Cleanup and Dismantling of Highly Contaminated Ventilation Systems Using Robotic Tools – 13162

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ABSTRACT

The UP1 plant reprocessed nearly 20,000 tons of used natural uranium gas cooled reactor fuel coming from the first generation of civil nuclear reactors in France. Following operating incidents in the eighties, the ventilation system of the continuous dissolution line facility was shut down and replaced. Two types of remote controlled tool carriers were developed to perform the decontamination and dismantling operations of the highly contaminated ventilation duct network. The first one, a dedicated small robot, was designed from scratch to retrieve a thick powder deposit within a duct. The robot, managed and confined by two dedicated glove boxes, was equipped for intervention inside the ventilation duct and used for carrying various cleanup and inspection tools. The second type, consisting of robotic tools developed on the base of an industrial platform, was used for the clean-up and dismantling of the ventilation duct system. Depending on the type of work to be performed, on the shape constraints of the rooms and any equipment to be dismantled, different kinds of robotic tools were developed and installed on a Brokk 40 carrier. After more than ten years of ventilation duct D&D operations at the UP1 plant, a lot of experience was acquired about remote operations. The three main important lessons learned in terms of remote controlled operation are: characterizing the initial conditions as much as reasonably possible, performing non-radioactive full scale testing and making it as simple and modular as possible.

INTRODUCTION

From 1958 to 1997, the UP1 plant at Marcoule – located in the South of France – reprocessed and recycled nearly 20,000 tons of used fuel for special defense application reactors as well as fuel from the first generation of electricity generating reactors in France (natural uranium fuel, CO2 cooled and graphite moderated).

The cleanup and dismantling of the UP1 plant and the associated units started in 1998. Since 2005, the UP1 facility has been operated by AREVA as a Management & Operation contractor to the French Atomic Energy Commission (CEA).

This is a huge decommissioning project with 14 main facilities, over 1,000 rooms and cells to dismantle and cleanup, 700 tanks, 21,000 tons of equipment (2% of which are High Level Waste).

The Decontamination and Decommissioning (D&D) project's end is planned for 2040.

Many challenges were encountered to operate at such an old and complex facility. It required the design and/or improvement of specific tools & processes. The decontamination and dismantling technologies and methods were systematically adapted to the equipment to be processed. Furthermore, a large number of cells and highly contaminated areas required developing and adapting remotely operated devices to conduct decommissioning operations. Some of the most complex cases required full remote conditions.

The paragraphs below illustrate two examples of remote controlled tools developed for the decontamination and dismantling operations of the old ventilation system of the MAR 200 facility.

MAR 200 was the continuous dissolution line facility in the high activity side of UP1.

DESCRIPTION OF THE WORK AND METHODOLOGY

Robotic and remote controlled operations are usually very expensive and time consuming but sometimes necessary especially when the environment is very "hot" with challenging access and limited space. Such was the case for the D&D of the first MAR 200 ventilation system.

At the beginning of the eighties, different operating incidents affected the ventilation system of MAR 200 which was shut down and replaced.

Taking into account the high level of contamination, the irradiation of materials, the shape of the rooms and the constraint of access, two different types of remote-controlled tool carriers were developed to perform the decontamination and dismantling operations of the ventilation system.

Decontamination of a ventilation duct using a robot

Resulting from an in-service valve leakage incident in 1982, a spent fuel dissolution solution spilled into a ventilation duct. Over the years, the solution had dried and crystallized to form a powder layer of varying thickness inside the duct. The duct is suspended in a radioactive corridor with no human access allowed.

The main objective of this project was to retrieve the powder deposit within the ventilation duct before subsequent dismantling operations. The objective was to collect 95% of this powder.

In order to better assess the initial condition of the duct, some investigation work was done. Several core drillings in the walls and opening cuts into the ventilation duct were performed to allow the insertion of instrumentation and sampling:

- Visual CCTV (Close-Circuit Television Camera) examinations were made with a borescope at three different locations within the duct, making it possible to view the entire surface and effectively observe the powdery deposit,

- Dose rate and gamma-ray imaging measurements were also performed inside the ventilation duct,
- Powder samples were taken under sealed conditions and transported to the laboratory for subsequent physicochemical and radiological analysis.

