DECONTAMINATION AND DISMANTLING OF THE PIVER PROTOTYPE VITRIFICATION FACILITY AT MARCOULE (FRANCE)

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ABSTRACT

The 1984 decision to decommission the PIVER pilot vitrification facility was followed by over three years of preparation during which the necessary administrative and operational structures were set up, safety permits and waste conditioning arrangements were secured, and additional technical means were designed and installed.

The operational phase began in 1988 with dismantling of the process equipment, followed by preliminary cell decontamination. System pipes were then cut up, first using telemanipulators and subsequently by human operators when the ambient dose rate dropped sufficiently to allow workers to enter the cell.

PIVER has now been fully decommissioned, and the main process cell is available for installation of a new research and development facility.

INTRODUCTION

The first active pilot unit for vitrification of fission product solutions, PIVER, began operation in 1969. Its primary objective was to demonstrate the technical and technological feasibility of vitrification under industrial conditions. The facility was operated from 1969 to 1973 with fission product solutions from reprocessed natural uranium gas-cooled reactor fuel: 25^3 of highly concentrated radioactive solutions recovered from 800 metric tons of fuel were vitrified in 12 tons of glass, cast into 167 canisters.

PIVER was then mothballed until 1979, when the facility was reutilized to vitrify fission product solutions generated by reprocessing fuel from the PHENIX fast breeder reactor: another 5 m^3 of solutions were solidified to produce 800 kg of glass in 10 canisters, demonstrating the feasibility of vitrifying solutions from reprocessed high-burnup oxide fuels.

The decision to decommission PIVER was made in 1984, after some 5 million curies had been vitrified. The objective was to thoroughly decontaminate the process cell in order to allow installation of a new research and development facility.

The decommissioning program lasted form 1984 to 1990, covering two main periods:

- 1984-1987: preparatory phase (organization, permits, methods, engineering studies, etc.)
- 1988-1990: decommissioning phase (equipment dismantling, cell decontamination).

Decommissioning has now been completed. The operation was performed by the Commissariat à l'Energie Atomique (CEA, France) with financial support from the Commission of the European Communities.

The Société Générale pour les Techniques Nouvelles (SGN) was responsible for organizing, defining and supervising tasks, and for the major engineering work. SGN also performed the safety analyses and implemented the conclusions in the PIVER decommissioning operations.

This paper covers the following aspects:

- a description of the PIVER facility,
- a review of the preparatory procedures,
- waste removal and conditioning requirements,
- a description of the decommissioning operations,
- an assessment of the results.

DESCRIPTION

PIVER is part of the Marcoule pilot reprocessing plant, and comprises two main cells (Fig. 1):

- The vitrification cell (074) on the ground floor consists of a rectangular stainless steel enclosure 10 m high measuring 9 × 3.1 m (300 m^2 total wall surface area) with barite concrete biological shielding 1.25 m thick. It includes 4 viewports providing full visibility of the interior. The equipment lock is sealed by two shielded doors. The cell included a monorail hoist and a heavy telemanipulator named *Caroline.*
- A storage cell (075) for concentrated fission product solutions is located beneath the vitrification cell. For plant operational reasons, cell 075 had to remain in use throughout the decommissioning procedure, imposingserious constraints on the decommissioning operations.

Process-related facilities in adjacent cells included electrical utilities (induction heating), reactant preparation and distribution systems, sampling units, process fluids (coolant, steam, vacuum lines, etc.).

The cell itself contained the following process equipment:

- 3 induction furnaces (one 4.5 m high, two others 1 m high) with 0.6 × 0.6 m cross sections (total weight: 2000 kg),
- 16 process vessels with capacities ranging from 20 to 400 liters (total weight 4000 kg),
- 40 small vessels with unit capacities below 20 liters (total weight: 500 kg),
- approximately 1300 m of pipes with a mean diameter of 15 mm.

The cell radiological conditions were highly constraining in 1984 at the beginning of the decommissioning period: very severe contamination, ambient dose rates of several $Gy{\bullet}h^{-1}$ with peaks of up to 10^{20} $Gy{\bullet}h^{-1}$.

