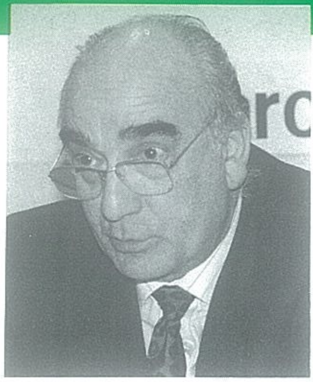
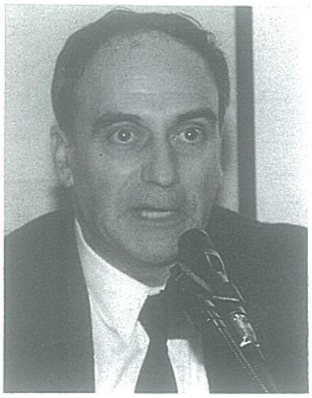


Enrique CABELLOS, Plant Director of Vandellós I NPP.

CLOSURE AND DECOMMISSIONING OF VANDELLOS I NPP

The February 1991 issue of the Spanish Nuclear Society Magazine was enterely devoted to publish the dabates and reports submitted during the Nuclear Power Plant Decommissioning meeting organized by the SNE, held in Barcelona in November, 1990.
The following article includes the presentations directly related to the decommissioning of the Spanish nuclear power plant Vandellós I.
Firstly Enrique Cabellos, Enric Plá, and Ildefonso Irún, provided an overall view of the current situation at Vandellós I; a summary of their analysis is published below. The second part of this article reports on the José M. Grávalos conference on the decommissioning process at Vandellós I.



Ildefonso IRUN, Head of Radiological Protection of Vandellós I NPP.

Enric PLA, Assitant Director of Vandellós I NPP.

BACKGROUND

In the first place, the incident that motivated the closing of Vandellós I should be briefly reviewed.
This incident occurred in October of 1989, and was explained precisely by Enric Plá in an annual meeting of the Spanish Nuclear Society. At that time, the definitive reports of this incident were already prepared. The incident was qualified as level 3 on the international scale, and thus was considered an incident, not an accident. It is of note that the source of the incident was a massive detachment of blades that caused a vibration in the turbine due to loss of mass, and as a result the oil pipes broke and fell on the bottom, thus causing the fire. More details will be given later about this Plant, which is the only graphite-gas type Plant in Spain. This fact is important from the standpoint of decommissioning. We will also discuss the radiological situation, and lastly we will consider plans for the future and the projected evolution of the Plant in conjunction with ENRESA.

PLANT DESIGN FEATURES

The Vandellós Nuclear Power Plant was the first to be built in Catalonia at the end of the 60's, motivated by the fact that the region's natural energy sources had been exhausted. Three alternatives were considered: the Canadian, American and French models. The latter was chosen for purely financial reasons. Plant construction began in June of 1967 and lasted for 56 months. The reactor was put into operation in February of 1972 and went on line in May of that same year. Thus, it has been operating for 17 years and a half and has produced of the order of 55,000 million kWh. It is located on the coast south of Barcelona, within the township of Vandellós and bordering on the township of Ametlla de Mar.
The Plant belongs to the French graphite-gas family, type "EDF4", which contains the entire primary circuit within a single pressure area. The reactor caisson is the pressure area, and is formed by a hexagonal, poststressed concrete prism whose internal cavity is cylindrical. The graphite pile at the top of this cavity is the reactor moderator, which is formed by a crisscross of 3.072 channels loaded with natural metallic uranium fuel elements with a magnesium-zirconium sheath. The steam generator in located at the bottom of the pressure area's internal cavity, and consists of 30 different towers joined together in 4 circuits. This Plant was conceived to have a redundancy of 4, i.e. one single steam generator circuit suffices to remove the reactor's residual heat, and 4 were provided. Since metallic uranium requires special care to prevent hydriding, a device for constant sheath rupture detection was provided, which in turn would monitor primary contamination. A computer was provided to control the approximately 45.000 fuel elements with a certain regularity, and its software was subsequently extended for constant Plant control. The sheath rupture detection

