

## **French Atomic Energy Commission Decommissioning Programme and Feedback Experience - 9080**

JP. Rozain<sup>(1)</sup>, JG. Nokhamzon<sup>(1)</sup>, C.Lecomte<sup>(1)</sup>

<sup>(1)</sup>Atomic Energy Commission CEA/DEN/DPA Saclay 91191 Gif-sur-Yvette Cedex, France

### **ABSTRACT**

Since the French Atomic Energy Commission (CEA) was founded in 1945 to carry out research programmes on use of nuclear, and its application, France has set up and run various types of installations: research or prototypes reactors, process study or examination laboratories, pilot installations, accelerators, nuclear power plants and processing facilities. Some of these are currently being dismantled or must be dismantled soon so that the DEN, the Nuclear Energy Division, can construct new equipment and thus have available a range of R&D facilities in line with the issues of the nuclear industry of the future.

Since the 1960s and 1970s in all its centres, the CEA has acquired experience and know-how through dismantling various nuclear facilities. The dismantling techniques are nowadays operational, even if sometimes certain specific developments are necessary to reduce the cost of operations. Thanks to availability of techniques and guarantees of dismantling programme financing now from two dedicated funds, close to €7,000M for the next thirty years, for current or projected dismantling operations, the CEA's Nuclear Energy Division has been able to develop, when necessary, its immediate dismantling strategy. Currently, nearly thirty facilities are being dismantled by the CEA's Nuclear Energy Division operational units with industrial partners. Thus the next decade will see completion of the dismantling and radioactive clean-up of the Grenoble site and of the facilities on the Fontenay-aux-Roses site. By 2016, the dismantling of the UP1 plant at Marcoule, the largest dismantling work in France, will be well advanced, with all the process equipment dismantled.

After an overview of the French regulatory framework, the paper will describe the DD&R strategy, programme and feedback experience inside the CEA's Nuclear Energy Division.

### **1. Context and Background**

The CEA's Nuclear Energy Division (DEN) nuclear facilities currently include seventeen reactors and thirty six other miscellaneous facilities, particularly laboratories, fuel processing units and facilities specific to waste management.

Some of these are currently being dismantled or must be dismantled soon so that the DEN, the Nuclear Energy Division, can construct new equipment and thus have available a range of R&D facilities in line with the issues of the nuclear industry of the future.

At CEA, the first nuclear facility dismantling operations go back several dozen years and involve numerous and varied facilities. The first operations of any significance took place in the 1960s and 1970s and covered, for example, the first plutonium plant at Fontenay-aux-Roses (total dismantling) and

small research reactors or critical models - CESAR and PEGGY at Cadarache and MINERVE at Fontenay-aux-Roses (civil engineering cleaned up and kept). At La Hague, the dismantling of AT1, a pilot workshop used by the CEA during the 1970s to process irradiated fuels from fast neutron reactors, was completed in March 2001 (IAEA former stage 3, excluding civil engineering demolition). On the other hand, during this period of first dismantlings, the intermediate-sized reactors (G1, Rapsodie) were only partially dismantled after shut down, mainly due to the lack of graphite and sodium waste management routes at the time.

About twenty facilities were thus dealt with up to 2001, in other words about half of all the nuclear facilities shut down permanently before this date.

Although the first dismantling operations proceeded at a steady pace, the same was not true during the

1990s, when the dismantling plan was slowed and very few sites could be completed. This was due firstly to changes in regulations, which induced modifications of the dismantling process, and secondly funding difficulties. At this time, as the CEA, a public owned institution, was not authorised to fund the sums required to dismantle its facilities and the operations took place on an ad hoc basis. Things improved from mid-1993 onwards, the operations were partly funded until 2000 by EDF and AREVA, both of whom had already been approached as they had been clients of the CEA's R&D programmes in the past in facilities now scheduled for dismantling.

In June 2001, the CEA decided, consistent with the supervision authority, to create a specific fund for the dismantling and clean-up charges of its civil facilities, with an initial allocation from industrial funds, from payment of an exceptional dividend from AREVA and from a portion of the AREVA shares held by the CEA. Provisions for the current and future "civil" dismantling stand at around €3,500M (€ 2008), at the beginning of 2008.

