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# VANDELLOS 1 NPP. DISMANTLING AT THE LEVEL 1

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**Abstract**

Because of the fire in a main turbogenerator in October 1989, the Spanish Ministry of Industry ordered the definitive shutdown of Vandellos 1 NPP.

The tasks allowed to the owner in the Ministerial Order were:

- the reactor defuelling,
- the operation radwaste conditioning.

The size of the reactor core needed to prepare an adequate defuelling plan in order to prevent the potential reactivity oscillations and ensure the refrigeration of the nuclear fuel remaining in the core.

The operation radwastes were divided in four types, according to the conditioning method:

- the low level solid radwaste,
- the irradiated metallic materials,
- the resins and zeolites used for decontaminating the liquid effluents,
- the radwaste stored in three graphite silos.

The low level solid radwastes were stored during operation in drums of 220 litres. Recently they were compacted at a pressure of 40 tones before to be shipped to the ENRESA disposal.

The irradiated metallic materials are, essentially, some parts of the refuelling machine.

For desactivating the liquid effluents, Vandellos 1 used both organic resins and zeolites. The presence of zeolites helps the cementation, but its rough surface makes difficult to flow in the pipes of the cementation plant. 35 $m^3$ of this mixture have been conditioned into 670 drums of 220 litres.

Vandellos 1 has three silos designed to store the graphite sleeves (reactor fuel support). In the silo number 1 some other radwastes were stored, as low level solid radwastes and two fuel elements. An international request for tenders was made in order to undertake the extraction and conditioning all these radwastes. The project was awarded to the Spanish/French Consortium EQUIPOS NUCLEARES-FRAMATOME.

The achievement of the graphite silos project needed to design specific devices for separating irradiated wires from graphite, and searching and extracting two fuel elements jumbled up with the graphite sleeves.

The spent fuel ponds have been emptied and its internals confined.

The radiological protection during dismantling activities took care of $\alpha$ contamination.

The plant safety is always surveyed by the Regulatory Authority (CSN) which required to revise the Technical Specifications several times, according to the nuclear evolution of the site.

## 1. Introduction

Vandellos 1 is a nuclear power plant owned by HISPANO-FRANCESA DE ENERGIA NUCLEAR, S. A. (HIFRENSA), whose shareholders are :

| | | |
|---|---|---|
| - | Fuerzas Eléctricas de Cataluña | 29% |
| - | Electricité de France | 25% |
| - | Empresa Nacional Hidroeléctrica del Ribagorzana | 23% |
| - | Iberdrola | 23% |

The construction of the plant started in June 1967. The technology belongs to the European model of natural uranium-graphite-gas cooled reactors, specifically based on a joint project between Electricité de France (EDF) and the Commissariat à l'Energie Atomique (CEA). Vandellos 1 is a replica of the GCR Saint-Laurent-des-Eaux NPPs in France.

The first criticality took place in February 1972, and the two main turbogenerators of 250 MW each were connected to the grid in May 1972.

Because of a fire in the main turbogenerator nº 2, in October 1989, the Spanish Ministry of Industry ordered the definitive shutdown of the station.

The total electrical production was 55,647 GWh, which means a load factor of 72.3 %. The reactor availability factor reached 92.2 %.

## 2. The dismantling process in Spain

In Spain, the three dismantling phases defined by the IAEA are shared as follows:

– **LEVEL 1**: under the responsibility of the owner.

*Duration*: The time needed for defuelling the reactor and conditioning the radwaste produced during the operational period.
*Funds*: The funds are provided by the owner.

– **LEVEL 2**: under the responsibility of ENRESA[1].

*Duration*: The time elapsed for achieving the decommissioning and dismantling plan submitted to the Spanish Ministry of Industry.
*Funds*: Tax in the electrical invoice to consumers, collected by ENRESA.

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[1]ENRESA (acronym of Empresa Nacional de Residuos, S.A) was created in 1984 to manage all radwaste produced in Spain.

- **WAITING PERIOD**: the nuclear site is under responsibility and surveillance of ENRESA.