system scans the 3,072 channels in 24-minute cycles. Therefore, one person is needed in the control room to attend to the reactor control part and another for the turbine part, since the computer takes care of the rest; however, it must be noted that all safety devices, in addition to being tripped by the computer, can act independently of the computers through wired circuits.
The fuel is renovated in this type of reactor during operation, since otherwise a shutdown of one year or more would be required to replace a fourth of the fuel every year, i.e. approximately 10,000 elements. For this reason, we refer to fuel renovation and not reloading. The machine responsible for renovating the fuel is called the main fuel handling device. It is coupled to one of the reactor's 109 loading wells and set at the same pressure as the inside gas (29 atmospheres), and after removing the corresponding cover, the irradiated elements are removed with a winch and grapple and replaced with new elements. The irradiation is calculated with software that takes the Plant's performance data into account, which are provided by the electronic computers; in this way, the channels that must be renovated in monthly campaigns can be calculated. The fuel element consists of a metallic uranium tube filled with graphite and clad in a magnesium sheath containing 0,5% zirconium. The element is placed in a graphite cylinder wrapper so that the grapple does not exert pressure on the sheath. In this way, during Plant operation, there is in fact a partial renovation of the moderator whenever a fuel element is renewed, which results in graphite sleeve waste management problems when operation of a graphite-gas Plant comes to an end.
After unloading the fuel elements from the reactor, they drop into cooling pools where they remain for more than 150 days. Due to the type os sheath and the type of material from which they are made —natural uranium— these fuel elements are quite vulnerable when submerged in water, even though the pool water is kept at a pH of 12 to diminish the magnesium solubility product. In spite of this, the specifications do not permit the fuel to be under water for more than 2 years, and this period is divided between the time that the fuel is cooling off in the Plant and the time it waits in the reprocessing plant.
The primary circuit is cooled by fans that we call blowers, and since each of these blowers has a power of about 12 MW, they are driven by steam turbines. When the Plant shuts down and good quality steam is no longer produced in the steam generator, an auxiliary power source should be provided to ensure removal of the residual heat. We call this source the auxiliary Plant, and it is composed of 4 conventional oil-fired boilers plus 6 turboalternator units rated at 2.5 MW, from which only 1 MW is produced. This auxiliary power unit is used to supply a standalone electrical distribution grid that is separate from the outside grid. In this way, even if there is a blackout in the outside grid, the Plant continues to be safe, bearing in mind that one single boiler and one single auxiliary unit suffice to assure residual heat removal.

RADIOLOGICAL PLANT FEATURES

Broadly speaking, there are two radiological blocks, one that would correspond to the installations associated with the reactor and the fuel loading, and the other to the spent fuel storage section, which includes the pools and all the associated circuits.
In principle, the installations associated with the reactor and fuel are fundamentally or almost solely maintained with a background of fission products, with some halogens and very low amounts of noble gases, and thus the activation products are predominant, of which the most representative are cobalt 60 and, in this kind of Plant, sulphur 35.
The storage-related installations are the pools, and specifically the effluent treatment plant for decontaminating pool water. The Plant design accounts for the possibility of sheath ruptures in pools, and the effluent treatment plant design is designed to decontaminate the water, specifically of cesium 137 and cesium 134 as the most representative, since ruptures would occur toward the middle of the storage period when short-lived isotopes would have decayed. In this case, fission products are present as residual water contamination, and basically contain cesium 137, as well as small quantities of uranium, transuranics and strontium 90.
The gaseous effluents resulting from Plant operation have normally been maintained at values below a hundredth of the authorized limits. Insofar as liquids are concerned, operations have practically used up the authorized limits during the first several years of operation, but lately, thanks to upgrades made in all these water decontamination treatment systems, they have become stabilized at values below 30% of the authorized limits. It should be emphasized, as often is when speaking of this type of Plant, that the collective doses resulting from operation are low; for example, the average annual collective dose is slightly above 30 rem per person.
After definitive shutdown, there are 4 important aspects from the radiological point of view: the currently existing radiological zones, the effluents, radwaste, and dosimetry. The controlled zones are all the levels of the pool building, the interior of the reactor caisson containment area, the filter rooms, the fuel handling equipment maintenance area, and the effluent treatment area, as well as auxiliary zones such as irradiation laboratories, the graphite silo casemate, etc. The monitored zones are basically the caisson auxiliaries, all the auxiliary circuits, the uranium storage, the decontamination zones, and the accesses to the waste storage.
The most representative radiological values associated with the inside of the containment range from 30 to 70 millirem/hour, with somewhat more singular zones that may reach 200 millirem/hour, and specifically singular points that may reach 2 rem per hour, with a superficial contamination below the normal contamination levels of 10^{-5} microcuries/cm^2 in alpha, and of the order of $5 - 10 \times 10^{-3}$ microcuries/cm^2 in beta-gamma. In the fuel handling equipment, the values do not differ much from those indicated above, although points may be reached during disassemblies in which higher, punctual values are obtained due to accumulation of dust or debris resulting from maneuvering friction. Outside these zones, the values obtained on the average are approximately a hundredth of those indicated above. In all the structures related to the fuel storage pools, the values may also be similar when jobs such as emptying the pool water are performed: from 30 to 50 millirem/hour, and superficial contamination values that can be detected in alpha, and of practically the same order of magnitude, $1 - 10 \times 10^{-2}$ microcuries/cm^2 in superficial beta-gamma contamination. In transit zones, the values are clearly kept below 1 millirem per hour. After more than 1 year of definitive shutdown, there has been no more radioactive isotope generation, and there has been a significant decay in the majority of the most common activation products. This basically affects the reactor zone, and with the decay of sulphur 35, cobalt 60 predominates. It affects less the pool spectra that were decayed activation spectra, with a greater prevalence of fission products. The most representative nuclide continues to be cesium 137, since cesium 134, which has a 1-year lifetime and almost always accompanies cesium 137, also tends to decrease.
As regards radioactive gaseous effluents, only krypton 85 must be accounted for as a noble gas, as the others have decayed sufficiently. The values of current discharges are of the order of a thousandth or oneten thousandth of the authorized limits. The halogens can be considered as completely decayed, and insofar as the particles are concerned, with cobalt 60 predominating, they are also at a thousandth to one ten thousandth of the authorized limits. At this time, liquid effluents are at 2.6% of the authorized limits for permitted values of accumulated