For the dismantling of nuclear facilities in the "Defence" sector managed by the Nuclear Energy Division, exclusively the facilities inside the UP1 reprocessing plant at Marcoule, a specific "Defence" fund was created in 2004 within the CEA, fed initially by final instalments from EDF and COGEMA from the portion due given their past participation in the plant's programmes. Provisions for the current and future UP1 dismantling are also close to €3,500M (€ 2008) at the beginning of 2008. Note that for both the civil and defence sectors, law n°2006-739 of 28 June 2006 on the sustainable management of radioactive materials and waste, and its application decree n°2007-243, henceforth impose the constitution of provisions and fix the modalities for use by the governing bodies to make sure that the funds required for dismantling current and future nuclear facilities are both lasting and available at the right moment.

## ***2. Current Regulatory Framework and Phasing of Dismantling Operations***

The regulatory context has changed radically since the 1960s.

Originally, the dismantling of nuclear facilities in the civil sector was regulated by Decree n°63-1228

dating from 1963, supplemented in 1990 by Decree n°90-78. In 2003, via its note SD3-DEM-01, the Safety Authority revised the practical modalities in applying this decree for the first time. Then in 2006 and 2007, Law n°2006-686 on transparency and safety in nuclear matters and its application decree n°2007-1557 on nuclear facilities set the current regulatory framework relating to the dismantling and decommissioning of licensed nuclear facilities. The various dismantling phases are now preparing for final shutdown, actual dismantling and decommissioning, as specified below.

A nuclear facility operator wishing to shut down his facility permanently must henceforth advise the Safety Authority. This information, which must be lodged at least three years before the date on which the operator intends to start the dismantling operations, is supported by an updated plan of the facility dismantling. In addition to presenting the preparations for the final shutdown, this plan must in particular describe and justify the dismantling strategy, the sequence of operations and the equipment required, the planned waste management outlets and the targeted final state of the facility after dismantling.

This information on shutting down a facility's operation is the start of the so-called preparatory phase for final shutdown. This transition stage, in the context of the facility's operating licence, sees the evacuation of all or part of the source term - evacuation of fuel in a reactor or emptying of process circuits in a laboratory, for example. This is also the stage for preparing for dismantling operations: evacuation of equipment scheduled for removal in the safety reference documents, creation of radiological inventories, site preparation, training teams, etc. The actual dismantling phase follows on from the preparation phase; this aims, in the event of total dismantling, to dismantle and evacuate the operational equipment and structures in the facility, including those parts which acted as radioactivity containment barriers. This phase requires further administrative authorisation subject to public enquiry.

At least one year before the planned final shutdown, the plant operator submits the authorisation request to the Ministers responsible for safety. This submission includes a file with the following main elements:

- the stages planned for the dismantling, their sequence, the general operating rules and the related safety report,
- the state of the facility and the site after dismantling,
- the risk and impact study for the dismantling operations, with in particular the methods planned to eliminate the waste from this dismantling,
- the forecasts for the subsequent use of the site,
- the updated internal emergency plan for the site where the facility is located,
- any monitoring and maintenance measures required after dismantling.

After examination by the Safety Authority and acceptance of proposals made by the operator, including those relating to the final state, the authorisation is issued as a decree setting especially the dismantling timescale.

Decommissioning of the facility, removing it from the legal and administrative framework of licensed nuclear facilities, requires notification by the Nuclear Safety Authority. The request for decommissioning, submitted after dismantling and control of the final state, is subject to various public consultations and a public enquiry, like for the final shutdown. For decommissioning, the enquiry covers any easements to be set up, use restrictions or precautionary measures, radiological measurements in the worked down area, for example.

In terms of the end state, note SD3-DEM-02 issued in 2006 specifies the requirements of the Safety Authority for complete clean-up of the facility's civil engineering structures, a major step in the total and unconditional release of the site. Initially, to define a minimum thickness of clean-up, the operator must rely on a representation of physical phenomena likely to result in the contamination or activation of structures involved in the clean-up, then defines and justifies a value for acceptable residual activity. For the total thickness to be removed, the operator must add an additional clean-up thickness to the modelled thickness as defined above, thereby applying an additional so-called basic precautionary additional margin.