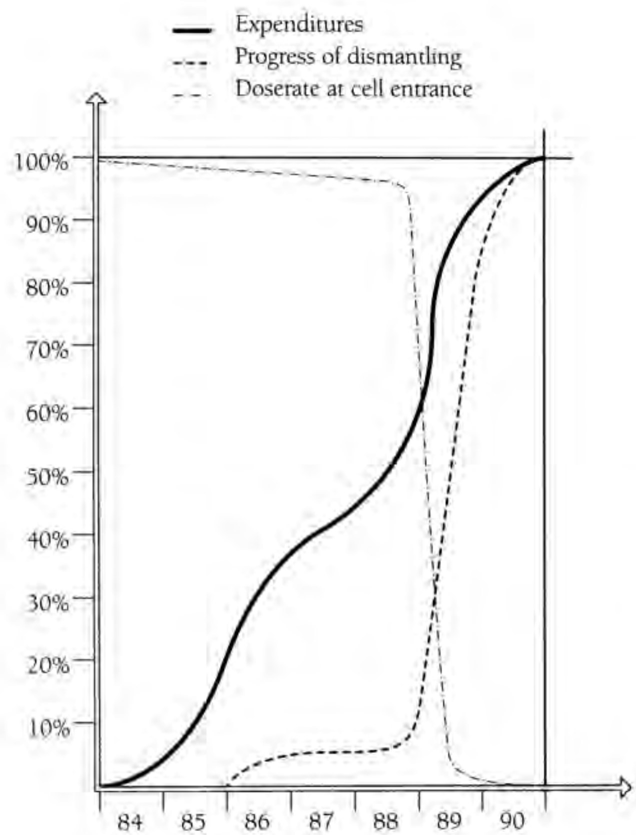

Fig. 1. PIVER facility (sectional view).

Finally, as a result of operating incidents and because of the limited possibilities for intervention, the floor of cell 074 was littered with technological waste, most of which was highly radioactive.

PREPARATION

During the preliminary phase, after identifying the specific constraints of the PIVER decommissioning program, an administrative and operational organization was set up, and some initial decontamination operations were carried out.

Constraints Related to the PIVER Decommissioning Program

In compliance with the Basic Nuclear Installation procedure, the PIVER decommissioning program was subject to regulatory safety and quality assurance provisions concerning such facilities.

Moreover, the concentrated fission product liquid storage unit beneath the vitrification cell had to be maintained in continuous operation throughout the decommissioning procedure. This implied identification and conservation of all related process pipes routed the vitrification cell.

These constraints significantly affected not only the preparatory phase but also the actual decommissioning operations.

Organization & Permits

The decommissioning operation was organized around a project leader, assisted by safety, quality assurance and planning specialists and an operational engineer responsible for the actual decommissioning work. With the help of a decommissioning technician, the operational engineer supervised two 4 man work crews organized in 2 daily 8 hour shifts, as well as maintenance, servicing and related operations performed by CEA and COGEMA technicians at Marcoule, and subcontractors engaged for specific tasks (engineering studies, special equipment, decontamination).

The project staff also prepared the administrative documents required to secure approval or authorizations from the French safety authorities and from the French radioactive waste management agency (ANDRA) responsible for accepting and storing the waste packages. These documents required regular updating as the work progressed.

The broad outlines of the PIVER decommissioning operation were specified in the PIVER decommissioning Safety Report, in the Operational Quality Assurance Program, and in the ANDRA-approved Waste Package Quality Assurance Program.

From a methodological standpoint, each operation was first documented and analyzed by all concerned parties in a PIVER Individual Decommissioning Task Report. Forty such reports were implemented during the active decommissioning phase between 1988 and 1990; they contained all procedures and safety requirements applicable to each operation.