activity in the last 12 months basically by pool water, i.e. with a significant reduction with regard to the average during operation. At this time, there is no fuel in the pools and commencement of the Plan for unloading the last reactor core is outstanding, which means that they may increase in the near future, although it is not expected that these orders of magnitude vary much. There are approximately 8 m^3 of primary reactor circuit desiccation water stored, with some 200 to 300 curies of tritium. The production of tritium in these Plants is characteristic, due to activation of the lithium that accompanies graphite impurities, and it is removed from the desiccation system of the primary circuit, which during normal operation must be kept very dry.

The current operational doses are practically null when no important work is being performed, and when there is a temporary job such as the recent one in the pools, there are collective doses in all cases lower than 1 rem per person. A somewhat higher level is to be expected when the waste conditioning phases begin, though the orders of magnitude should not exceed those normally encountered in normal operation.

The solid radwastes are separated into the following generic groups: the graphite, fundamentally in the sleeves although there are also irradiated metallic parts in other graphite reactor elements, usually associated with reactor fuel handling operations (grapples, cables and maneuvering elements), the resins or zeolites that have also been used, from the selective decontamination treatment of pool water cesium, and miscellaneous technological wastes such as filters and other contaminated parts, garments, rubble, etc., from general operational jobs. These wastes have been stored without prior conditioning, and this must now be done. At the present time, the balance in this respect is as follows: as regards irradiated parts, the wells in which they are usually put in, inside metal cases, are approximately 8% full, with slightly more than 800 curies in 70 cases. As regards the graphite silos, the first one is about 50% full, the second about 97%, and the third is 100% empty because it has still not been used; these were the three initally anticipated for the entire operation, with a total in the first of more than 6,000 curies, in the second of 67,000 curies and some 150,000 existing sleeves plus the more than forty thousand that will be removed from the reactor, 43,628 to be exact.

As for the resins, there are 33 m^3 and 239 curies, and the pits in which they are stored are less than 50% occupied. The silo in which the miscellaneous technological wastes are located in cans is practically full, at 97% of its capacity, with 14.5 curies, although it should be noted that this silo has previously been completely filled twice, and the waste was transferred to graphite silo 1; it is the only silo that was filled up during operation.

The anticipated wastes in this phase are the shutdown ventilation system filters; this system is the one that is currently cooling the reactor, and since in normal operation it was only used in the scheduled shutdowns during the year and now it is permanently operating, it can conceivably cause a significant increase in the number of filters. Otherwise, the only important thing is the graphite reactor sleeves from the 43,628 fuel elements that must still be unloaded. It is not expected that waste production will exceed the quantity that would have been produced during the same period if normal operation had continued.