Note that for all these aspects linked to the regulations in force, the regulatory framework for dismantling "Defence" sector nuclear facilities resembles that of the civil sector; by way of example, the ministerial authorisation for starting dismantling operations in the defence sector facilities is the equivalent of the civil sector's final shutdown and dismantling authorisation decree.

### ***3. The Nuclear Energy Division Choices in Terms of Dismantling***

#### ***The Main Ideas***

The Nuclear Energy Division dismantling plan ensures the end of cycle of shutdown facilities and contributes to optimum management of all experimental tools, as already indicated above.

Given the availability of funds required for the dismantling operations and past experience, which has validated the techniques for future dismantling, the CEA's Nuclear Energy Division has adopted the following principles for its future dismantling of facilities or part facilities.

To reduce the risk levels as quickly as possible and make the most of the experience of operating teams, radioactive clean-up is launched without delay once production is finally shut down.

Immediate dismantling is normally chosen after this clean-up work to avoid loss of information on facility construction and operating conditions, as well as to avoid the extra expense from extended monitoring of the facility and maintaining its current condition. For optimised management of waste generated by these dismantling operations, new interim storage facilities have been or will be constructed at the Marcoule and Cadarache centres. This policy is supported by optimised management of all transport containers and packaging, resulting in some cases in the construction of new equipment.

Delayed dismantling can be an option if the gain from the decay of short-lived radionuclides (simplified dismantling operations and reduced waste management costs) is greater than the extra

expense in extended monitoring of the facility and maintaining it in its current condition.

Delayed dismantling is also chosen when it is reasonably possible to wait for a waste evacuation outlet to open for operation - graphite, for example thus negating the need to construct new interim storage facilities.

The target final state for the facility once dismantling is complete must lead to total decommissioning of this facility for its potential re-use without restriction or monitoring or its demolition into conventional waste. The cleaned-up facility therefore no longer has a nuclear waste zone. When this objective is considered too difficult to achieve by the DEN, interim solutions will be envisaged, for example total release with easements relating to localised hot points.

For the site to be released (soils and buildings) after dismantling, the calculated dose from the residual activity, under an envelope scenario, must not exceed 300  $\mu\text{Sv}/\text{year}$ . Further optimisation is based on miscellaneous criteria, including: cost and consequences of work (structural behaviour, dosimetry of sites, etc.) relating to the situation of the facility (CEA centre, nuclear or otherwise, public space, etc.) and its specific features (history, spectrum, etc.).

The clean-up and dismantling operations are performed according to target costs and timescales. Protection of workers is achieved through seeking to reduce integrated doses; for protection of the environment, efforts are made to reduce the volume and level of radioactive waste and effluents generated.

Since the start, the DEN has distinguished between two major families of nuclear facilities in its dismantling plans:

- reactors (as well as accelerators and irradiators) which require preliminary calculation to assess the structures activation, and intervention simulations to prepare for dismantling which is frequently controlled remotely,
- hot laboratories, processing workshops and waste treatment facilities with the main

problem relating to contamination via dry or wet processes.

### *Assessment Method for Dismantling Costs*

Initially, version 5 of the estimating computing tool called ETE-EVAL is mainly used to assess the cost and financial risks of a facility dismantling project.

The ETE-EVAL V5 model assesses times, quantities of effluents/waste, doses and costs generated by the clean-up/dismantling operations of a nuclear facility. The modelling approach adopted is to produce an inventory of the facility, to cost it room by room and assign a standard scenario (or standard cell) to each room which brings into play a certain number of clean-up or dismantling tasks. These tasks are associated with ratios which, multiplied by quantities from the inventory, are used to calculate the primary quantities (times, effluent volumes, waste volumes and weights, doses). The determination of the overall cost of clean-up/dismantling of a nuclear facility is based on assessing primary quantities (costs of manpower, waste and effluents), and adding manpower-related services (laundry, induced waste, consumables, etc.) and general items (operating costs, arrangements, etc.).

The ETE-EVAL V5 model can use 28 standard scenarios (cells with high dose rates, medium dose rates, low dose rates, glove boxes, shielded containments, internal or external channels, pathways, etc.).

