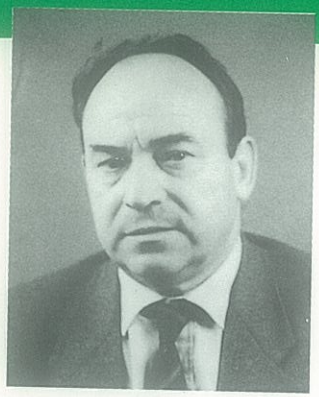

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RADIOACTIVE WASTES: A RESEARCH PROGRAMME

A. URIARTE

Nuclear power plants generate radioactive wastes within which irradiated or spent fuels are included. All countries are seeking the best and safest way to manage these radioactive wastes, including those from hospitals, industries and research centers. We must not forget the decommissioning of nuclear facilities as a waste source. However, mining and milling uranium wastes are not included because this kind of waste is normally conditioned *in situ*.

Radioactive waste management includes several activities that could be separated into two basic groups:

- "Initial" management (treatment, conditioning, etc.).
- "Final" management (disposal).

In this document we are going to refer only to the first group of activities the purpose of which is to suitably prepare waste for disposal. This is called conditioning of the "source term". When we refer to "source term", we understand that it must be a well-know thing, both qualitative and quantitatively. It is necessary to establish characterization techniques for obtaining the required identification. Thus, "initial" management includes two main groups of activities:

- Treatment and Conditioning.
- Characterization and Identification.

All industrial activity should require the development of a research programme that should be realistic insofar as subjects, priorities, terms and resources (human and financial). In the case of radioactive wastes as "source term", this programme must be based on the following terms in Spain:

- It must be coherent with the radioactive waste plan provided by ENRESA (National Spanish Enterprise for Radioactive Waste Management).
- It has to agree with the European Community research programmes for radioactive waste management and decommissioning of nuclear facilities, from the financial, scientific and technological points of view.
- It has to be carried out in conjunction with international research programmes, with organizations from other countries (DOE-USA, UKAEA, CEA-FRANCE, AECL-CANADA, etc.) or in the field of international institutions (IAEA, NEA-OCDE, etc.).

Therefore, taking into account that CIEMAT (former Junta de Energía Nuclear) has to give advice and technological support to ENRESA, a research programme has been developed in CIEMAT the main subject of which is the planning and performance of activities related to the "initial" management of radioactive wastes and decommissioning of nuclear facilities. This programme is divided into four units:

- Treatment and conditioning of low and medium level wastes.
- Characterization of radioactive materials and wastes.
- Decommissioning of nuclear facilities.
- "Initial" management of high level wastes.

For the first two, activities must be developed with clearly identified objectives on a short and medium term basis.

The other two must be developed on a long term basis and with many more human and financial resources.
The research activities for low and medium level waste treatment and conditioning must comply with the following

- To improve some of the treatment and conditioning processes used or to develop alternative processes for increasing decontamination factors or safety.
- To select and develop techniques for some wastes which are not suitably conditioned for disposal.

The research on radioactive waste and material characterization must cover the following main subjects:

- To develop and implement techniques for measuring several magnitudes of waste before treatment and conditioning, of the immobilization matrices, of the packing material and of the conditioned wastes. This knowledge will make it possible to correct the detected defects.

Research on decommissioning of nuclear facilities has two main objectives:

- To generate the least amount of radioactive wastes.
- To produce the lowest radiological load possible on the people who must perform the decontamination and dismantling operations.

With reference to the high level wastes, research must be aimed at achieving the suitable management of spent fuels considered as wastes. These activities can be divided into two main groups:

- Temporary storage.
- Conditioning for disposal.