Following the investigation work, the initial conditions were identified:

- The solution had spread inside the ventilation duct over a distance of 14 meters (46') and then dried and crystallized, resulting in powder formation,
- Approximately 15 cm (6") of powdery deposit were observed inside in the ventilation duct,
- There was an estimated 700 kg (1543 lb) of powder deposited inside the duct,
- According to the chemical and radiological analysis, the powder contained mostly uranium nitrate, and traces of plutonium,
- The initial dose rate ranged from 0.14 to 1 Gy/h (14 to 100 rad/h) inside the duct.

A picture of the powder deposits observed inside the duct using CCTV examination is given in Fig. 1.

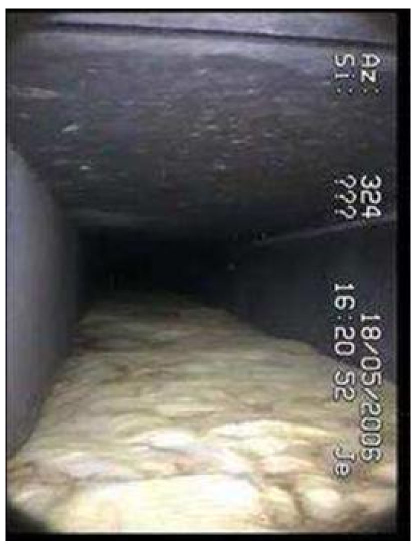

Fig. 1. Powder deposits inside the ventilation duct

The measured dose rates in contaminated areas were too high for contact work so remote operation was the only solution to perform the decontamination work. The criticality risks could not be excluded from the analysis, thus increasing the complexity of the tools required to retrieve the powder but also to process it. Given the radioactivity and physicochemical properties of the powder, the only possible waste solution within the site was the vitrification process.

Taking into account the analysis of the initial condition, the retrieval and processing scenarios were defined.

For the retrieval of the powder, a dedicated small robot was designed from scratch and totally adapted to the environmental constraints. Indeed, preliminary analysis and inactive tests (full scale) with simulants have shown that the powder could be sucked up using a remote-controlled tool carrier throughout the length of the horizontal duct. The results from these tests were also used to define hose materials and hose reel control methods to minimize deposits inside the hose during suction operation.

The tool carrier was designed to be inserted through specially created openings and to carry various cleanup and inspection tools (see Fig. 2). Each robot was equipped with a suction nozzle connected to a nitric acid dissolution unit via a hose and reel assembly.

Fig. 2. Remote-controlled tool carrier equipped for intervention inside the ventilation duct

The tool carrier was managed and confined by two new dedicated glove boxes and it was controlled from a remote terminal located in an adjacent corridor. The two glove boxes were connected to the ventilation duct and they were used to deploy the remote inspection, retrieval and decontamination equipment (see Fig. 3). The first glove box allowed access to the duct and maintenance operations on the remote carrier and the second glove box contained the hose reel.