The tasks relating to each standard scenario (seventy tasks possible altogether) vary in type: intervention in tanks, pools and basins, radiological controls, remote operation, manual interventions, etc....

The ratios are classified into three categories (around 16,000 available):

- primary ratios (234, independent of the standard scenario adopted and the installation). These ratios are used to quantify the waste generated by the various tasks,
- scenario ratios (13,133, variable with the standard scenario). These ratios basically relate to clothing and hourly outputs,

- o ratios depending on the facility in question (2556). These ratios relate to the operating charges, hourly rates, material and consumable costs, waste and effluent treatment costs, etc.

These technical and economic ratios are entered in the "GREEN" database, shared partly between CEA and AREVA (primary and scenario ratios). Ratio development has benefited from operating feedback from AREVA and the CEA from clean-up sites and facility maintenance operations.

At the end of life of a facility and when the methods must serve as a basis for scheduling and managing dismantling activities, the dismantling cost estimations are built up in more detail than when used to obtain the initial financial envelope. They are then normally based on a dismantling strategy, putting together a detailed scenario of operations to be carried out and an industrial dismantling schedule. They act as an operational quotation and as the start point for defining the project reference documents and establishing the expenditure schedule.

#### ***The Organisation Set Up to Perform the Dismantling Operations***

The Nuclear Energy Division has set up a project organisation for its dismantling operations. The Nuclear Energy Division acts as the owner, project supervisor for strategic and operational project coordination, production of safety files and "nuclear operator" radiological protection assignments. The CEA normally operates the licensed nuclear facilities as nuclear plant operator. Once work has progressed to a certain extent and the nuclear risk has dropped (evacuation of nuclear materials, system clean-ups), facility operation may be outsourced. Note that for the dismantling programme for the UP1 plant at Marcoule and under the recovery of the site by the CEA, operation of the facilities are currently sub-contracted to the former plant operator.

The Nuclear Energy Division also controls the upstream figures for dismantling costs, as indicated above. It has teams specialised in quotation costing (ETE-EVAL) and knowledge management (REX team) for this purpose. It has also set up competence centres under the auspices of the Nuclear Protection and Safety Division (DPSN) in

the fields of expertise support for the dismantling, criticality and environmental studies in particular. The clean-up and dismantling operations are outsourced (to a prime contractor), unless a specific feature of a facility or special equipment requires particular CEA expertise. When substantial overseeing is required (large or complex batch), this is outsourced with the execution contracts integrated or not in the service provided. The sub-contracting is normally adapted to the project situations: overall sub-contracting of a project can only take place if the initial state of the facility is known, i.e. if the project risks are mostly under control.

Except for certain traditional services, such as final demolition of civil engineering or project management support, the contracts are awarded to companies accepted by the CEA's Radioactive Clean-up Companies Acceptance Committee (CAEAR) in the fields concerned, through tenders open to all these companies.

The CAEAR develops an acceptance and monitoring process for companies involved in radioactive clean-up, based on assessment questionnaires and systematic audits (quality and activities) by CEA's qualified auditors.

The areas covered are:

- o facility operation,
- o studies and project supervision
- o performance of work for miscellaneous waste classification levels.

The projects produce work appraisal feedback and can generate site audits; in case of problems, these may lead to the company being excluded from the CEA tenders until they are accepted once more.

#### ***4. Dismantling Programmes by the Nuclear Energy Division***

Based on principles defined above, the Nuclear Energy Division has put together a multi-annual dismantling plan covering all its nuclear facilities, regardless of whether they are already shut down or still in service.

As already stated, this dismantling plan is a component in the general Nuclear Energy Division strategy, particularly concerning the future of its research centres, namely the concentration of experimental nuclear facilities on the Cadarache and Marcoule sites and the denuclearisation of the

Fontenay-aux-Roses and Grenoble sites. One of the objectives is to have dismantled by 2025 all the facilities shut down between 1980 and 2010. A glimpse of the plan is given below, centre by centre (in some cases the former regulatory procedure is mentioned).