TECHNICAL PREPARATION

Determination of the Cell Radiological Status Prior to Dismantling

Gamma scanning was carried out in the cell to locate zones of high activity concentration. A gamma teletopography method developed by the CEA to localize radioactive sources was used to identify and quantify the strongest sources in the cell. The technique involved photographing the cell using a camera containing several films with different sensitivities to visible light and gamma radiation. Computerized image processing generated a photo of the cell on which different irradiation levels were represented by a calibrated color palette.

Following this assessment, the decision was made to decontaminate the cell equipment internally via the process lines. This operation appreciably reduced the activity in the cell by removing 1.1×10^{14} Bq (2900 Ci) in 4.5 m^3 of solution to be vitrified.

Identification of Equipment to be Dismantled

A 3-D imaging system using photographs taken through the viewports allowed comparison with the cell layout drawings to ensure accurate identification of pipes and process vessels to be dismantled, and those required for continued operation of the fission product liquid waste storage facility located beneath cell 074.

Additional Telemanipulation Facilities

In addition to renovating the existing *Caroline* heavy telemanipulator, additional remote manipulation equipment was required for decommissioning. A pair of *LaCalhène* MT200 master-slave telemanipulators was installed opposite a viewport for handling purposes and to place cutup waste into drums. A standard pantographic telemanipulator arm known as *Antoine*, capable of supporting 100-kg loads and a variety of tools, was procured, modified and installed.

Tooling

A range of additional tools compatible with Antoine was designed and built to allow a wider variety of in cell operations. These included a hydraulic shear capable of cutting stainless steel tubes up to 60 mm in diameter, a commercial disk cutter modified for easy installation and removal on *Antoine*, and two type of plasma torches including one operated in contact with the workpiece to avoid the problem of maintaining a constant torch-to-workpiece distance.

All these tools were interchangeable and designed for quick installation by operators in the cell access lock.

Planning

First, the task sequence was defined as accurately as possible based on an examination of the PIVER cell installation drawings and on the cell irradiation maps. The human resources necessary to execute these tasks were then determined, assuming simultaneous in cell cutting operations and removal of waste packages from the building by two work crews. The duration of each operation was estimated to define the work schedule.

A master schedule, covering all the major decommissioning operations, and monthly work schedules with itemized task breakdowns were prepared and continuously updated. The monthly schedules identified and defined each task to be carried out, and provided the basis for administrative preparation: task reports listing procedures for each in cell operation, specification of any special human or mechanical resources for each task, and determination of the expected contents of each waste package.

WASTE PROPERTIES, REMOVAL AND CONDITIONING

Waste Characterization

A quantitative and qualitative estimate of the wastes generated by decommissioning cell 074 was prepared during the preliminary phase. The principal waste forms included:

- glass debris and granules designed to trap ruthenium, containing up to several tens of curies of beta-gamma emitters with a contact dose rate liable to reach several $Gy \cdot h^{-1}$;
- inductors (concrete-encased copper windings) from the vitrification furnace, with contact dose rates of up to several hundred $Gy \cdot h^{-1}$;
- scrap metal (tubes, brackets, vessels, etc.) to be cut up, with contact dose rates sometimes exceeding 1 $Gy \cdot h^{-1}$.

These wastes were removed from the cell intact (inductors and process vessels) or cut up and packed in drums (pipes and scrap).

Waste Activity Assessment

Representative samples of the activity in cell 074 were analyzed to define the radionuclide spectrum, comprising mainly ^{137}Cs (80%); alpha-emitters accounted for less than 0.003% of the activity. The dose rate of every waste package or component removed from the cell was measured at 1 meter; based on the irradiation measurement and on the predefined spectrum, a specially developed computer code was used to determine the total activity of the waste material and the expected contact and 1meter irradiation levels of the conditioned waste package ready for shipment to the surface storage site.