  *Duration*: The length of time is 25 - 30 years. During this period, the disqualified area of the site is returned to the owner, which can use it for any purpose.
  *Funds*: The same as at level 2.

- **LEVEL 3**: Under the responsibility of ENRESA.

  *Funds*: The same as at level 2.

Concerning level 1, the tasks allotted to the owner HIFRENSA in a Ministerial Order of 31 July 1990 were:

- to unload the reactor core and ship the spent fuel off the site,
- to condition of the radioactive waste generated in operation.

## 3. Unloading of the reactor core

The size of the reactor core (a cylindrical pile of graphite of 15.73 metres of diameter and 10.20 metres high, with 3072 loadable channels) needed to prepare an adequate defuelling plan in order to prevent the potential reactivity oscillations and ensure the refrigeration of the nuclear fuel remaining in the core.

It is important to note that the unexpected definitive shutdown didn't allow (the plant) to manage the last fuel load. So, the unloading was undertaken with a very large spectrum of burn-up. Two days before the shutdown, the monthly refuelling campaign has just finished.

The elaboration of the reactor defuelling plan required an analysis of:

- the cooling of the remaining loaded channels,
- the reactor reactivity evolution,
- the pond cooling capacity.

As a first approach, and according to the criteria adopted in the Saint-Laurent-des-Eaux A1 NPP, the following points were considered:

(1) First and foremost, the reactor channels had to be defuelled in an increasing order of cooling flow rate (in the Saint-Laurent-des-Eaux NPP, where the unloading of the reactor core took place very soon after the shutdown, the cooling of the channels remaining loaded was the first priority).
(2) To maintain the triangular symmetry during the defuelling, due to the position of the three sets of neutron chambers around the core. (This criterion had been respected throughout the operation for the refuelling).
(3) To avoid large variations in the average of the nuclear fuel burn-up remaining in the reactor, in order to minimize the reactivity changes, and to seek to keep the reactivity at the lowest possible value.

Two years after the reactor shutdown, the priorities for the defuelling plan were revised. It was more important to avoid the increase of the potential reactivity, since the residual power was a secondary factor.

In order to accelerate the decrease of the potential reactivity, it was necessary to unload the intermediate reactor zone.

The new order of priorities was:

(1) To defuel 12 "supercells" from the intermediate zone.
(2) To maintain the triangular symmetry.
(3) To defuel the reactor in increasing order of the channel cooling flow rate.
(4) To defuel the channels with lower burn-up.

The plan issued from the new priorities was applied in June 1992, 15 months after the start of the reactor defuelling.

The unloading of the reactor started in April 1991 and ended in October 1994. The unloading program was adapted to the availability of the reprocessing plant. So, there was no problems in ponds, neither in the dissolution of magnesium (cladding) nor in the cooling capacity.

## 4. Conditioning of the radwaste generated in operation

**VANDELLÒS 1 NPP**
**RADWASTE PRODUCTION (LIFETIME: 55 647 157 Mwh)**

| | |
|---|---|
| LOW LEVEL SOLID RADWASTE | – Compactible: 545 drums in operation + 275 in level 1<br>– Non-compactible: 139 drums in operation + 32 in level 1<br>– Filters: 20 drums in operation |
| RESINS + ZEOLITES | – Volume produced: 34.1 $m^3$. Cemented in 670 drums of 220 l |
| GRAPHITE SLEEVES | – Crushed graphite: 1000 tons in 240 containers of 6.5 $m^3$<br>– Support wires: 2 tons in 74 containers of 0.35 $m^3$ |
| IRRADIATED MATERIALS | – Various 1.71 $m^3$ 4.44 E+12 Bq (at 31.12.93)<br>– Absorbers 3.62 tons in 19 containers of 0.35 $m^3$ |
| LIQUID RADIOACTIVE RELEASES | – Global except $^3H$: 81.11 Ci in operation + 2.70 Ci in level 1<br>– $^3H$: 3780.00 Ci in operation +504.86 Ci in level 1 |
| GAS RADIOACTIVE RELEASES | – Noble gases: 3.54 E+14 Bq (mainly $^{41}A$) in operation<br>2.00 E+12 Bq (mainly $^{85}Kr$) in level 1<br>– Halogens + Particles (T>8 days): 2.87 E+9 Bq in operation<br>1.01 E+7 Bq in level 1<br>– $^3H$: 3.30 E+11 Bq in operation |
| NUCLEAR FUEL REPROCESSING RADWASTE | Reprocessing still in progress |

