Graphite Waste Tank Cleanup and Decontamination under the Marcoule UP1 D&D Program – 13166

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ABSTRACT

The UP1 plant in Marcoule reprocessed nearly 20,000 tons of used natural uranium gas cooled reactor fuel coming from the first generation of civil nuclear reactors in France. During more than 40 years, the decladding operations produced thousands of tons of processed waste, mainly magnesium and graphite fragments. In the absence of a French repository for the graphite waste, the graphite sludge content of the storage pits had to be retrieved and transferred into a newer and safer pit. After an extensive R&D program, the equipment and process necessary for retrieval operations were designed, built and tested. The innovative process is mainly based on the use of two pumps (one to capture and the other one to transfer the sludge) working one after the other and a robotic arm mounted on a telescopic mast. A dedicated process was also set up for the removal of the biggest fragments. The retrieval of the most irradiating fragments was a challenge. Today, the first pit is totally empty and its stainless steel walls have been decontaminated using gels. In the second pit, the sludge retrieval and transfer operations have been almost completed. Most of the non-pumpable graphite fragments has been removed and transferred to a new storage pit. After more than 6 years of operations in sludge retrieval, a lot of experience was acquired from which important "lessons learned" could be shared.

INTRODUCTION

During more than 40 years, the decladding operation of the fuel from the first generation of nuclear reactors in France (natural uranium fuel, gas cooled and graphite moderated) produced over 3,000 tons of processed waste consisting mainly of magnesium cladding fragments but also graphite dust and fragments.

Graphite and magnesium waste were stored within 13 pits located in the G2-G3 decladding facility.

As a prelude to the graphite waste retrieval program, scheduled to start around 2015 on the Marcoule site, AREVA is conducting for the French Atomic Energy Commission (CEA) a demonstration program consisting of the full retrieval and transfer of over 115 m3 of water mixed with graphite dust from the decladding facilities of the UP1 processing plant, as well as the complete decontamination of the storage pits.

In the absence of a repository for the graphite waste, the graphite sludge content of two storage pits (pit 7 and 14) was at first retrieved and transferred using the operating equipment, into a more recent and safer pit with additional capacity and located in the MAR400 facility. An overview of the UP1 decladding facility is given in Fig.1.

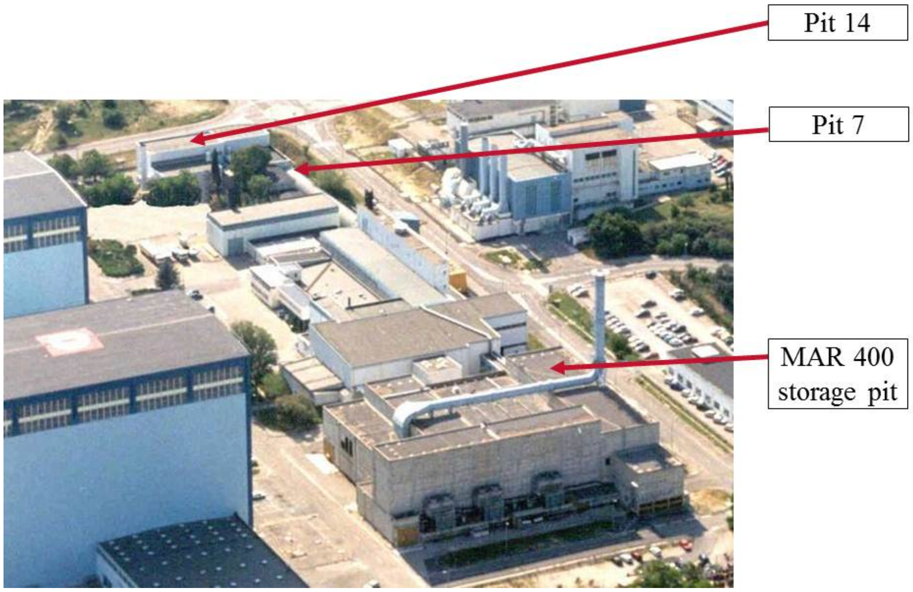

Fig. 1. The UP1 decladding facility

In order to evacuate the residual graphite sludge and fragment in the bottom of each of these pits, a dedicated project organization was set up and a R&D program was launched. The main steps of this project are described below.