### ***Cadarache Centre***

- The HARMONIE pile is now totally dismantled. In contrast to the guidelines adopted by the DEN (see § above), the lightweight-construction buildings have been demolished. Notification of decommissioning is expected in 2008. HARMONIE was a critical,  $1\text{kW}_{\text{th}}$  model intended to study materials in the fast neutron reactor design. This reactor was commissioned in 1965 and shut down in March 1995. The permanent shutdown of the reactor operation was confirmed in December 1997 after removal and evacuation of nuclear materials. An authorisation application for the final shutdown and dismantling operations for the facility was submitted in April 2002. The decree authorising the dismantling operations appeared in January 2004.
- The ATUE, enriched uranium treatment workshops, commissioned in 1965 and shut down in 1995, will be totally dismantled in 2010. These industrial-size workshops were used for the dry conversion of uranium hexafluoride into sinterable oxide, wet chemical reprocessing of fuel assembly manufacturing scrap and incineration of organic liquids. Note that the structures' contamination level was revised upwards at the end of the dismantling programme.
- RAPSODIE is a fast neutron reactor with  $40\text{ MW}_{\text{th}}$  power. It was shut down in 1983 and its final shutdown was pronounced in 1985. The facility's dismantling operations started in 1987 once the relevant authorisation was granted, with a view to achieving a state corresponding to former stage 2 of the IAEA. These operations were temporarily halted due to an accident (explosion) in 1994 when residual sodium in a tank was being treated. Today, the clean-up and dismantling operations are

continuing with decommissioning by 2017 in view. The decree authorising the dismantling is expected in 2008. Note that the activation of the internal reactor structures has to be reassessed.

The dismantling project scope also includes:

- a cutting and post-irradiation examination laboratory (LDAC) for fuel assemblies from the RAPSODIE, PHENIX, PWR, PWR-MOX and KNK II reactors,
  - a neutron radiography reactor.
- The Cryoprocessing workshops, the PHEBUS reactor and the waste processing station will be dismantled shortly.

### ***Fontenay-aux-Roses Centre***



This involves dismantling the last nuclear facilities remaining in service on the Fontenay-aux-Roses site, the objective being total denuclearisation of the site by 2018.

- Building 18 and its annexes, built in 1954 was shut down in 1995 for the R&D section. Its role was radiochemical studies on significant quantities of plutonium from irradiated fuels and transuranic elements. The decree authorising the dismantling work was issued in 2006, fixing the end of dismantling at mid-2017. Building 18, covering about  $10,000\text{ m}^2$  of "hot" laboratories, houses a number of shielded lines and glove boxes. Major clean-up work has taken place since the facility was shutdown, particular on the shielded lines. A difficult site still has to be started; this involves the PETRUS shielded line where major quantities of radionuclides are still present. In addition, this

line is distinct from other shielded lines due to its interconnection with a local, highly-contaminated "effluent tank" following an incident in the 1970s when the laboratory was in service.

- The RM2 facility in building 52 still has to be dismantled. In this former radio metallurgy laboratory devoted to studying plutonium-based fuels, the experimental equipment has been removed from the cells and the walls have undergone a pre-clean-up operation. The end of cell structure demolition is planned for 2010, with decommissioning of the premises in 2011.
- The effluent and solid waste processing station is partially dismantled. The low-level effluent treatment process was shutdown in 1994 and dismantling of the evaporator and interim effluent storage tanks is now completed; the building has been cleaned up and arranged for interim storage of part of the waste which will be generated during the dismantling of building 18.

The incinerator constructed in 1967 for the purpose of reducing the volume of combustible solid was finally shut down in 2000. It has now been totally dismantled.

The other buildings included in the scope of this processing station will remain in service as support workshops until PETRUS is totally dismantled before being dismantled themselves.

- The decay storage facility for solid radioactive waste will remain in service until the end of dismantling operations on the Fontenay-aux-Roses site. Its dismantling will start after evacuation of 50 litre drums containing intermediate irradiating waste generated by the dismantling operations as well as those already stored temporarily in shafts. Its decommissioning is scheduled for 2018.

### **Saclay Centre**

- The high-level laboratories built in 1954 and shut down in 1996 were dedicated to experiments on radionuclides. A certain number of clean-up operations have taken place under the permanent shut down reference framework. Of the sixteen

laboratories enclosing shielded cells, nine are already empty of any process and cleaned up. The decree authorising dismantling was published in autumn 2008.

- The ULYSSE reactor and the non-lasting part of the liquid effluent treatment station will be dismantled shortly.