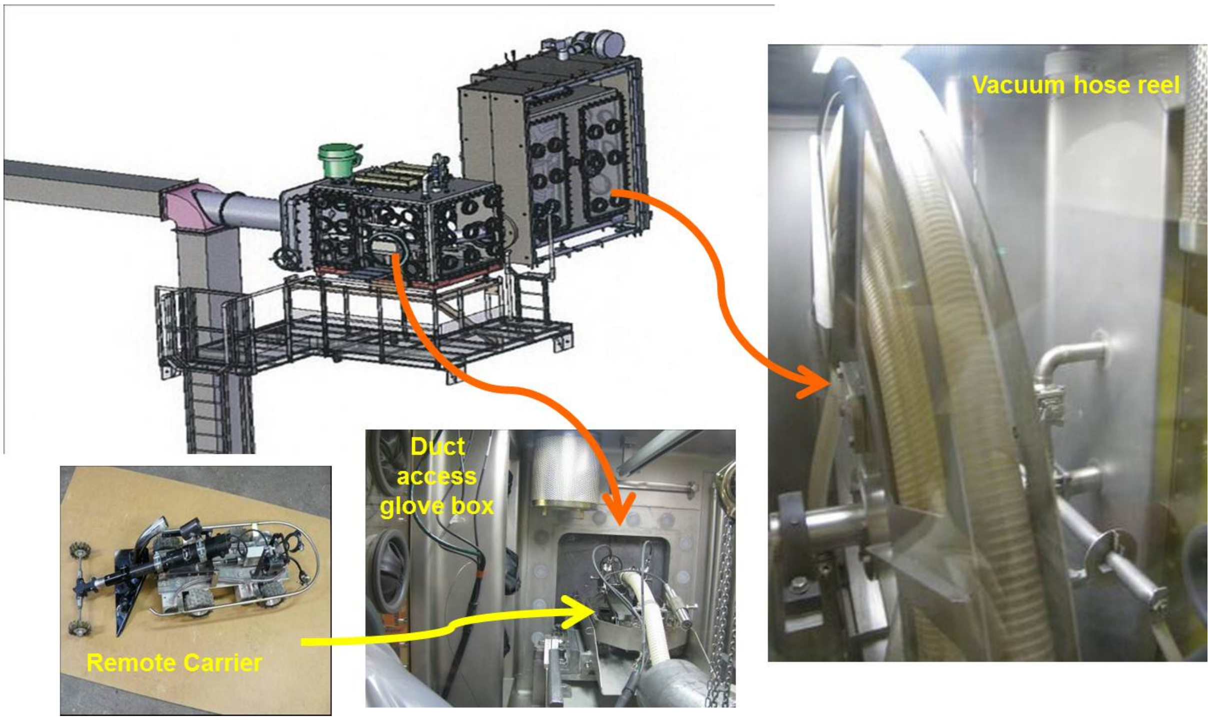

Fig. 3. The 2 new glove boxes connected to the ventilation duct

Vitrification being the only possible outlet, a new dedicated dissolver located in an adjacent cell was installed for the processing of the retrieved powder. The sucked powder was dissolved by 15 kg (33 lb) batches (due to criticality risks) in nitric acid. Then the effluents were transferred to the vitrification facility of the site via existing buffer tanks and pipes.

Dismantling the filter room and the associated duct gallery

Following two operating incidents in the 1980s, spent fuel dissolution solutions spilled into the ventilation duct network via an extraction conduit. The network was also contaminated with uranyl nitrate vapor during another event. As the entire ventilation filter room and the associated duct gallery were affected, this ventilation network, dedicated to the treatment of gaseous effluent from spent fuel dissolution process and vitrification process, was then shut down and replaced.

The filter room (see Fig. 4.) is 15.7 meters long, 11 meters wide and 6 meters high (52'x37'x20') and contained 28 filter chambers and the associated exhaust plenum. Each filter measured 1 meter long, 1 meter wide and 5 meters high (3'x3'x16').

There were 3 ventilation duct networks: High Flow (HF), Medium Flow (MF) and Uranium Store (ST).

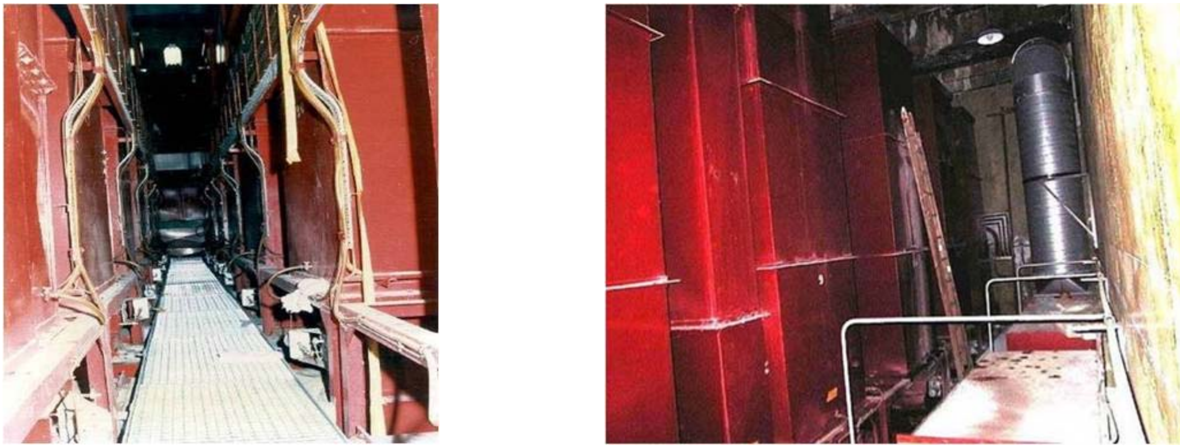

Fig. 4. Filter room

The duct gallery (see Fig. 5.) is 39 meters long, 3 meters wide and between 1.40 and 3.20 meters high (130’x10x4.7’to10.7’).