The computed values ensured compliance with ANDRA waste package specifications:

- maximum permissible activity: 37×10^{10} Bq for each radionuclide per ton of embedded waste
- maximum contact irradiation level: 2 m $Gy \cdot h^{-1}$
- maximum 1meter irradiation level: 0.1 m $Gy \cdot h^{-1}$

Waste Removal and Conditioning

The waste removal and conditioning procedure from the cell to the storage site included the following major steps (Fig. 2):

- dismantling and/or cutting inside the cell;
- packing of cutup waste in 100 liter drums, or preparation of bulky items (inductors, process vessels) for removal from the cell;
- removal from the cell via the entry lock, with irradiation measurement to determine the waste activity;
- placement in an approved container (concrete cylinder or concrete-lined steel cube;
- radiological monitoring (contamination and irradiation);
- transfer to the Marcoule solid waste conditioning facility;
- injection of cement grout in container and final radiological examination;
- shipment to the surface storage site.

Each waste package was accompanied by a special document file containing all the information required for precise identification: radiological data (activity), waste properties (contents, nature, weight, shape, etc.) and waste position in the package.

DECOMMISSIONING OPERATIONS (1988-1990)

Dismantling of Process Equipment

After the waste materials littering the floor of cell 074 had been removed in containers, work began on the process equipment by cutting the units from their mounting brackets. The equipment items and cutup scraps, including mounts and pipe sections, were packed in drums inside the cell, then removed to an adjacent room for conditioning in approved waste containers.

When the dose rate in the cell entry lock dropped to a level allowing both doors to opened at the same time, large equipment items with low activity (vessels and condensers) were removed from the cell in one piece for conditioning in approved containers. This strategy limited the extent of the cutting operations, and thus tool wear and maintenance responsible for significant occupational doses.

Cell Decontamination

Several cell decontamination operations were carried out using very high pressure (400 bar) and high pressure (150 bar)