### **Grenoble Centre**



This involves dismantling all the nuclear facilities at the centre, culminating in total denuclearisation of the site in 2012. The first facility to have been decommissioned was the SILOETTE pool reactor with a thermal power of 100 kW<sub>th</sub>; reactor operation shutdown in 2002, decree authorising the dismantling operations obtained in 2005, end of dismantling work in 2006 and decommissioning in 2007.

- MELUSINE, built in 1958, is a pool reactor with a power that gradually increased to 8MW<sub>th</sub> in 1971. It was used for material tests, basic research experiments, analyses by activation and for the production of radionuclides. The final reactor shutdown was announced in 1993 and the decree authorising the dismantling operations was obtained in 2004. Today dismantling work on the facility is virtually finished and the facility is scheduled to be decommissioned in 2010. In practice, the dismantling work has revealed the existence of more specific activity than foreseen in the structures of the upper part of the reactor pool. This has led to additional work, particularly the cutting of the front pool block.



- SILOE is an pool research reactor with a nominal power of 35 MW<sub>th</sub>. It went critical for the first time in 1963 and was shutdown in 1997. This reactor was dedicated to material tests, the analysis of fission products generated in the fuel rods, the production of radionuclides and silicon doping.

Dismantling was preceded by a so-called permanent shutdown phase, during which the reactor fuel and fissile and radioactive materials contained in irradiation devices stored in the pool were evacuated, contaminated circuits were cleaned and operations like the evacuation of obsolete objects took place.

The decree authorising the dismantling operations was issued in 2005. The remote-controlled dismantling of the reactor vessel head has proceeded satisfactorily, however the irradiation levels read locally have precluded certain manual operations and increased the operations timing overall. Today, the demolition of internal concrete structures is going to start; this solution has been chosen over clean-up by skimming in the light of operating feedback from the MELUSINE reactor.

Decommissioning of the facility is scheduled for 2012.

- The hot laboratory LAMA, commissioned in 1961, ceased its research activities at the end of 2002. Its purpose was examinations and tests using its shielded lines to determine the laws of irradiation behaviour for fuels and materials. These themes include monitoring the fuel behaviour during irradiation, changes in the fuel in the water system in the event of "severely degraded core" accidents and the monitoring of fertile and absorbent assemblies for the rapid neutron system. The LAMA received objects for examination from experimental reactors (SILOE, OSIRIS, etc.) and some power reactors (PHENIX, BUGEY, etc.). The LAMA is currently in permanent shutdown phase; all the nuclear materials and waste have been evacuated, with the final operations taking place early in 2008. The LAMA dismantling file is currently being processed by the Safety Authority and the dismantling decree published in 2008. Facility

decommissioning is scheduled for 2012. Until now any clean-up has been nominal.

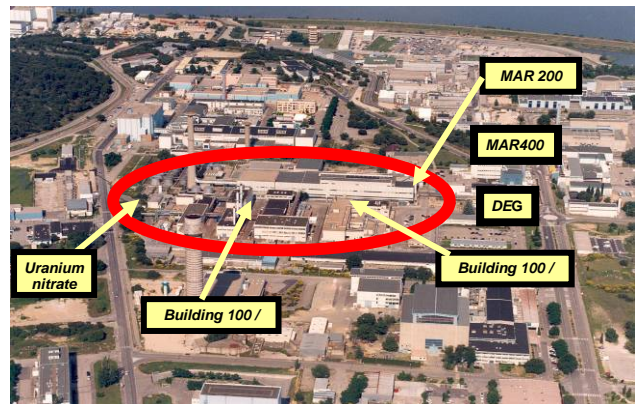
- In the effluent and solid waste treatment station, commissioned in 1959, and more especially its radioactive waste decay interim storage, commissioned in 1972, only the functions useful for the dismantling of nuclear facilities on the site have been retained.

During the recently-completed permanent shutdown phase, the tanks, evaporator, incinerator, compacting press, IER (ion exchange resins) treatment, waste concreting and NaK hydrolysis units have all been shut down and dismantled.