ADMINISTRATIVE SITUATION

At this time, article 3 of the Plant's final operating permit has been suspended by a ministerial decree published in the "Boletín Oficial del Estado" of July 31, 1990. In this document, the Ministry gave HIFRENSA three months time to submit certain documents, which consisted of the typical official documents for normal operation but with the novelty that the plant has been shut down, and thus their preparation has required a certain amount of imagination to solve specific problems. For example, when an incident occurs in a normal plant, it reverts to a shutdown situation; our plant is already shut down, and thus it cannot revert to a further shutdown situation. The residual heat in the reactor at this time amounts to 327 kW, and thus the existing nuclear risk is very low, since there is a mass of about 2,400 t of graphite plus 600 t of shielding graphite. Thus, to raise the temperature to the sheath melting point of 650 degrees, more than 1 month would have to elapse, and if detailed calculations were performed, they would show that melting would never occur; in other words, the dissipated heat would exceed the generated heat.

Adoption of a 5-year period to unload the core was motivated by strategic reasons, considering the international contract with the reprocessor, COGEMA, although obviously it could be unloaded in 17 months if we worked in shifts. The fuel can be left for 5 years without any problems by maintaining minimum cooling air quality constants in open circuit.

ENRESA will become the responsible operator, as stipulated by the ministerial decree, when the last fuel element is removed from the site. HIFRENSA has the obligation to condition a series of wastes. The applicability of the different techniques for graphite conditioning must be considered, as well as the use of robotics and remote control to remove graphite from the silos. It is ENRESA's responsibility to decommission the contaminated zone, and HIFRENSA's responsibility to decommission the uncontaminated elements. Therefore, the entire installation must be characterized to determine what elements are contaminated and/or irradiated and how contaminated they are, and to make the strategic, economic and technical decisions on what is most advisable. There will be elements that can be decontaminated, and there will be elements that are not worth decontaminating, but these will create waste, so a general policy must be developed to establish guidelines for the work. Obviously, we must collaborate fully with ENRESA since, to a certain extent, it is going to inherit a plant that it is not familiar with and that HIFRENSA must leave in conditions that are safe to work in.

Participants in the Round Table. From left to right: Luis Echávarri (Consejero of the Consejo de Seguridad Nuclear), Juan Algueró (Director of Ascó NPP and member of the Steering Committee of the SNE), Alberto López (Director of ENRESA), and Fernando Roset (Director of HIFRENSA).

DECOMMISSIONING ALTERNATIVES UNDER STUDY FOR VANDELLOS I NPP

José María GRAVALOS

When a power plant is decommissioned, it is advised that different alternatives be taken into account with regard to activity scheduling, techniques, decommissioning procedures, decontamination, etc. The study of the advantages and disadvantages of the different alternatives results in a Decommissioning Plan (DP) for the installation. To define the future DP for Vandellós I, three possible scenarios are considered, each with a specific scope and strategy. In broad outline, these three scenarios are as follows: indefinitely keeping the plant in a final situation of definitive shutdown (scenario 1); decommissioning the conventional and radioactive parts, except for the concrete reactor vessel and internals (scenario 2); and total decommissioning that would leave the site radiologically clean for future use without any restrictions (scenario 3).
In addition, there is a phase prior to decommissioning proper that consists of totally defueling the core, as well as conditioning operating radwastes and transporting them away from the site.
The Decommissioning Plan should include aspects such as scope, scheduling, methodology, radiological monitoring, manipulation, transportation, waste management and organization, in order to achieve the proposed objectives such as: assuring public health and safety, minimizing the environmental and visual impact, and preparing the site for other uses.

Jose María GRAVALOS, Head of
ENRESA's Engineering Department.

The initial phase will include plant zoning that distinguishes between clean zones, toxic waste or dangerous zone (asbestos and others), and radiologically controlled zones. The decommissioning of structures and buildings in radiological zones consists of the following phases:

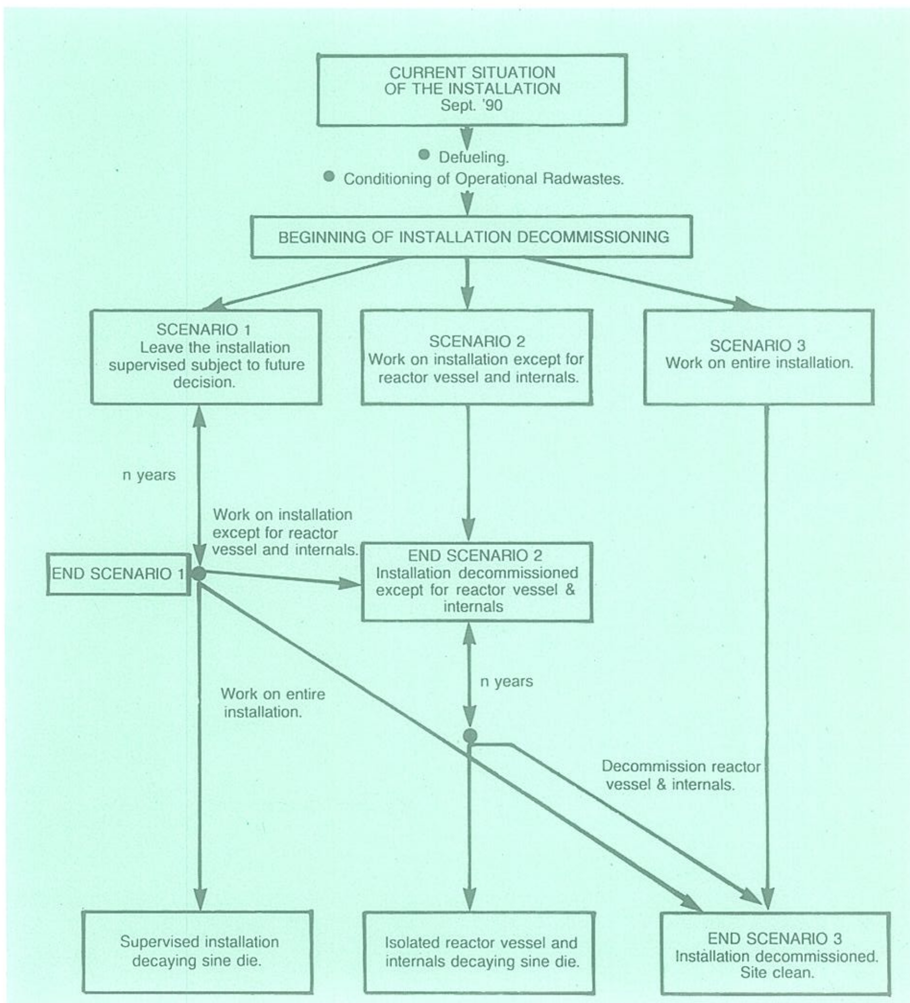
- Dismantling and removal of radiological components.
- Decontamination and declaration as clean zone.
- Conventional demolition.

It is very important to provide an exemption procedure that serves to optimize management of materials resulting from decommissioning.
The decommissioning alternatives are discussed below, along with the advantages and disadvantages of each scenario.

ZONINGS AND PRELIMINARY INVENTORY OF COMPONENTS WITH RADIOLOGICAL IMPLICATIONS

Once the possibilities regarding the decommisioning strategy to be followed in C.N. Vandellós I have been reviewed, it is necessary to establish the bases for selecting the most suitable one. The first step in this direction is to quantify the problem. For this purpose, preliminary studies have been performed to determine the preliminary material inventory for future decommissioning of the Vandellós Nuclear Power Plant. An analytical

F I *CN Vandellós I Decommissioning Planning.*



methodology is used, going from the general to the particular and reaching a level of detail that permits the discretization of the installation into large components or small homogeneous component groups.

In the preliminary zoning, the zones have been defined in accordance with the radiological zone classification criteria included in the Vandellós i NPP Radiological Protection Manual. These account for the existing levels of radiation, contamination and environmental contamination.

When determining the Preliminary Component Inventory, the zone where each component in a specific system is located and its mass or volume are defined, and a radiological implication concept is also attributed to it. The latter qualitatively indicates if it is contaminated or irradiated due to process or functional reasons and to what extent. From all the installation functions, about a thousand component groups have been obtained, of which 151 groups have radiological implications, which amount to 13,625 t of materials that should be managed as waste; of the later, only 12.7% are products that are just contaminated, and the other 87.3% are activated or activated and contaminated products.

On the other hand, the total mass has been broken down in terms of the type of material, and it has been found that concrete accounts for 31%, steel 44%, and graphite 22.5% of the total.

As for the Preliminary Activity Inventory, the first of the internal concrete reactor vessel components, radiological inventory of the has been performed, and the activities due to neutron flux activation have been obtained; the activities due to contamination, both in the concrete reactor vessel internals and in external circuits, are in the analysis phase.