The sludge is composed of:

- Water,
- Graphite dust and fragments from used nuclear fuel decladding operations, and
- Zeolites from pit water filtration.

The radiological objective is to reach residual irradiation and contamination levels in the pit compatible with minimal surveillance requirements.

Pit 7 was used to store graphite chips and tiles produced during used nuclear fuel decladding activities in the process pits. This transfer was to allow the graphite waste to settle. The water used to transport the graphite was filtered and returned to the process pits. Since the capacity of pit 7 was insufficient, additional storage was provided using pit 14.

During the Waste Management 2009 conference, a first presentation was made by AREVA regarding the graphite retrieval and transfer operation from pit 14.

The initial conditions of pit 14 are defined as below:

- A 360 m3 pit (10 m x 5 m x H 8 m) with a stainless steel liner, containing 5 m3 of residual graphite sludge that could not be removed using existing tools during the operational phase;
- The sludge contained only very small quantities of chips since it was mainly the supernatant that was transferred from Pit 7 by pumping;
- The ambient dose rate was 20 mGy/h (2 rad/h).

After an extensive R&D program with full-scale non-radioactive testing performed on a dedicated test platform in the AREVA Hall of Research Beaumont (HRB) near the La Hague processing plant, the equipment necessary for the sludge retrieval operation was designed, built and tested. The main characteristics of the sludge retrieval and transfer process were:

- Mobilization and dilution of the sludge using a high pressure water jet lance;
- Use of submerged open-type centrifugal pumps, working one after the other, one for collecting the sludge and the other, placed in a 300 liter tank, for transferring the sludge;
- A 2.2 m/s transfer velocity, corresponding to a 18 m3/h flow rate in the ND 50 Schedule 40S transfer pipe;
- Control of the maximum concentration (100 g/l) for the sludge to be transferred by adding dilution water coming from a buffer tank at the suction head;
- Use of a mass flow meter to control the transfer;
- Backflush using supernatant pumped from the receiving tanks.

The sludge retrieval work from pit 14 was performed remotely with the assistance of an electrical tele-manipulator “PYTHON” arm (manufacturer SIT, lifting capacity: 30 kg) mounted on a telescopic mast (6.5 meter extendable, see Fig. 2). All the work activities were coordinated from a trailer located outside the decladding facility.

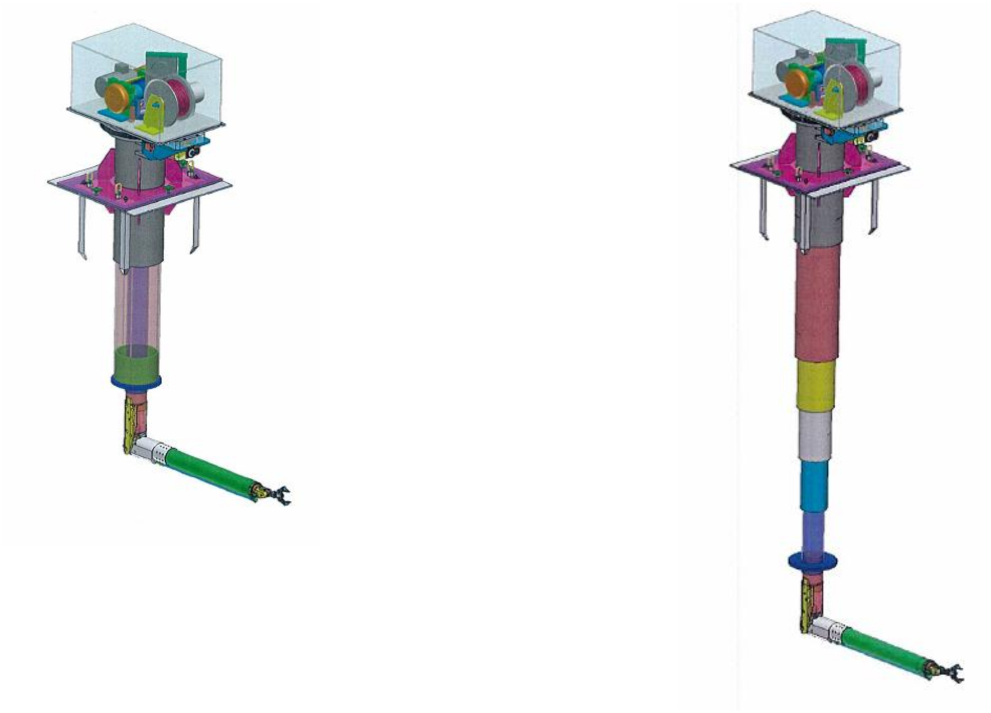

Fig. 2. 3D model of the PYTHON robotic arm

In 2009, the sludge retrieval operations (see Fig. 3) were completed. The remaining operations to be performed were:

- The decontamination and cleanup of pit 14,
- The sludge retrieval, decontamination and cleanup of pit 7.

Fig. 3. Sludge retrieval operation in pit 14

DECONTAMINATION AND CLEAN-UP OF PIT 14

Pit decontamination and cleanup

By February 2009, all the sludge was pumped out. The following operations to be performed were the collection of non-pumpable fragments, equipment removal from the pit, their evacuation, the decontamination and cleanup of the steel walls.

The graphite chips were removed using the remote-controlled arm equipped with a shovel (see Fig. 4). After rinsing and radiological testing, they were sorted and placed in a stainless steel canister. Then the canister, placed in a cask, was transported to Pit 11 for storage.

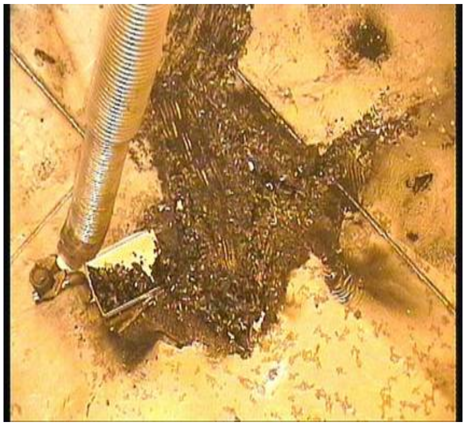

Fig. 4. Graphite chips removal

The stainless steel liner was decontaminated by spraying an acid gel on it, using a spray ramp mounted on the tele-manipulator arm (see Fig. 5). Unfortunately, due to the presence of “grease” stains, the radiological target could not be reached. So, the use of a basic gel was chosen instead. With this new gel, which served also to neutralize acid, the radiological criteria were reached.

Fig. 5. Decontamination of the pit liner, using a spray ramp mounted on the robotic arm

The radiological measurement was made by using adapted tools on the robotic arm of the tele-manipulator (see Fig.6):

- the fixed contamination was measured by using a shielded and collimated detector,
- the non-fixed contamination was measured on smears.

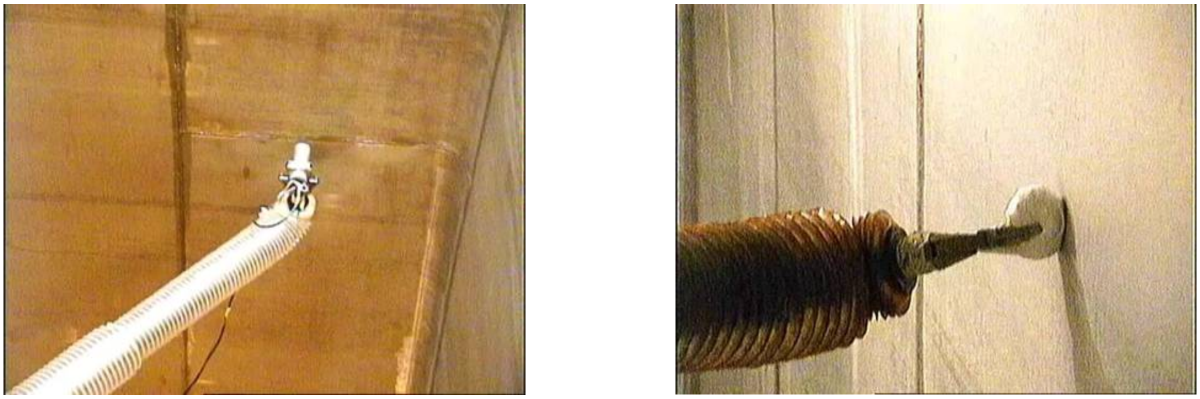

Fig. 6. Radiological measurement using the robotic arm

Results from sludge retrieval and cleanup operations in pit 14

Sludge retrieval operations from pit 14 were performed from April 2007 to July 2010 and were successful (see Fig. 7). More than 11,000 man hours were required.