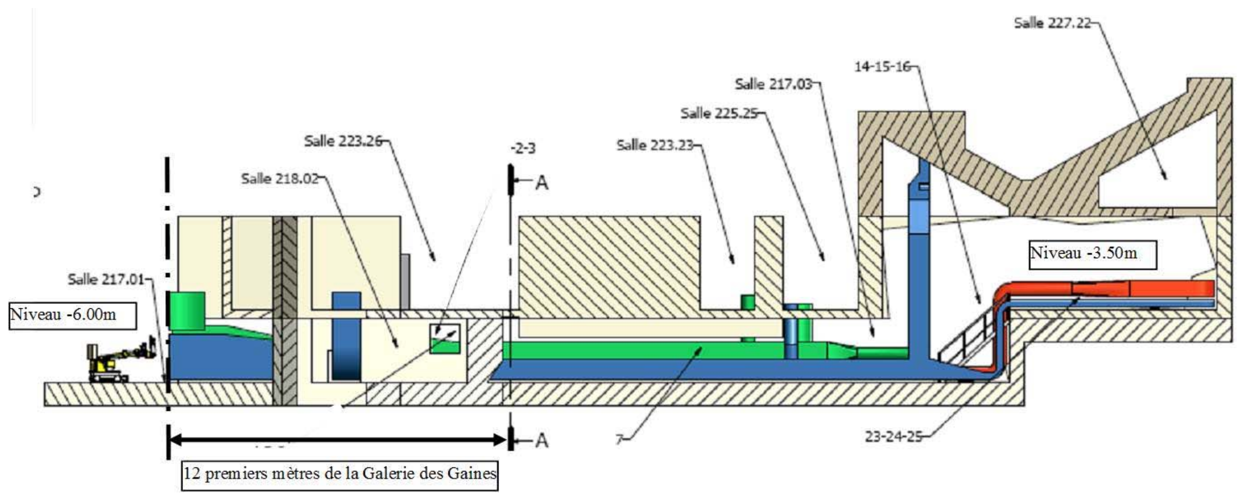

Fig.5. Duct gallery

To increase the knowledge of the initial condition in the duct gallery, more investigation work was carried out using a remote controlled robot called EDI (Engin D’Intervention, see fig. 6). EDI is a lightweight carrier vehicle equipped with a measurement probe (with remote transmission to the control station), and also with a dome camera at the front, a fixed camera at the rear and two lights. It was also used later to assist remote-controlled devices in cutting operations (providing extra lighting and transmitting video images to the control room).

Fig. 6. The EDI robot

The initial conditions were identified as follow:

- The HF and ST network are, in principle, irradiating and the dismantling operations should produce irradiating metal waste that must be sent to the Marcoule decontamination facility in lead-plated handling casks,
- The MF network is, in principle, not very irradiating and the dismantling operations should produce low-level metal waste that must be sent to the Marcoule solid waste treatment facility in standard handling casks,
- The ambient dose rate was between 2 and 52 mGy/h (0.2 to 5.2 R/h) with hot points at 0.3 G/h (30 R/h),
- The level of contamination was above 10,000 Bq/cm2,
- The radiological measurements revealed no criticality risk,
- The complicated shape of the room.

Because of the high level of contamination and Irradiated materials, the challenging access and limited space, the different floor levels and ceiling heights in the working room and also because of the different sizes of the equipment to be dismantled, a dismantling scenario based on specialized robotic equipment was required.

Depending on the type of work to be performed (investigation and characterization, cutting, fixative spraying, concrete scabbling, hot points drilling, vacuum cleaning, etc.) and shape constraints of the rooms and equipment to be dismantled, different kinds of robotics tools were developed and based on a Brokk 40 platform specifically modified to take into account the nuclear constraints.

Usually the remote controlled carriers and its robotic arm were equipped with different kinds of cleanup and dismantling tools, i.e. a disk grinder, a pneumatic drill to treat hot points in the concrete, a hydraulic (or electrical) gripper for moving metal sheets and debris, a vacuum cleaner… They were also equipped with a measurement probe, a camera and a lighting system.