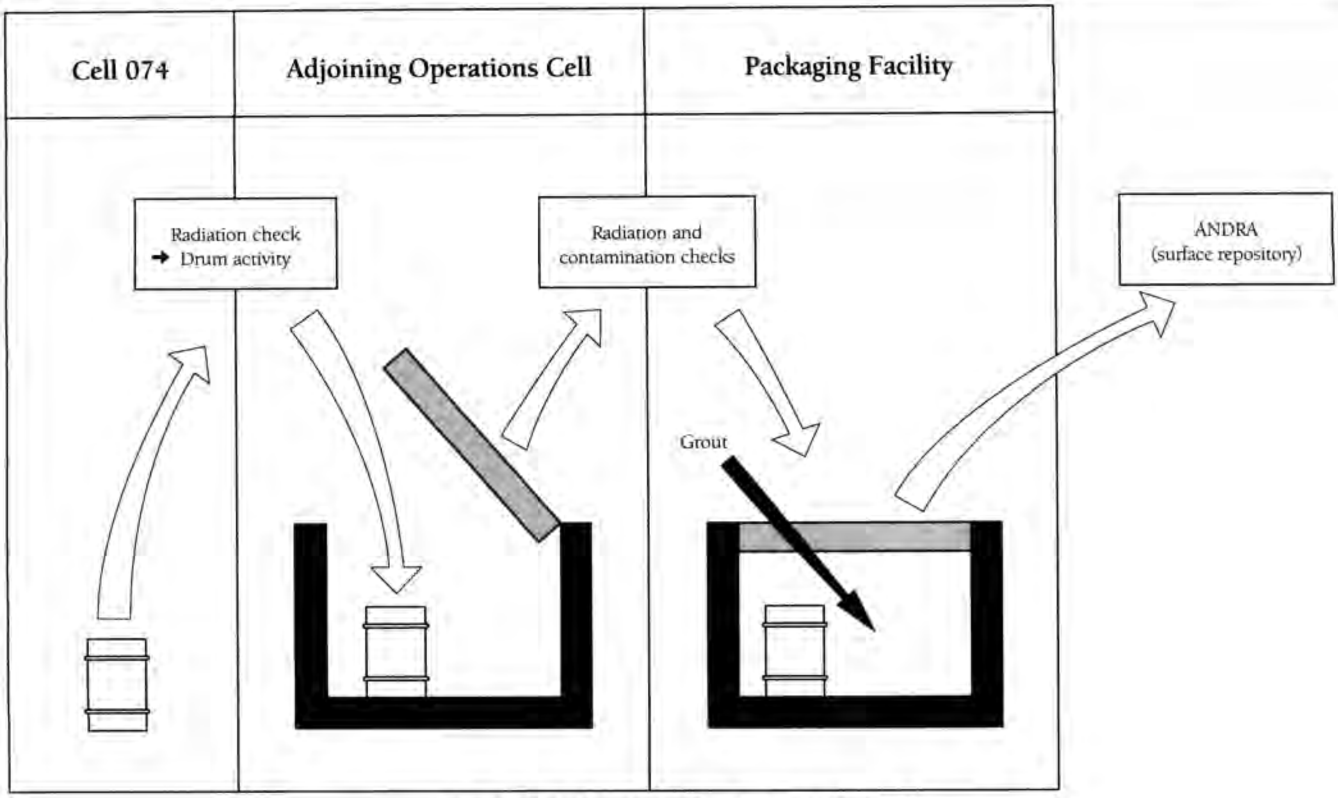

Fig. 2. Solid waste packaging and disposal.

water jets, first using telemanipulators and then by brief human entry into the cell when the irradiation level dropped below 2 m Gy•h^{-1}. These operations were very effective, and carried large amounts of highly radioactive debris (glass or scrap metal) to the cell drain channel, where they were collected by a special remote controlled caterpillar robot named *Oscar*, equipped with a shovel.

All the small waste was scraped up and removed from the cell floor, conditioned in small containers and transferred to the PIVER vitrified waste interim storage facility.

Dismantling the Telemanipulators

When the irradiation level dropped to levels compatible with human presence in the cell, the telemanipulators became an unnecessary hindrance for the remainder of the operations. The MT200 units were therefore removed, and the *Caroline* and *Antoine* robots were dismantled and conditioned in approved waste containers.

Pipe Cutting

Additional biological shielding was placed around points where the residual irradiation levels remained high, and most of the pipes were cut up by operators inside the cell. The pipes had all been identified and marked to avoid cutting those required to ensure continued operation of the fission product liquid storage unit beneath the cell.

RESULTS

At the end of 1990, all process equipment and pipes designated for dismantling had been removed from the cell, the residual labile contamination was virtually nil, and the ambient irradiation level was about 0.10-0.15 m Gy•h^{-1}. It was thus possible to work in the cell under normal conditions: the objective assigned to the PIVER decommissioning project staff was accomplished.

Solid and Liquid Waste

The following solid waste forms were produced:

- 37 cylindrical packages representing a final volume of 71^3 containing approximately 1.8×10^{13} Bq (500 Ci);
- 25 cubic packages (unit volume 5 m^3) representing a final volume of 125 m^3 containing approximately 2.2×10^{13} Bq (600 Ci);
- 800 waste drums (unit volume 100 liters) representing a final volume of 32 m^3 after compaction and conditioning, containing approximately 2.6×10^{12} Bq (70 Ci);
- 4 canisters of high-level waste transferred to the PIVER vitrified waste storage facility, representing a volume of 0.3 m^3 and containing approximately 8.1×10^{13} Bq (2200 Ci).

Liquid waste production included the following:

- 4.5 m^3 of very high level solutions containing about 1.1×10^{14} Bq (2900 Ci) from internal decontamination of process equipment;
- 2.7 m^3 of very high level solutions containing about 8.1×10^{13} Bq (2200 Ci) from external decontamination of process equipment and washing of the cell walls;
- 17.3 m^3 of intermediate level solutions representing 8.9×10^{12} Bq (240 Ci) from decontamination of the cell walls.

The very high level solutions were transferred to the Marcoule vitrification facility, and the intermediate level solutions to the Marcoule liquid waste treatment station.

The total removed activity of approximately 3.2×10^{14} Bq (8700 Ci) was distributed as follows:

- 61% in approximately 25 m^3 of liquid waste (58% HLW and 3% ILW),
- 39% in approximately 230 m^3 of solid waste (25% HLW and 14% conditioned in ANDRA containers for surface storage).