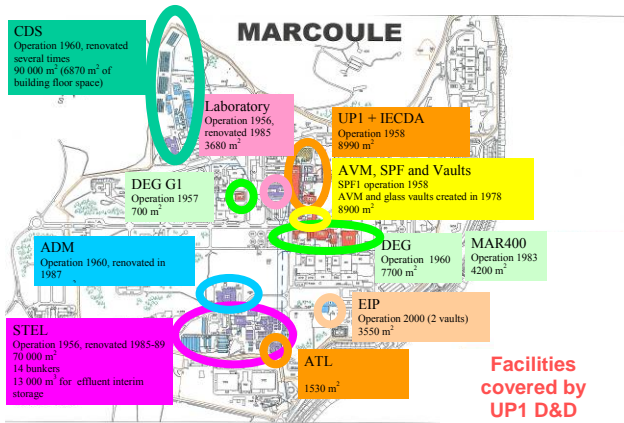
The de-stocking of irradiating waste packages for interim storage in the Cadarache facilities should be completed in 2010.

The dismantling decree was published in september 2008. The final dismantling will include demolition of buildings (lightweight construction). The target is decommissioning in 2012.

### *Marcoule Centre*







Major dismantling activities are currently underway on the Marcoule site, particularly the UP1 processing plant.

- The UP1 plant, commissioned in 1958, for reprocessing of irradiated fuels from G1, G2 and G3 reactors and extraction of the plutonium intended for deterrent. The plant's activities were extended to other customers (utilities) in 1976, in particular EDF for the reprocessing of fuels from its gas cooled reactors. At the end of 1997, after forty years in operation, the permanent shutdown of the UP1 plant was announced. Eleven facilities fall under the UP1 dismantling programme: five production facilities for fuel decladding, plutonium extraction and fission product treatment and six support facilities principally for waste treatment and conditioning. There is a wide variety of equipment to be dismantled: glove boxes, shielded lines, tanks, decladded fuel stores, conveyors, interim storage pools, pits, industrial equipment for decladding, dissolution, chemical separation, concentration, chemical conversion, vitrification, etc.

The aim is to decommission the facilities to former stage 2 of the proposed IAEA classification.

The end of clean-up and dismantling operations for chemical treatment facilities is scheduled for around 2018. The first activities to be completed will be in the "intermediate-activity" part. The final activities will involve the dissolvers and evaporators in the "high-activity" part and the related tanks.

A first dismantling state for the decladding workshops will be achieved in 2011, with

redevelopment of ventilation and electrical systems to reduce the monitoring costs throughout the old waste recovery operations. Dismantling of the decladding workshops is scheduled for completion in 2033. The dismantling of the vitrification workshops and its fission product storage tanks is scheduled for after the plant to allow vitrification of the last rinsing effluents. This will also be a two-phase operation, with the final phase scheduled for after the evacuation of the highly irradiating glass and technological waste containers in interim storage in the vitrification workshop pits.

The first part of the entire UP1 plant dismantling, going until end 2010 and entrusted to a group of companies coordinated by the former plant operator, is progressing nominally. All the technical difficulties have been or are about to be solved.

- The G1 reactor, the first reactor in the natural uranium-graphite-gas system and built in 1955, was shut down in 1968. The shutdown and partial dismantling work took place between 1968 and 1987, the cell block was contained and the 110m heights stack, demolished in 2003 by using explosives. The ground surfaces released around the reactor block were reused in the 1980s to install inactive pilots and prototypes dedicated to developing fuel processing processes. These pilots are now being dismantled.

Total dismantling of the reactor will start in about 2020, i.e. when the graphite waste storage enters into service.

- The APM - Marcoule Pilot Workshop - built in 1959 was shutdown finally in 1997. It was created to confirm, at pilot scale, the correct, active operation of processes adopted or proposed for the processing plants now operated by AREVA at La Hague. 36 tonnes of irradiated fuels of miscellaneous types and origin (UNGCR, PWR, FBR, etc.) were processed between 1974 and 1997. The fission product industrial vitrification system was also developed within the APM.

The fuel processing equipment and related tanks have now been rinsed and the first dismantling has started. Note that the

experience acquired from this rinsing is currently widely used for advanced rinsing of fission product storage tanks in the UP1 programme.