ESTIMATE OF DECOMMISSIONING COSTS BY REFERENCE TO OTHER PLANTS

To determine the decommissioning costs, it is necessary first to have decided on one of the viable alternatives and to know what decommissioning plan is to be used.
In the case of Vandellós, we are still in the process of deciding between several alternatives and thus the decommissioning plan is still not drawn. For this reason, it is very difficult to calculate costs, even by way of an orientation.
However, if we consider the cost of other completed or projected decommissionings, indirect estimations can be made by using comparative parameters such as the following:

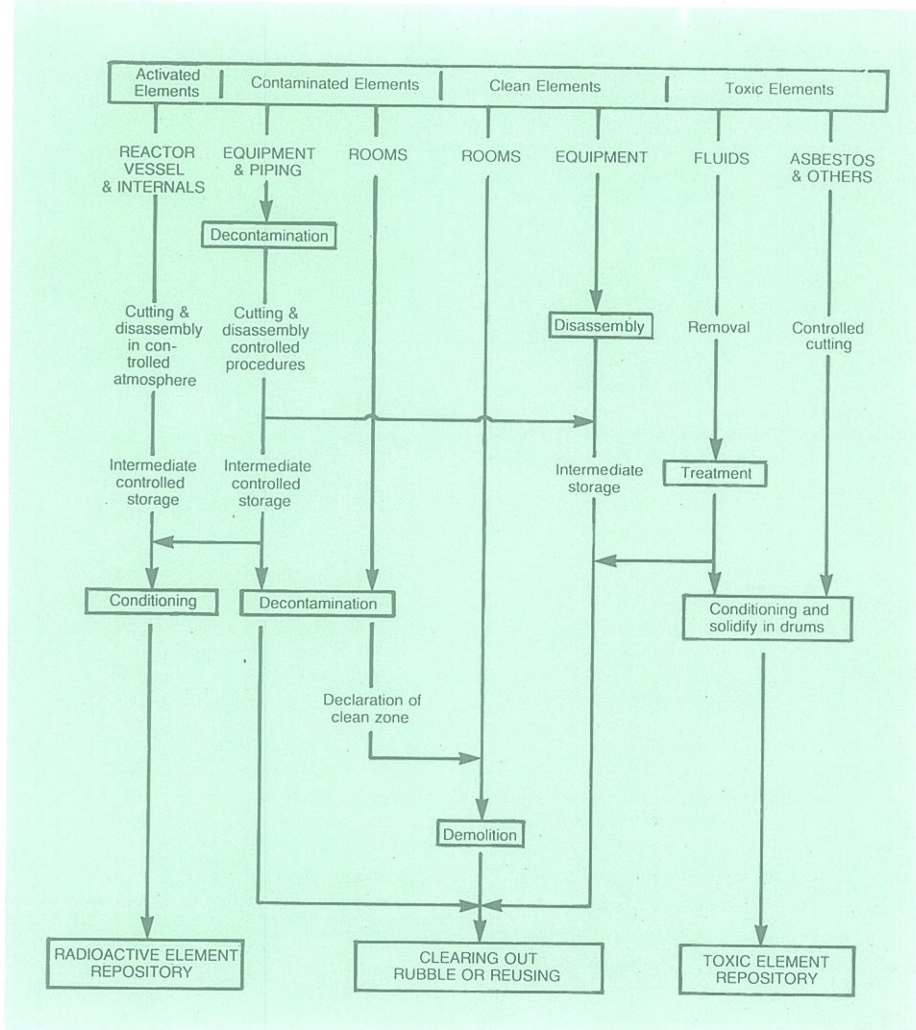
— Electrical power of the installation.
— Cost of the initial investment in the installation.
— Amount of power generated.
— Power generation rates.
— Others.

Before estimating the cost with any of these factors, the factors that directly affect decommissioning costs should be pointed out, such as the following:

— Personnel costs of the installation's owner.
— Trade labor costs.
— Decommissioning method costs.
— Decommissioning and removal costs.
— Radwaste volumes.
— Volumes of nonradioactive waste to be removed and stored.
— Effects of Plant size and type.
— Contingency costs.
— Radioactive levels and occupational exposure.
— Effect of several units on the same site.
— Environmental radiation and public exposure.
— Waiting periods.
— Physical safety.
— Other factors to be considered are the future use of the site; operating, power, water levy costs; costs resulting from compliance with regulations; price escalation; correcting visual and aesthetic impacts; staff reduction; insurance, compensations and taxes.

As regards the cost estimate by reference to other decommissionings as a fonction of the electric power, there is no direct ratio between the cost of decommissioning and the installation's power, not even within the same technology. As shown in the following diagram, we have obtained a range of points of decommissioning costs as a functions of power, regardless of the technology and with all cases referred to an immediate level 3 decommissioning.

F II *Material Treatment According to Their Status.*



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