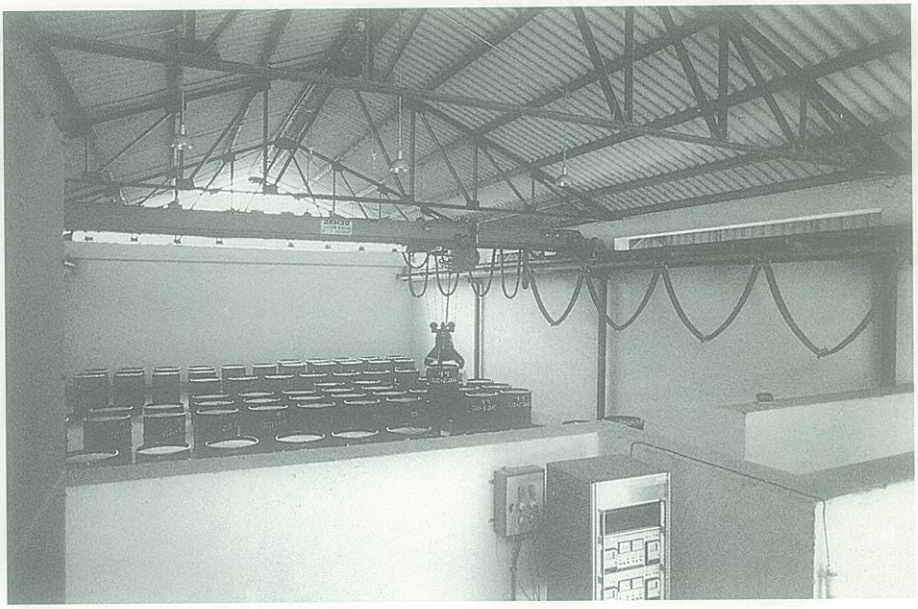
TREATMENT AND CONDITIONING OF LOW AND MEDIUM LEVEL RADIOACTIVE WASTES

At present, only cements and concretes, with or without additives, are used in Spain for immobilization and conditioning of low and medium level wastes. The definitive storage or disposal of these wastes will probably be carried out in shallow land burial facilities, for which two criteria will determine the research programme for this kind of wastes:

- The use of only one matrix for immobilization and conditioning: cement or concrete.
- Acceptance of conditioned waste for definitive storage at surface facilities.

The use of cements and concretes as immobilization agents has advantages and disadvantages.
The advantages include: low cost, known technology, several trademarks, suitable immobilization of alpha radionuclides, improvement with additives, etc. The disadvantages include: cracking, radiolysis, poor immobilization of cesium (Cs-137), presence of several components in the waste (aluminium, ion exchange resins, ashes, sulfates, etc.), requirement of previous tests for treatment and conditioning of each type of waste, etc. All these aspects require research activities in order to obtain well conditioned packages for final disposal.
In a first evaluation the following have been established as matters to be researched:

- Conditioning of ion exchange resins produced by nuclear power plants.
- Treatment of organic liquids used in the scintillation technique.
- Conditioning of ashes produced by incineration of heterogeneous solid wastes.
- Treatment and conditioning of graphite from Vandellós I nuclear power plant (GCR).
- Study of cement setting processes in terms of the chemical composition of the waste (borates, sulfates, etc.).



F I *Interim storage of Radioactive Solid Wastes*

CHARACTERIZATION OF RADIOACTIVE MATERIALS AND WASTES

"Initial" management of radioactive waste requires thorough knowledge of the process, from the time it is generated until it is prepared for disposal or definitive storage. This knowledge includes:

- Radioactive composition.
- Chemical composition.
- Physical characteristics.
- Mechanical characteristics.