Five remote controlled vehicles, controlled from a central control room using their camera and radiation probe, were used for the dismantling of the filter room and the duct gallery:

- The EDA (Engin D'Assainissement) was used in the filter room for cutting the lowest part of the filter chamber, for doing the cleanup work (vacuuming, varnishing…) and for moving the metal sheets and debris.
- The EDD (Engin De Démantèlement) vehicle was designed for working on heights. It consisted of a TOUCAN 800 platform lift equipped with the robotic arm of a Brokk 40. It was used for cutting the highest part of the filter chamber and duct in the filter room and later for the first two meters of the duct gallery.
- The EDR (Engin De Remplacement) vehicle replaced the EDA and was used to transfer the metal sheets and duct sections to the filter room for further cutting in smaller pieces and waste packaging. It was also used to reduce the radiological hot points.
- The EDM (Engin Démantèlement Marcoule) was designed to remotely deploy a metallic access ramp. The rear bumper was removed allowing the EDM to climb the access ramps to reach the -3.50 m level (a 2.5 meters (8.3') high step with a 31° slope (with respect to ground level) of the duct gallery. It was used to dismantle the ventilation duct then to clean up the ground of the higher level of the duct gallery.
- The EDG (Engin de Démantèlement de la Gaine) had an optimized height in preparation for dismantling the last 16 meters of the ventilation duct gallery at the -6.00 m level where the gallery ceiling height was reduced from 2.20 m to 1.40 m. The tool-holder was equipped with a semi-automatic 90° rotation device for cutting in every position. The EDG was also able to sweep the gallery floor and vacuum the ground.

