas cooled reactors spent fuel reprocessing operations in La Hague, FRANCE, in a joint effort between COGEMA and SALVAREM, a prototype of a robot capable of measuring radiation, decontaminating and cutting material under water using ultra high pressure water with abrasive was developed and produced, for use in the former decladding facility. The material consisted of radiologically contaminated, metal structures from mechanical assemblies. This paper presents the experience gained in these operations between late 1994 and the first quarter of 2000 in our La Hague reprocessing plant.

The goal of the work was to dismantle the contaminated, radiating mechanical assemblies under water, using a prototype robot called AQUARAD as a substitute for human workers, with no risk to environment, completion of the work on time, with acceptable and financial costs and in a manner that kept worker exposures ALARA.
WORK PERFORMED

The remotely controlled AQUARAD robot, capable of measuring radiation, decontaminating, and cutting up large, complex metal assemblies under water, was installed in 1994 in the Decladding Facility in the West Cell of the storage channel. The Decladding Facility, located on the south side of the high activity building, measures approximately 67.5 meters long and 26 meters wide. It was used exclusively for mechanical processing of spent fuel from French gas-graphite reactors.

The following were found in the West Cell and the storage channel of this facility:

- A complex installation named "dissolver loading device" (Pelle d'Alimentation du Dissolveur or "PAD" in French) designed to provide a continuous supply of spent fuel elements for the dissolver;
- various types of fuel baskets to be dismantled.

The dissolver loading device consisted of two sets of rails enclosed in tubes, a pushing chain, an elevated cradle, a tipping device, a set of thick metal structures (5,500 x 2,000 x 1,800 mm), used to support the "PAD". All these elements weighed approximately 22 metric tons and were difficult to access (figure 1).

The cylindrical stainless steel fuel baskets were 1,550 mm in diameter, 400 mm in height, with a shell and base in 3-mm thick perforated plate. They were reinforced with numerous metal stiffeners with thickness varying between 30 and 70 mm.

COGEMA successfully experimented with dismantling another category of metal assembly that would be difficult to cut up using traditional methods consisting of a filter cartridge, emptied of filtering agent, from the light water reactor fuel storage pool.

The cylindrical stainless steel cartridge was three meters long and with an outside diameter of 0.90 meter and weighed approximately 770 kg. One of its features was that it had a central tube, approximately 0.30 meter in diameter and three meters long, linked to the outer wall and to the central axis by a great number of baffle plates and metal stiffeners that were difficult to cut up.

Using the ultra-high-pressure water with abrasive, COGEMA designed a piece of equipment on a gantry support with three axes – X, Y and Z, to carry out the work described above, in a radioactive medium. The Z movement on the main gantry structure was used to submerge the cutting nozzle to reach the support to be cut without having to take the part out of the water, as was the case in the past. The former method often involved long, tedious procedures, as the part had to be cleaned beforehand and hung up before being cut up on the spot, with possible increases in worker exposures.

Before the robot was introduced, the installation to be dismantled had to be taken to the tool, or workers had to take the equipment to the installation. Now the radiation-measuring/decontamination/cutting apparatus moves on its own, controlled by a computer, to the place where the work is to be done. The operator remains at a distance and can monitor the operations on a video system. Using digital controls the operator directs, orients his tool, and adapts its displacement to the geometry of the part to be dealt with. Figure 2 illustrates an example of the reduction in volume of complex stainless steel structures cut up under water by the AQUARAD Robot. The structure was approximately 5500 x 2000 x 1800 mm.

The AQUARAD robot was designed to avoid any particles being dispersed into the environment.
The phases in the work performed under water by the robot, on the apparatus to be dismantled are:

- measuring radiation,
- minimum decontamination to meet ANDRA radioactivity criteria
- loading the first section onto a sling and cutting it into pieces in accordance with a previously developed cutting plan,
- putting the pieces of the section into a cubic fiber concrete container (CBFK),
- loading the second section onto a sling, cutting it into pieces and putting the pieces into a container,
- repeating the above phases until the final section has been cut up,

Throughout these phases, the mixture of abrasive and dust from the cutting operations is partially recovered by the jet recovery system, while the remainder is taken up later by a specific suction/filtration system after decanting.