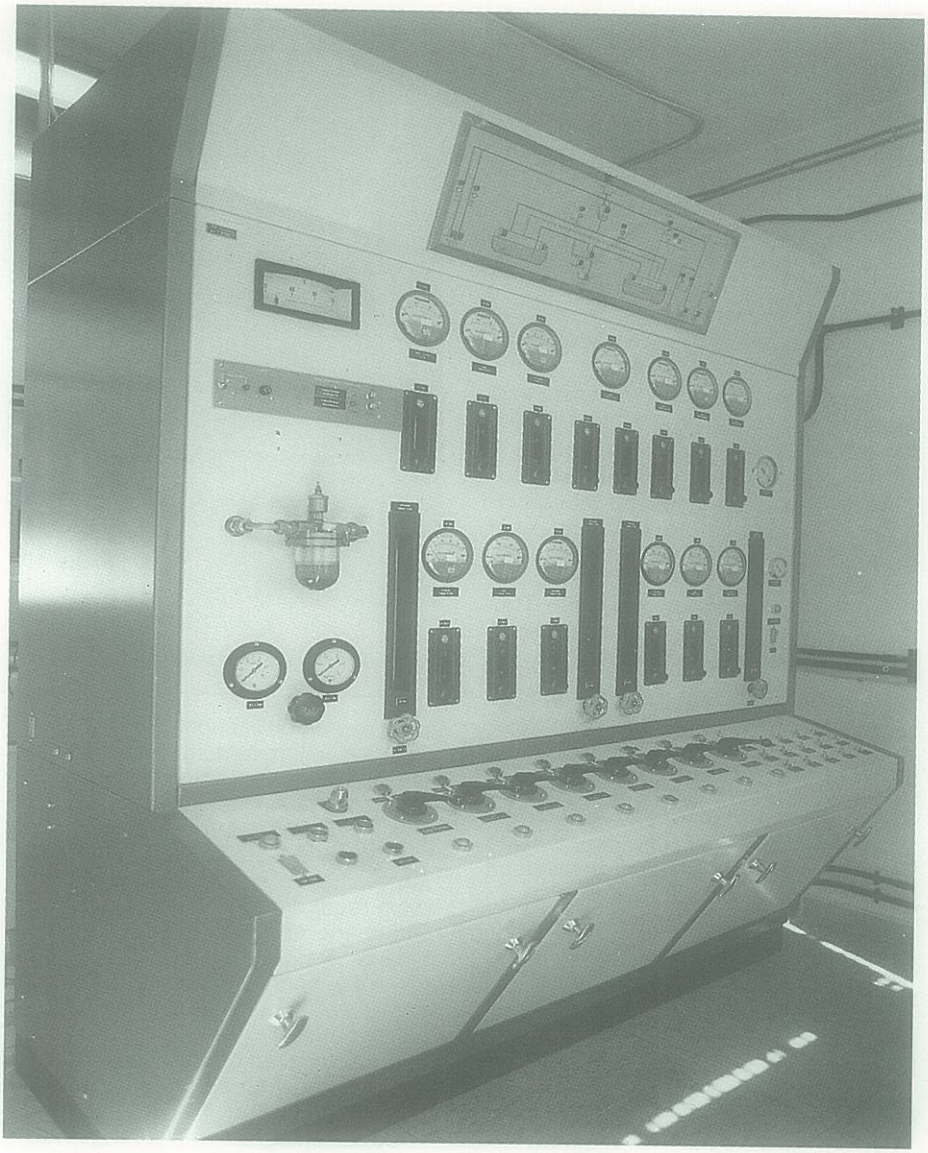
The first point is basic because the radioactive characteristics will determine the conditioning and disposal of the waste. Destructive and non-destructive methods are being studied; the former methods include measurement of long-life radionuclides such as C-14 Na-59, Na-63, Sr-90, Nb-94, I-129, Pb-210, Ra-226, Ra-228, etc., and the latter include the use of gamma spectrometry for identification and quantification of radionuclides in drums containing radioactive wastes. A very important characteristic of the conditioned waste is its leaching rate due to the watery medium of the repository. Measurement of this characteristic requires the use of many previous techniques.
Knowledge of the chemical composition is very important for treatment as well as conditioning of the waste. This research could be aimed at developing destructive and non destructive tests to detect the presence of toxic organic materials, free water and pores in the matrix, etc.
The tests to measure physical and mechanical properties must include: density, fissures, homogeneity, compressive strength, flexural strength, porosity, etc. All the above should be aimed at developing the necessary techniques to support a national laboratory for characterization of low and medium level wastes.

DECOMMISSIONING OF NUCLEAR FACILITIES

Prior to 1987, 43 nuclear reactors with 5.1 GWe were closed down and they

are currently in different stages of the decommissioning process. By the year 2000, about 63 reactors with 12.8 GWe will be thirty years old and they will be near on the verge of closing. Therefore, decommissioning of nuclear facilities and management of the generated wastes form one of the greatest challenges to the nuclear energy industry.
To decommission a nuclear facility, dismantling techniques are required. These activities are being carried out to a greater or lesser extent, either partialy or totally, since nuclear energy and its applications were introduced in our country many years ago.
Sometimes it is advisable, when possible, to previously decontaminate the equipment, system of facility which is to be dismantled, so as to produce the smallest radiological load possible on those performing these operations.
At present, CIEMAT is decommissioning obsolete facilities related to the first part of the nuclear fuel cycle. Decommissioning of the JEN-1 reactor forms the basis of a research project to study and develop techniques of decontamination and dismantling, as well as of treatment and conditioning of generated radioactive wastes. The purpose of this research project is to set up a test facility where tools for the dismantling and decontamination processes could be evaluated and developed.
One of the most important aspects of decommissioning is recycling non-radioactive materials. The problem is to know where the limit is between radioactive and non-radioactive materials. This is a very important subject to be researched, from an economical and radiological point of view. The main research activities in this project are:

- Decontamination processes and techniques.
- Cutting techniques and tools.
- Treatment and conditioning of generated wastes.