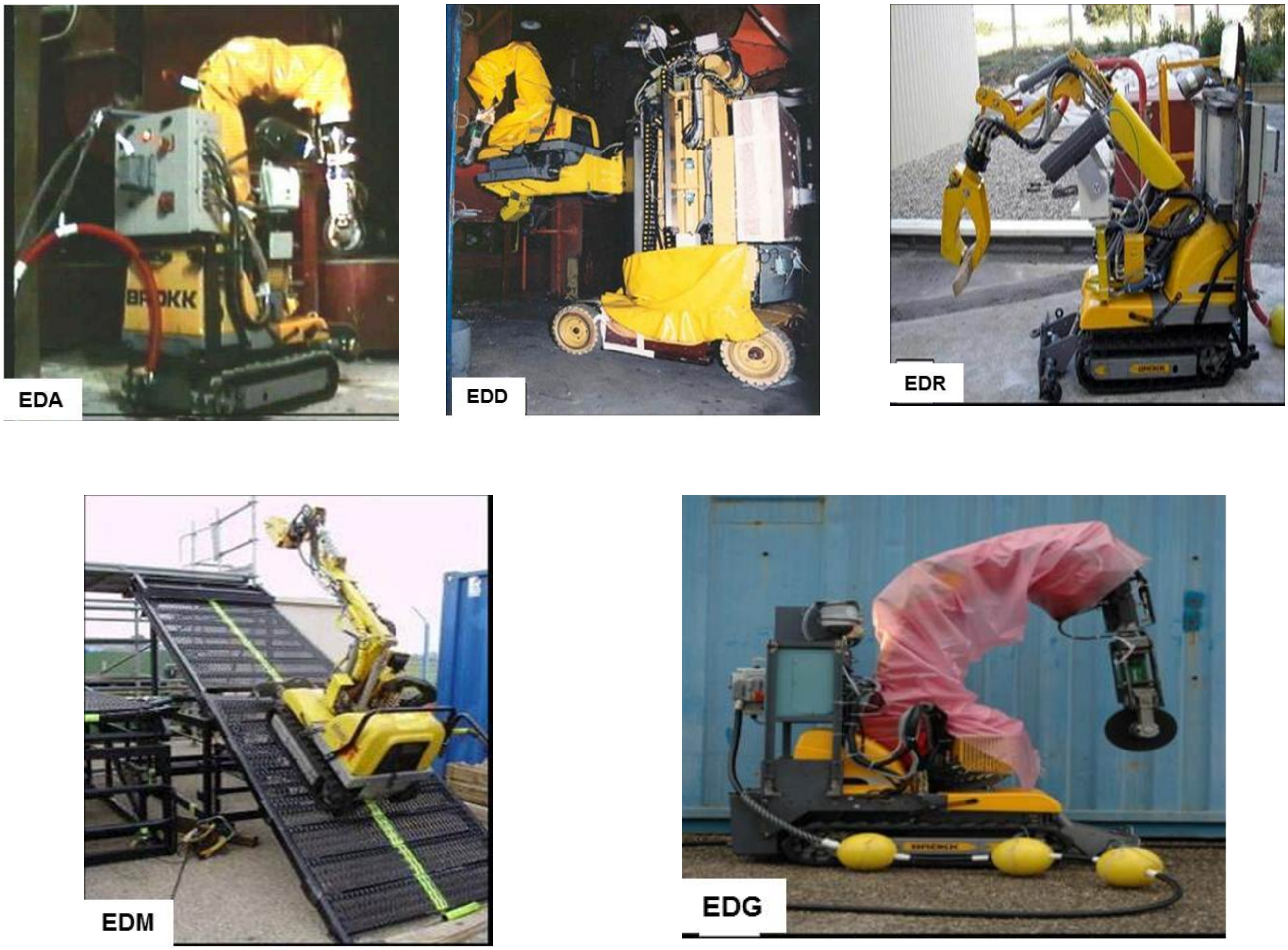

Fig. 7. The five remote controlled vehicles

Thus, the operating scenario was implemented using the different robotic tools as described below.

Filter room (see Fig. 8):

- Remove filters and transfer them to Marcoule Decontamination Facility
- Cut out and reduce the size of the filter chamber, ventilation duct and exhaust plenum
- Decontaminate metal sheet debris with a HP water jet washing machine

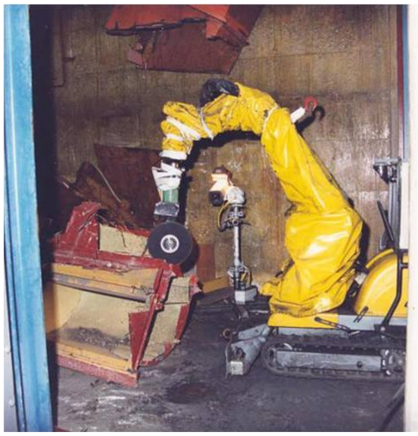


Fig. 8. Duct cutting in the filter room using EDA (left) and EDD (right)

Duct gallery (see Fig. 9):

- Open ducts using disk cutter
- Vacuum dust and powder and spray fixatives on metal surfaces inside the duct
- Cut out ducts using disk cutter
- Transfer metal sheet debris to the ventilation filter room for further size reduction

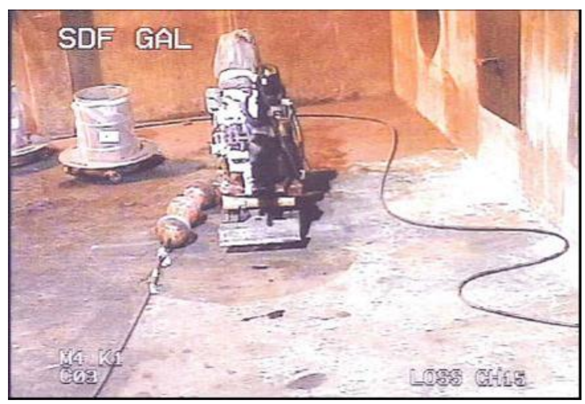

Fig. 9. MD duct cutting (left) and duct gallery vacuuming (right) using EDM

In both cases, the ground was vacuumed and the residual hot spots dose rate higher than 10mGy/h (Dr >1 R/Hr) were treated using a pneumatic drill (until the steel reinforcement level), and the rubble and debris were swept out.

The waste was packaged in metallic boxes or 30 gal drums, shielded as needed (200mR/Hr).

RESULTS

Decontamination of a ventilation duct using a robot

The 3 year project was completed in December 2011 and included one year of preparatory layout and construction work for the retrieved material dissolution unit. Project costs were controlled as planned according to the pre-conceptual design forecast.

The powder retrieval objectives were achieved. A total of 452 kg (996 lb) of powder was collected in 59 batches, corresponding to a total radioactivity of 155 TBq (4185 Ci). The final dose rate ranged from 0 to 37 mGy/h (0 to 3.7 rad/h), corresponding to a decontamination factor of approximately 770. On the Fig.10 you can see the final condition of the ventilation duct after brushing the floor.

Fig. 10. Duct floor after brushing

All the powder was retrieved despite unexpected events:

- Discovery of solid crust layers on the ventilation duct floor
- Clogging of the hose reel
- Finding higher than expected dose rates

The modular design of the tool carrier made it possible to rapidly install two cutting wheels on the front end to deal with the solid crust layer. The clogging of the hose reel was due to the adhesion properties of the powder associated with changes in atmospheric humidity. This phenomenon (not taken into account during the design and testing) was solved using an air dryer and a hydrometer installed in the glove box inlet.