About 144 m3 of water were used, mainly for sludge dilution and liner rinsing operations after decontamination. This relatively low level of water added was due to the water recycling loop.

Using gels, the decontamination factor reached was about 10 and the residual dose rate was under 100µGy/h (expected < 0.1 mGy/h – 10mrad/h).

Fig. 7. Final status of pit 14 after decontamination and cleanup operations

SLUDGE RETRIEVAL OF PIT 7

Initial conditions of pit 7

The pit 7 is 6.55 meter long, 4.55 meter large and 7.38 meter high for a total volume of 220 m3. It has an epoxy coating type liner (while the liner of the pit 14 is made of stainless steel) and a small opening on the concrete roof allows access to the pit.

The ambient dose rate was 250 mGy/h (25 rad/h).

It contained an estimated volume of 14 m3 of residual graphite sludge that could not be removed using existing tools during the operational phase. Because of past operations, the sludge contained more graphite chips and tiles that could not be pumped out as for pit 14 (see Fig. 8). The estimated volume of non-pumpable fragments was 200 liters.

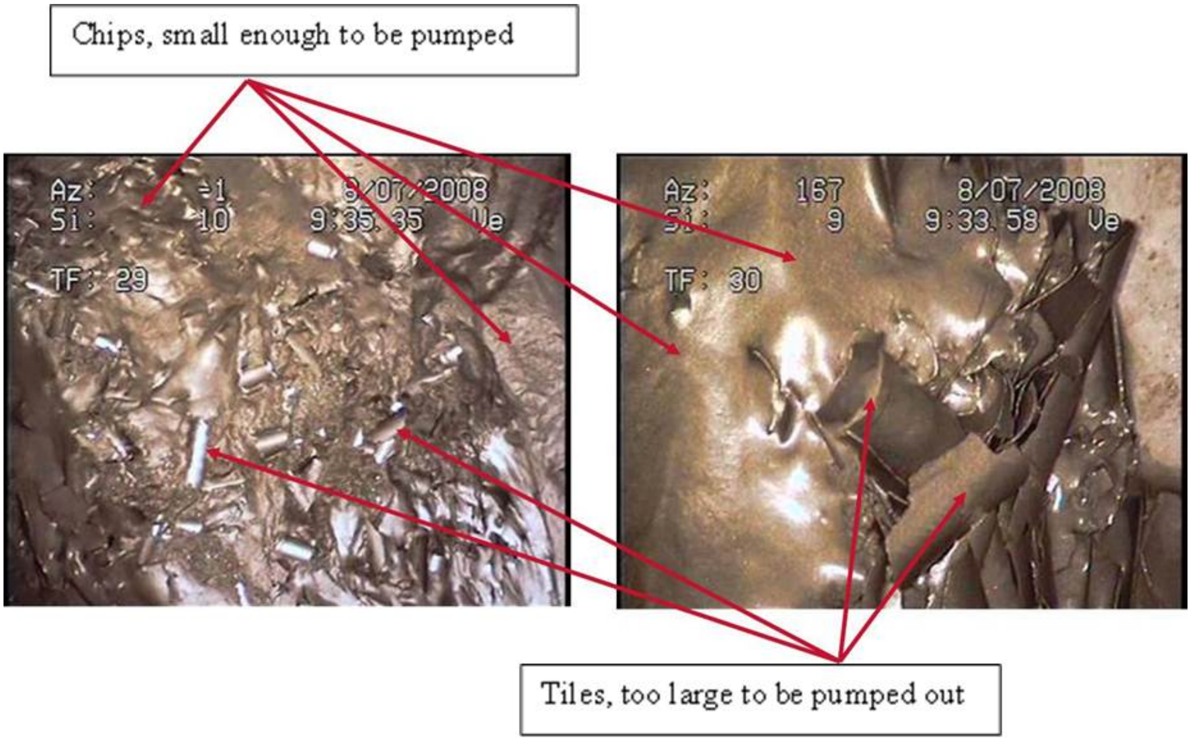

Fig. 8. Non-pumpable fragments in the sludge

Unlike pit 14, pit 7 was originally built to receive the graphite waste resulting from the decladding process; so it was equipped with a lot of specific equipment (such as sludge spraying pot, a pump skid, …) which had to be dismantled after the sludge retrieval and before the cleanup operations.