The operating radwastes were divided in four types, according to the conditioning method:

- low level solid radwaste,
- irradiated metallic materials,
- resins and zeolites used for decontaminating the liquid effluents,
- radwaste stored in three graphite silos.

*4.1. Low level solid radwaste*

During operation, the low level solid radwaste were stored in drums of 220 l.

In 1977 and in 1983, Vandellos 1 was authorized to put the low level solid radwaste into the silo 1. A compacting plant equipped with a press of 40,000 kg of capacity was installed in the site in 1990. The compacting ratio is about 1/3. The conditioned drums are shipped off to radwaste disposal site of ENRESA.

The total production of low level solid radwaste is estimated at:

- Compactable: 545 drums in operation + 275 in level 1
- Non-compactable: 139 drums in operation + 32 in level 1
- Filters: 20 drums in operation

Non-compactable drums hold radwaste like contaminated scrap iron or of similar stiffness. In the drums with filters are immobilized with cement used filters from the contaminated liquid circuits.

*4.2. Irradiated metallic materials*

The irradiated metallic materials are, essentially, some parts of the refuelling machine. No specific conditioning has been required. They have been handed over to ENRESA 1.71 $m^3$ of irradiated materials with a total activity of $4.44 \times 10^{12}$ Bq at 31.12.93.

Furthermore, the neutron absorbers from the reactor core, stored in the silos with the graphite sleeves (see 4.4), are also irradiated metallic materials, but they have been managed in the graphite project.

*4.3. Resins and zeolites*

For decontaminating the liquid effluents, Vandellos 1 used both organic resins and zeolites. In the conditioning, the presence of zeolites helps the cementation, but its rough surface makes flow difficult in the pipes of the cementation plant. 35 $m^3$ of this mixture has been conditioned into 670 drums of 220 litres and shipped off to radwaste disposal site of ENRESA.

*4.4. Graphite and diverse radwaste*

Vandellos 1 has three silos (8.7 m high, 7.2 m wide, 24 m long and 0.75 to 1 m thick concrete walls) designed to store the graphite sleeves (reactor fuel support). In the silo number 1 some other radwastes were stored, as low level solid radwastes and two fuel elements.

**VANDELLÒS 1 NPP**
**RADWASTE INVENTORY OF THE GRAPHITE SILOS**

| Type of radwaste | SILO 1 | SILO 2 | SILO 3 |
|---|---|---|---|
| GRAPHITE SLEEVES | **36123**<br>195.1 tons | **107450**<br>580.2 tons | **43778**<br>236.4 tons |
| SOLID GRAPHITE CYLINDERS | **4834**<br>50.7 tons | **60**<br>0.7 tons | |
| ABSORBERS (metallic elements) | **210**<br>1.5 tons | **282**<br>2.1 tons | |
| METALLIC REACTOR BASKETS | **3**<br>0.048 tons | **1**<br>0.016 tons | |
| COMPACTABLE RADWASTE (equivalent drums) | **891**<br>58.8 tons | | |
| METALLIC DRUMS | **38**<br>2.5 tons | | |
| FUEL ELEMENTS | **2**<br>0.02 tons | | |

A Resolution of the General Direction of Energy dated 22nd March 1991 required HIFRENSA to undertake the extraction and conditioning of the waste stored in the silos. HIFRENSA argued that the graphite sleeves had to be considered as structural waste, but the government resolution established that they had to be treated as operating waste.