Radiological Assessment

The initial irradiation level in the cell was several $Gy \cdot h^{-1}$ (1 $Gy \cdot h^{-1}$ at the cell entrance, with hot spots of 1020 $Gy \cdot h^{-1}$). After decommissioning, the ambient dose rate was approximately 0.1 m $Gy \cdot h^{-1}$; a few stronger point sources were isolated by additional biological shielding.

The ambient dose rate cannot be further reduced, as it is primarily attributable to the fission product liquid storage facility located beneath the cell.

The overall dosimetry results totaled 0.44 man-Sievert, itemized as follows:

- 50% for tool maintenance and repairs;
- 30% for decontamination of the cell and adjacent rooms;
- 20% for removal of the waste packages.

Human Resources

A total of 92000 man-hours were required to complete the PIVER decommissioning operations:

- 50% by CEA technicians (cutting, maintenance, waste removal),
- 25% by subcontractors with piecework contracts,
- 25% for supervision and engineering studies.

Cost Assessment

The total budget for the PIVER decommissioning operation was about 50 million French francs ($8 million), itemized as follows:

- 26% for engineering studies and preliminary operations (including equipment investment costs),
- 24% for general services (waste treatment, health physics, etc.),
- 24% for CEA labor costs,
- 15% for subcontracting firms,
- 11% for supplies (biological shielding, cutting tools, etc.).

Overall Assessment

Figure 3 illustrates the percentage variations of three major parameters for the PIVER decommissioning operation: work progress (evaluated by assigning points to each scheduled task), dose rate at the cell entrance, and financial cost.

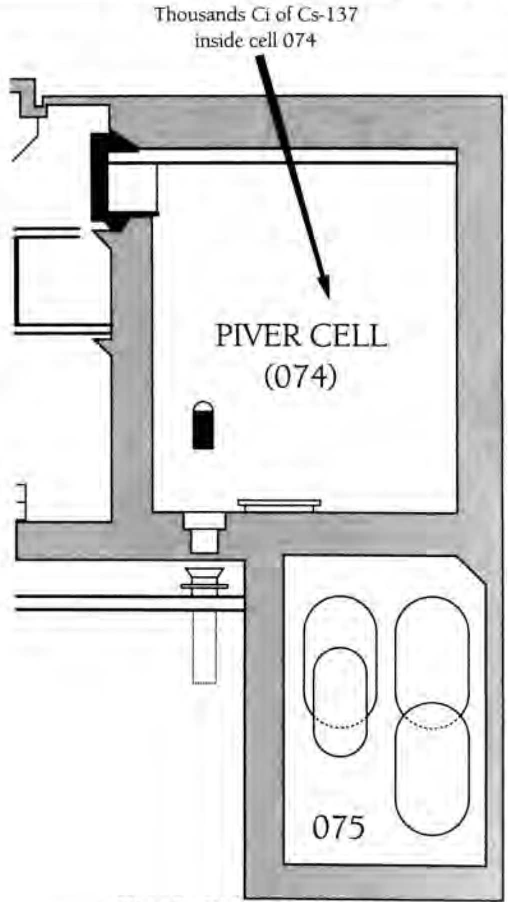

Fig. 3. Progress diagram.

CONCLUSION

The program provided valuable information relevant to decommissioning of PIVER, a nuclear installation with high irradiation levels and severe fission product contamination which may be applicable to other facilities of a similar nature:

- Equipment cleaning and internal decontamination provisions must be included in the design, and must be maintained operational as long as possible during the decommissioning phase.
- Activity removal in liquid form is highly effective and can avoid the use of equipment in very hostile environments, and thus minimize maintenance requirements and occupational doses.
- The preliminary engineering studies and planning must be extremely thorough to ensure efficient organization and suitable task scheduling.

PIVER was not only the world's first waste solidification facility capable of vitrifying high level fission product solutions, but also the first of its kind to be decommissioned.