The graphite sludge had to be transferred to a safer pit in the MAR400 facility using the existing pipe layout for several hundred meters while the distance between pit 14 and 7 was only 50 m.

Adaptation of pit 14 equipment and process to pit 7

Most of the equipment and process used successfully for pit 14 were re-used for pit 7 operations. But taking into account the differences between the two pits and a slightly different environment, some adaptations were needed.

A ventilated containment airlock was installed above the pit and two core-drillings were performed through the upper slab in order to install the remotely-controlled manipulator arm used for pit 14. Taking into account the lessons learned from the use and maintenance of this device, some technical improvements were made, in particular to increase its reliability; i.e. a more robust gear box was installed.

The principle of combining two pumps (one for sludge collection, the other one for sludge transfer) working together in series was kept as it had been working successfully for pit 14 operations.

Taking into account the sludge concentration in debris and the longer distance between pit 7 and MAR400 facility, additional water was used to dilute the sludge and to facilitate the sludge transfer along the pipe lines. In order to minimize the production of effluent, a pump was installed in the receiving pit to send the supernatant back to pit 7. By doing this, it was also possible to clean the pipe lines between the two pits.

To avoid the clogging of the longer pipe lines due to the large size of the graphite pieces, a 5 mm strainer was installed on the suction pipe in the pit 7, instead of an 8 mm one used for pit 14.

Because of a greater concentration of non-pumpable fragments, a sorting table was installed in the bottom of pit 7 (see Fig. 9). This table allowed the screening of the fragments and optimized the filling of the 10-liter stainless steel containers (tip-up table with a funnel).

Fig. 9. Inside view of pit 7 with the sorting table

With an ambient dose rate more than ten times higher than pit 14, respecting the ALARA principle, additional lead protections were installed above the pit in order to minimize the workers radiological exposure.

Sludge retrieval operations

A 3D sketch of the layout of pit7 to retrieve and transfer the graphite sludge to MAR400 is given on Fig. 10.

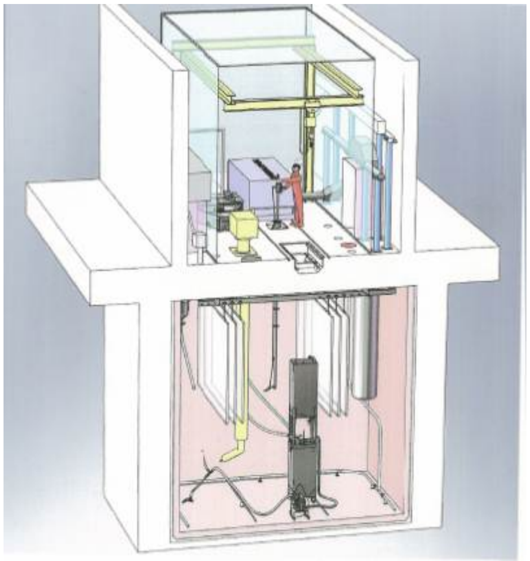

Fig. 10. 3D representation of sludge retrieval equipment in pit 7

The sludge retrieval operations from pit 7 and the transfer to MAR400 were started in February 2010.

Since then, most of the sludge has been successfully retrieved using the following process:

- Mobilization and dilution of sludge using supernatant;
- Sludge suction to fill out the intermediary tank containing the transfer pump;
- Control of concentration (C) in solid form:
  - If C < 100 g/l, sludge transfer to MAR400 by 500 l consecutive batches, followed by another 500 l supernatant batch to rinse pipes
  - If C > 100 g/l, a complementary dilution is performed using the supernatant stored in a buffer tank.

As expected, a lot of non-pumpable fragments were found and treated using the methodology described below.