HIFRENSA made an international request for tenders, in order to accomplish a fixed price project, according a set of technical specifications. The project was awarded to the Spanish/French Consortium EQUIPOS NUCLEARES-FRAMATOME.

The owner keeps the nuclear responsibility of the project with regard to the Nuclear Safety Council (CSN) and also maintains the relationships with this regulatory organism.

The achievement of the graphite silos project needed to design specific devices for separating irradiated wires from graphite, and searching and extracting two fuel elements jumbled up with the graphite sleeves.

In general terms, the objectives of the graphite project has been to perform the removal, sorting, preliminary packaging and temporary storage of radwaste, while considering:

- the applicable regulations,
- ALARA exposure and radiation protection standards,
- releases limits,
- the aim of achieving the smallest possible number of preliminary packages.
- keeping secondary radwaste down to a minimum.

The project has been developed as a plant modification, and to obtain the authorization to operate the documents submitted to the assessment of the Regulatory body were:

- a technical description of facilities,
- a risk analysis,
- a radiation protection plan,
- a quality assurance programme
- an operating organization.

Three items were deeply assessed by the designer and by the Regulatory Body:

- the ventilation system for ensuring the confinement,
- the radiological measures for environmental control,
- the fire protection system.

Other special radiological measures were implemented to control some specific activities. In particular, during the search and handling of the fuel elements there were:

- Continuous α- monitor of silo air with a removable filter.
- Complementary silo air sampling.
- Continuous β-monitor in working areas.

The sampling filters were measured in the laboratory by γ-spectrometry (searching $^{241}$Am, $^{137}$Cs and $^{60}$Co) and α/β counter (gas counter).

The comprehensive control of personnel has led to systematic nose wipe test, if working in an atmosphere with significant α o β contamination, even with breathing protection.

A mobile containment has been disposed for the extraction of radwaste. This facility protects a pair of holes of the silo against the open air. A telemanipulator arm is fitted into one of those holes and loads a basket fitted in the other one. When full, the basket is hoisted and introduced into a transfer cask.

The cask is transferred to the hot cell in the prepackaging workshop and unloaded. The hot cell is equipped with a set of devices to allow a selection of radwaste and to direct them towards the different conditioning ways.

The graphite sleeves, the most common radwaste, are transferred to a crushing machine with a high intensity magnetic separator. A magnet deflects the stainless steel wires towards a shielded container with a thickness of 180 mm of iron plus at least 60 mm of lead, at least. The graphite falls down to a cubic steel container of 8 mm thick.

The searching and extracting of the fuel elements needed to set up several systems of detection, in order to reduce the possibility of crushing a piece of uranium.

These systems were:

– visual, through a camera,
– Ge-detector, searching the $^{137}$Cs inside the silo,
– two NaI-detectors controlling each loaded transfer cask.

- a simulation of the silo operation,
- a test of the magnetism of absorbers caught by the telemanipulator arm. (Absorbers and fuel elements had the same appearance).

The first fuel element was found in good condition and extracted with the current jaw of the arm. The second one was found in a very damaged condition and it had to design a special tool for taking it out.

As densities of graphite and uranium compounds are very distant, a test with a vacuum machine, carried out with small lead bullets and clean graphite, showed the impossibility to extract uranium by this method. As neither uranium nor graphite are magnetic materials, it was not possible to extract them selectively by a magnet.

Therefore, a cryogenic sticking device was designed, and the problem was safely solved. The scrap uranium was taken out without contaminating neither the surrounding graphite nor the silo's atmosphere.

## 5. Dismantling of the spent fuel ponds

Due to the water of the spent fuel ponds is a shielding and not operating radwaste, to empty them had to be a task of ENRESA in the level 2 phase of the dismantling. Nevertheless, in order to take advantage of operating personnel and the availability of the equipment, HIFRENSA agreed to accept the responsibility of undertaking this activity previously to the hand over.

The spent fuel ponds have been emptied, their internals dismantled and confined and the liner cleaned up, according to a project elaborated by ENRESA and abstracted from the general level 2 dismantling project.