Dismantling the filter room and the associated duct gallery

The dismantling of the filter room occurred between 2002 and 2006. It was followed by the dismantling of the duct gallery and by the final cleanup of all the rooms between 2006 and 2011. About 150,000 man hours of work were spent and more than 150 metric tons of metallic waste were produced.

The contractual final ambient dose rate of lower than 2 mGy/h (20 mR/h) and no hot point above 10 mGy/h (1 R/h) was reached. In spite of pneumatic drilling down to the first layer of reinforcement, some hot spots remained in certain limited zones which had been covered with lead plates.

An overview of the rooms before and after the D&D operations is given on Fig.11.

Fig.11. The space between filter room and the duct gallery before and after D&D operations

Regarding cutting efficiency, an average of 4.6 linear meters cut per disk grinder operating hour was reached throughout the duration of work and there were about 2 hours of cutting operations a day.

The work time organization for remote controlled cutting operation is given below on Fig. 12.

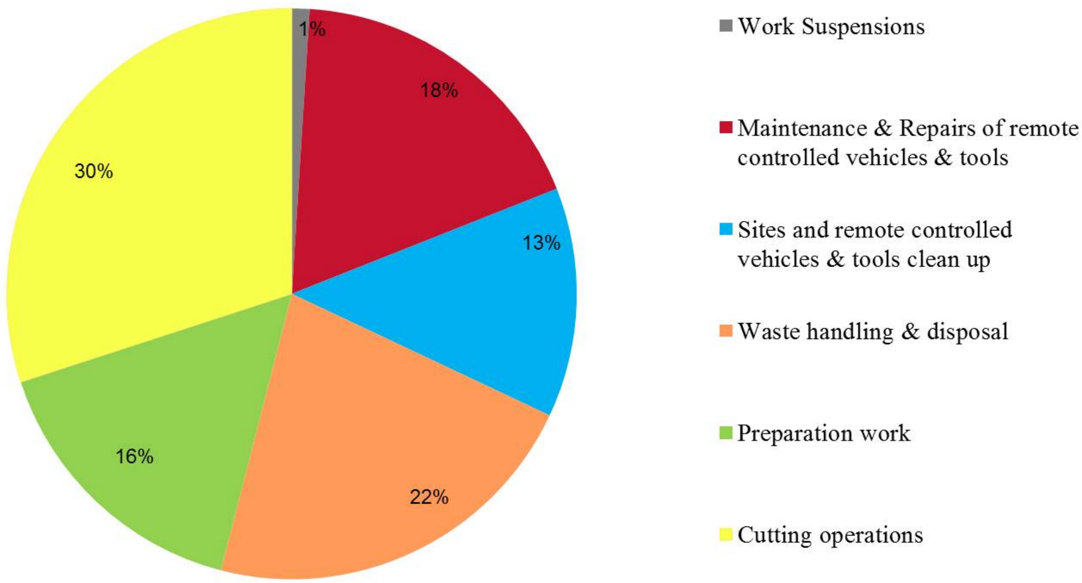

Fig. 12. Work time organization for remote controlled cutting operation

The most frequent sources of breakdowns were linked to disk grinder and hydraulic problems. That said, with time, it was electric breakdowns that became predominant.

The number of breakdowns and the duration of repairs have increased in time due to aging (obsolescence) of the equipment. Thus, the EDA remote controlled vehicle had to be replaced by the EDR after 2,000 hours of use.

Lessons learned

The specification of the remote controlled operation by the D&D scenario results from an accurate and complete analysis of the situation, the environment and the initial conditions.

Usually remote operations are used when the room or the equipment is very "hot" and when the environment is very constrained.

A simple and modular design of the remote-controlled device is critical to deal with the uncertainties of such a project in a highly radioactive environment.

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

Comprehensive investigation and measurement must be performed in order to better know the initial condition of the space.

CONCLUSION

After more than 10 years of D&D work on the Marcoule site, AREVA and CEA have developed a strong knowledge about the cleanup and dismantling of highly contaminated ventilation systems using robotic tools. A dedicated small robot designed from scratch as well as robotic tools developed on the base of an industrial platform were successfully used for the clean-up and dismantling of the old ventilation system of the continuous dissolution line facility of the Marcoule UP1 plant. The acquired experience and the lessons learned will allow us to perform better on similar project within AREVA but also with external customers.