Work is currently in progress, radiological characterisation of cells and study of remote-controlled operation scenarios, waste evacuation, dismantling of small units and arrangements to facilitate future dismantling: access to the cells, creation of a line for fast waste output. Dismantling of this pilot workshop, a facility of more than twenty large concrete shielded cells, is scheduled for completion by 2020, with a ministerial dismantling authorisation ("defence" facility procedure) expected in 2013.

### 5. Development of Dismantling Tools at the CEA

Each dismantling operation therefore requires suitable tools involving techniques for measuring the radioactivity ( $\alpha$ ,  $\beta$ ,  $\gamma$ ), decontamination, cutting, remote operation, material and waste management etc.

Some of these tools have been or are being developed at CEA:

- gamma and alpha cameras for mapping, an essential decision-making aid in defining scenarios for operations in a hostile environment,
- calculation tools to assess the activation of structures,
- portable system for detecting surface uranium contamination,
- rinsing sequences for specific reagents (tested successfully in the APM site and used to rinse fission product storage tanks in the UP1 facility),
- decontamination by gels, foams, electro-decontamination, high-pressure water sprays, ice ball or carbon dioxide sprays,
- laser cutting which should be used in the RAPSODIE facility and the UP1 fission products storage tanks given its current performances,
- a remote-controlled dismantling system with force feedback (MAESTRO), with a slave arm with a 60kg at 2.30m, which should allow 80 kg/day of cut material/waste

conditioned and packed in small-volume drums, i.e. more than double the capacities of current tools; this MAESTRO system will be used to dismantle the PETRUS shielded line at Fontenay-aux-Roses and in all probability the APM cells,

- A software program simulating operations and human or robot interventions in support of the ALARA approach.

### 6. Lessons Learned

To day, after more than 40 years of dismantling and decommissioning work, it is now generally admitted that prompt decommissioning could gain benefit from:

- the operator's experience and memory are well used,
- surveillance and refurbishment costs should decrease,
- and the stakeholders, particularly the public could be more confident.

Waiting let the implementers get some benefits from natural radioactive decrease of short lived elements, and then doses delivered to the personnel should be lower. Techniques generally improve during time and are less costly. Techniques and decommissioning project organization and management have evolved, personnel has highest radiological and non radiological protection, security and safety conditions have brought some change in the situation during the period.

Other feedback experience has been gained on the

- Decommissioning:  
To have a successful work several conditions should be fulfilled such as:
  - knowledge of the facility's radiological mapping,
  - work and tasks organization previously well defined,
  - well adapted techniques,
- Operating:  
Feedback experience shows that it is absolutely/really necessary to clean up periodically all along his lifetime the facility, especially when spot contamination occurs during operation.

At this prospect, to have in the future easier and more effective decommissioning, it is necessary to keep in new design for future erection of new facilities the experience gained on past decommissioning projects:

- At the design stage:  
Design should take into account systematically decommissioning constraints: easy accesses, remote material, lifting resources, non porous material (to avoid contamination trapping), viewing (by using cameras or lead shielding windows), and avoid built blind cells without accesses.
- For the next future decommissioning operation:  
Education and training are essential, decommissioning is a profession and implementers, staff and workers, are to be experienced.

2016, the dismantling of the UP1 plant at Marcoule, one of the largest dismantling work in the world, will be well advanced, with all the process equipment dismantled.

## ***CONCLUSION***

A special feature of dismantling operations at the CEA comes from the diversity of facilities to be dismantled, which are predominantly research facilities and therefore have no series advantage. There is tremendous operating feedback, however. For more than forty years in all its centres, the CEA has acquired experience and know-how through dismantling research reactors or critical models and laboratories or plants. The dismantling techniques are nowadays operational, even if sometimes certain specific developments are necessary to reduce the cost of operations. Thanks to availability of techniques and guarantees of dismantling programme financing from two dedicated funds, close to €7,000M for the next thirty years, for current or projected dismantling operations, the Nuclear Energy Division has been able to develop, when necessary, its immediate dismantling strategy. Currently, nearly thirty facilities are being dismantled by the CEA's Nuclear Energy Division operational units with industrial partners. Thus the next decade will see completion of the dismantling and radioactive clean-up of the Grenoble site and of the facilities on the Fontenay-aux-Roses site. By