The dismantling work on the complete dissolver-loading installation (PAD) took place over several short periods in 1995 and 1996. Nine spent fuel baskets were dismantled with the same working conditions, from 1997 to 1999. A pool filter cartridge was dismantled during the second half of 1999.

**PROCESSES IMPLEMENTED**

The process enables the clearing, dismantling and volume reduction of any complex, radiologically contaminated, metal structure up to 200 mm thick (carbon steel).

The operations carried out by the AQUARAD robot, are:

- The probe is used to determine the starting point,
- A Comparison between the position programmed and the actual position is made,
- Adjustments are made if required,
- The probe is used to recognize the profile where the operation is to be performed (decontamination, cutting up etc.),
- A comparison between the route programmed and the route to be taken is made,
- Adjustments are made if required,
- The operation is performed (decontamination, cutting up etc.),
- Measurement of the deviation between the route determined by the automatic controller and the route reset during the operation to be performed.

The main features of the AQUARAD robot are:

- Flow rate of water: 3 to 5 liters per minute,
- Water pressure: between 3500 and 4000 bar (50,000 psi),
- Speed at nozzle outlet: between 600 and 900 meters per second,
- Cutting capacity: carbon steel up to 200 mm thick,
- Steel cutting: done by a water + abrasive (sand) mixture,
- Decontamination: water only,
- Flow rate of abrasive: ≈ 0.1 liter per minute,
- Cutting speed: variable, depending on the thickness of the material (for example: 40 mm per minute when cutting up a 50-mm thick stainless steel part),
• Machine with 5 movements:
  * 3 axes at right angles (X, Y, Z);
  * shank rotates around 360°;
  * wrist rotates around 180° on a vertical plane.

WASTE PRODUCTION

The waste resulting from this work is mainly metallic pieces and particles contaminated by beta-gamma emitters.

A dose rate measurement is taken on the radiating waste. The presence of beta-gamma emitters in the waste is not a constraint as regards acceptance for LLW surface disposal in France. A check simply has to be made to make sure that the packages do not have a dose rate above 2 mSv on contact. The beta-gamma emitter activity is calculated using a transfer function.

The check on the alpha emitter contamination is based on the alpha / beta-gamma activity ratio determined on the basis of the analysis of representative samples. The types of packages of waste produced were:

• 120-liter metal drums for waste from maintenance operations,
• cubic fiber concrete containers for waste generated by the material cut up and cutting products.

The AQUARAD robot meets the objective of reduction in the volume of waste.

The ease with which its cutting function was used to cut up complex metal structures allowed COGEMA to:

• optimize the way in which the packages are stowed in the containers,
• generate much less waste from the operation (operations performed at a distance) than from operations carried out manually and practically in contact with the radioactive source,
• have access to cutting areas that are inaccessible in manual mode.

The production of solid waste from dismantling two different-sized installations with varying complexity is shown, in figure 3. It should be noted that dismantling the dissolver loading installation, carried out while the AQUARAD robot was being perfected, generated half as much packaged waste as would have been produced by the same operations performed manually.

The dismantling of the pool filter cartridge carried out by the AQUARAD robot, once optimized, generated two-thirds less waste products than would have been produced by manual operations.