Using a shovel mounted on the remote controlled arm, a pile of non-pumpable fragment is loaded on the sorting table. After rinsing and screening, the biggest fragments (> 6 mm) are transferred in the 10-liter container. Then a dose rate measurement is performed on the container. If its dose rate is below 1.3 Gy/h, the container is placed in a shielded cask and transferred to pit 11 for storage.

However, upon reaching the bottom of pit 7, the radioactivity increased significantly as the sludge level was getting closer to the expected layer of non-pumpable fragments. The lead protection was adapted to maintain the airlock environment compatible with worker interventions (maintenance, transfer of graphite container...).

After the production of about 40 containers of non-pumpable graphite fragments and a constant increase of their measured dose rate, operations were put on hold. A specific dose rate measurement was performed in the bottom of the pit 7. It confirmed the presence of fragments more radioactive than graphite, probably uranium scraps.

A report was submitted to the Nuclear Safety Authority. In order to allow the operations to be restarted, AREVA proposed the development of a specific container to store temporarily the most irradiating fragments before making a decision about how to evacuate them from the pit. This container was approved under certain conditions such as to keep the fragments under water.

To keep irradiating fragments under water, a special 2-liter canister was fabricated (see Fig. 11). The level of water inside the canister was controlled using a float-type level gauge.

Fig. 11. 2-liters canister for storage of irradiating fragments

In order to optimize the filling of the 10-liter containers for graphite fragments and the 2-liters containers for the most irradiating fragments, the sorting table was modified.

Then, a new operating procedure was set up in order to allow the sorting of the non-pumpable fragments.

Using the remote controlled arm equipped with a radiological probe and pliers, the most radioactive fragments on the sorting table are being identified and loaded in a stainless steel basket, filled with water. Then, the basket is transferred inside the 2-liter canister and temporarily stored in the bottom of the pit. The fragments with a dose-rate lower than 400mG/h are loaded in the ordinary 10-liter container.

Current progress of sludge retrieval in the pit 7

The sludge retrieval operation has been almost completed and nearly the entire bottom of the pit is visible (see Fig. 12).

Fig. 12. End of sludge retrieval with containers for non-pumpable fragments

About 14 m3 of graphite sludge has been pumped out, 56 ten-liter containers of non-pumpable graphite chips and tiles were filled. Among them, 47 already transferred to pit 11 and 3 had to be sorted again, because of a higher radioactive content that allowed for storage in pit 11.

Filling the first 2-liter canister with the most irradiating fragments is in progress, and fabrication of three other canisters is on-going.

It is expected that, by the beginning of 2013, the sludge retrieval operations, the evacuation of all the graphite containers to pit 11 and the retrieval and packaging of the highly irradiating fragments will be finished.

The remaining work consists of:

- The dismantling of all the internal parts and process equipment of the pit,
- The removing of the epoxy liner by scrapping using a Brokk,
- The end of the retrieval process and the transfer of the 2-liter canisters to a new storage.

Lessons learned

The use of submerged open-type centrifugal pumps, working in series, one for collecting the sludge, and the other for transferring the sludge, is very efficient.

Effluent management in the sludge retrieval process is key. In order to minimize the water added to mobilize the sludge, the re-use of the supernatant pumped in the receiving pit works very well.

The use of a mass flow meter to control the solid concentration of the sludge to be transferred is an essential tool.

Fuel fragments are to be expected in any legacy waste resulting from a decladding process of used nuclear fuel.

Given the complexity of the project, full scale non-radioactive testing is indispensable for ensuring the proper operation of the various tools.

CONCLUSION

AREVA performed the first graphite sludge retrieval operation on pit 14 of the UP1 decladding facility, from April 2007 to July 2010. It was a success. The pit is now completely empty, the stainless steel walls are decontaminated and the radiological end state target is reached.

Since February 2010, AREVA has begun the sludge retrieval operations on a second pit. After some modification of the equipment and process, the work is progressing well despite some difficulties linked with a significant increase in the measured radioactivity within pit 7. Indeed, the presence of uranium scraps lead AREVA to develop some new solutions in order to deal with these highly irradiated fragments. The retrieval work is now expected to end at the beginning of 2013.

The graphite retrieval and pit clean-up demonstration program, conducted by AREVA under a CEA contract, proved successful in terms of the feasibility and reliability of the equipment that was used.