The work started in January 1996 and ended in May 1997. This large extended period is due to the stoppages for improving the hall ventilation and work procedures. The lessons learned from the $\alpha$ contamination incident in Saint-Laurent-des-Eaux were considered in Vandellos 1 from the beginning.

The ponds were the temporary storage of the spent fuel. The separation of the graphite sleeve from the uranium cartridge took place under the water. The sleeves were transferred and stored in the graphite silos. The uranium cartridges, after a cooling period, were shipped off to the reprocessing plant.

The spent fuel ponds of Vandellos 1 are a set of four ponds, separated by hatches, in which there were the internals required to separate sleeves from the uranium cartridge and to store them. A pipe with a lift connected the ponds with a dry hot cell. The total volume of water was 1315 $m^3$.

The dismantling of the ponds consisted in:

- dismantling of aerial parts not contaminated and storing in an appropriate area,
- emptying of water throughout resins,
- dismantling, decontaminating, cutting and packaging of internals.
- decontamination of the liner, at least up to 4 $Bq/cm^2$ for $\beta+\gamma$ and 0.4 $Bq/cm^2$ for $\alpha$,

- storage of cut materials and packaging inside an empty pond,
- confinement of stored materials with sealed concrete slabs of 15 cm thick.
- deep final cleanup of the hall and collection of all secondary radwaste produced.

## 6. Evolution of the Technical Specifications

The safety of the plant is always surveyed by the Regulatory Authority, which required several revisions of the Technical Specifications, according to the nuclear evolution of the site.

While the residual power was < 1 MWth, the reactor core air cooled and most fuel was in the core, the requirements were:

- 1 fan in operation + another on standby
- 2 air-conditioning units in operation
- 1 external power supply
- 2 auxiliary boilers
- 2 auxiliary turbo-generators
- 1 amid 4 heat exchangers on standby
- 1 amid 4 turbo-blowers on standby

With a residual power < 30 kWth and less than 50 % of nuclear fuel into the reactor core:

- 1 fan in operation + another on standby
- 2 air-conditioning units in operation
- 1 external power supply
- 1 diesel
- 1 heating boiler

Finally, when the reactor core was unloaded:

- no air circulation
- 1 auxiliary fan to maintain a depression (>2 mbar) inside the reactor containment

## 7. Radiological health

The radiological protection during dismantling activities took care of alpha contamination. A significant increase of hall contamination, at the end of February 1996, during the dismantling of the ponds, led to control personnel, in spite the breathing protection.

**VANDELLÒS 1 NPP. GRAPHITE SILO PROJECT. TOTAL DOSES**

| | Staff | Contractors | Total |
|---|---|---|---|
| Number of workers | **36** | **101** | **137** |
| Total doses (mSv·P) | **138.14** | **632.32** | |
| Max. individual dose (mSv) | **10.92** | **53.26** | |

### VANDELLÒS 1 NPP. GRAPHITE SILO PROJECT. TOTAL DOSES

| | Operation | Maintenance | Total |
|---|---|---|---|
| Number of workers | 72 | 65 | 137 |
| Total doses (mSv·P) | 336.06 | 434.40 | 770.46 |
| Max. individual dose (mSv) | 14.50 | 53.26 | |

### VANDELLÒS 1 NPP. DISMANTLING OF THE PONDS. TOTAL DOSES

| | Staff | Contractors | Total |
|---|---|---|---|
| Number of workers | 4 | 39 | 43 |
| Total doses (mSv·P) | 6.25 | 248.27 | 254.52 |
| Max. individual dose (mSv) | 2.74 | 30.19 | |

### VANDELLÒS 1 NPP. DISMANTLING OF THE PONDS. INTERNAL DOSE CONTROL (INCLUDED ABOVE)

| | Staff | Contractors | Total |
|---|---|---|---|
| Number of workers | 2 | 13 | 15 |
| Total doses (mSv·P) | | 132 | 132 |
| Max. individual dose (mSv) | | 20 | |