RADIOLOGICAL OUTCOME

The COGEMA Radiation Protection Department (SPR) deal daily with the doses integrated by the workers, thus limiting the dose integrated by the workers to the maximum value defined as an objective on La Hague site (10 mSv over a 12 months period).
As the AQUARAD robot is a remote-controlled device that works underwater, this means that the doses to operators may be kept to a minimum. Water has the following advantages:

- it limits, during cutting operations, the dispersion of radioelements, whether liquid, solid or gas - it acts as a containment,
- it constitutes an extremely good protection against radiation exposure, thus leading to lower dosimetry values for the operator (ALARA principle),
- the process may be viewed directly or using watertight video cameras,
- it may be used to cut up parts with different types of shapes, with very high dose rates.

The Radiological Balance (figure 4) gives a comparison between the work carried out using the AQUARAD robot (dose rates expressed in man.mSv) and an estimate of the same work performed manually by workers.

**FEEDBACK**

The work performed by the AQUARAD robot was carried out successfully, but we should not forget the difficulties encountered. From the outset they were due mainly to:

- using new technology in a hostile environment (identifying suitable parameters for the operations, timing the projection of the abrasive, dealing with frequently blocked piping etc.),
- The demanding maintenance required for the mechanical assemblies under water,
- the relatively frequent absence of visibility in the pool water (damage to video cameras and floodlights, difficulties with pool filtering units etc.),
- The absence of suitable handling equipment,

The scheduling of the operations and the care applied to their preparation allowed us to adapt rapidly to the conditions encountered. The feedback allowed us to progress normally in executing the tasks involved in the work while paying special attention to three fundamental points:

- the total absence of environmental impact,
- the lowest possible radiation exposure for the staff involved,
- using the prototype robot with competitive financial costs.

**CONCLUSION**

COGEMA, working with SALVAREM, dismantled and packed, in complete safety, using the AQUARAD robot, complex, contaminated, mechanical installations, involving some operations difficult to perform using currently used standard processes.

COGEMA continues to study the possibilities to use the AQUARAD robot to other operations on similar installations. Because of the amount of technical data about the operations recorded during the six years of work, COGEMA have acquired rich experience in the field of nuclear installation dismantling.
THE AQUARAD ROBOT - UHP WATER CUTTING USING GRIT

Fig. 1

- BEARING
- SUPPORTING MAST
- PROJECTOR
- CAMERAS
- CUTTING ROBOT
- FRAME FOR EQUIPMENT
- CUTTING HEAD
- BOTTOM POND FRAME
THE AQUARAD ROBOT
EQUIPMENT CUT USING THE AQUARAD ROBOT

POND FILTRATION CARTRIDGE

COMPLEX METALLIC STRUCTURE

FUEL BASKET

Fig. 2
# THE AQUARAD ROBOT WASTE PRODUCTION

## 1 - DISSOLVER LOADING INSTALLATION (PAD)

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<tr>
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<th>AQUARAD Robot</th>
<th>Manual operations - estimate</th>
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<tbody>
<tr>
<td>Number of 120-liter drums</td>
<td>400</td>
<td>1600</td>
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<tr>
<td>Number of CBFK containers</td>
<td>12</td>
<td>15</td>
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<td>Solid waste packed for ANDRA (m³)</td>
<td>78</td>
<td>147</td>
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## 2 - POOL FILTER CARTRIDGE

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<td>Number of 120-liter drums</td>
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<td>Number of CBFK containers</td>
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<tr>
<td>Solid waste packed for ANDRA (m³)</td>
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<td>6.3</td>
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### THE AQUARAD ROBOT

#### RADIOLOGICAL BALANCE

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<th>Activity</th>
<th>AQUARAD Robot</th>
<th>Manual operations - estimate</th>
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<tr>
<td><strong>1 - DISSOLVER LOADING INSTALLATION (PAD)</strong></td>
<td>99*</td>
<td>200</td>
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<td>Total integrated doses man.m Sv</td>
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<tr>
<td><strong>2 - POOL FILTER CARTRIDGE</strong></td>
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<td>1</td>
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<tr>
<td>Total integrated doses man.m Sv</td>
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* Of which approximately 50% are due to the maintenance of the robot.

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*Fig. 4*