F II *Control Room of Storage Facility for Radioactive Liquid Wastes*

"INITIAL" MANAGEMENT OF HIGH LEVEL WASTES

Many different aspects have contributed to considering spent or irradiated fuels produced by Spanish LWR nuclear power plants as high level radioactive wastes. Therefore, direct disposal of these wastes after prior conditioning must be considered on a long term basis.
"Initial" management of spent or irradiated fuels starts when they are unloaded from the nuclear reactor. The first stage is storage in the reactor pools for radioactive and thermal decay. The interim storage capacity of the Spanish light water nuclear power plants is about ten years, but this will have to be extended by using dry or wet techniques, either in the reactor sites or in a centralized site.
In either case, with dry or wet interim storage, either at the reactor or away from the reactor, non-destructive tests must be performed to check the integrity of the stored fuels either underwater or in hot cells. Therefore, it will be necessary to develop and up date some techniques to study the integrity of the fuel rods under storage conditions.
In the particular case of dry storage, it will be necessary to perform heat transfer studies to measure the temperature of the fuel rods in terms of the characteristics of the irradiated fuel elements and the storage conditions.
The second stage of the "initial" management of the spent fuels is their conditioning for final disposal. There is still no industrial process to carry out this stage, although there are advanced research programmes in countries such as Sweden and the German Federal Republic. In any case, the package containing the spent fuel must have the following characteristics:

- good mechanical integrity,
- low corrosion,
- good thermal conductivity,
- good radioactivity containment.

The first Spanish research project could be based on the following points:

- Development and performance of destructive and non-destructive methods and techniques for a complete characterization of the irradiated fuel (fission product inventory, fissionable materials, actinides, mechanical and physical characteristics, corrosion of cladding, leaching of UO_2 pellets, etc.).
- Study of cask materials used for final storage (carbon, steel, copper,

titanium, stainless steel, hastelloy, etc.).

In order to carry out the first proposed point, it is necessary to have suitable facilities (hot cells). At present, we do not have these facilities in our country. Therefore, it will be necessary, in the short term run, to reach an agreement with any organization with experience and facilities such as the Joint Research Center (JRC) of the European Communities.

Spanish participation in the international projects LOFT and PHEBUS could be advantageous for this programme, basically to develop techniques and methods for characterization of irradiated fuels.

RESEARCH PROGRAMMES OF THE EUROPEAN COMMUNITIES COMMISSION

There are two research programmes on radioactive wastes in the European Community. One of these programmes is carried out at JRC in Ispra (Italy) and Karlsruhe (Germany) and the other is a shared-cost action by member countries. The present research program (1988-1991) at JRC entails three main projects: the PETRA facility, actinide control and waste characterization.

The PETRA facility is located in Ispra (Italy) and its main purpose is to study the treatment and solidification processes of PUREX wastes produced by fuel reprocessing, in order to improve the "final" management of certain wastes. This facility will be started up at the end of this year and its future will be defined in terms of the interest of the community countries or other customers.

Actinide control is based on non-destructive test equipment for measuring the amount of plutonium in drums containing conditioned wastes before its final storage. This project is being carried out in Ispra (Italy).

The characterization of wastes is being directed toward vitrified wastes and irradiated fuel elements and is being carried out in Karlsruhe Center. The present shared-cost action programme (1985-1989) is divided into two main parts. The first involves six groups of activities; one of them addresses the treatment and conditioning of wastes and the others their characterization.

The current programme (1984-1988) of the European Communities for decommissioning nuclear facilities is carried out entirely as a shared-cost action by the member countries. This programme is divided into two parts; the first involves seven groups of research and development projects, such as decontamination processes, dismantling techniques and treatment of waste materials (steel, concrete, graphite, etc.). The second part is based on the testing of new techniques under real conditions and is performed in facilities of the member countries.

Spanish participation in these research programmes involves the following projects:

- Conditioning of ion exchange resins produced by nuclear reactors (CIEMAT and ENRESA).
- Identification of radionuclides in drums containing conditioned wastes (CIEMAT and ENRESA).
- Development of a closed eletropholising system for decontamination of underwater surfaces, performed by ENSA (Equipos Nucleares, S. A.).
- Development of vibratory decontamination with abrasives, performed by ENSA (Equipos Nucleares, S. A.).

All the above summarizes the research activities that CIEMAT suggests as part of the "initial" management of radioactive wastes and decommissioning of nuclear facilities. The main purpose of these activities is in accordance with the research and development plans and programmes of ENRESA and the European Communities.

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the order date.

The standard steps in the calculation are as follows:

- Steam Generator modelling.
- Loads and environmental conditions application.
- Stress and deformation result analysis.
- Evaluation of the results on the basis of the applicable standards/codes.

The following types of analysis are performed on these calculations:

- Basic Sizing Analysis: Fundamental dimensions are defined on the basis of the pressure and temperature design.
- Structural Analysis: It defines the primary stresses on the high stress areas and monitors them against limits provided by the applicable codes and standards.
- Thermal analysis: It defines the thermal gradient of the walls and discontinuous areas due to the different temperatures of the primary and secondary fluids.
- Fatigue Analysis: It defines the primary and secondary stresses produced by the inside pressure, thermal gradients and external mechanical loads existing in each of the different operational conditions. These data are monitored against referenced limits provided by the applicable codes and standards. Finally analysis of the most critical points of the components is performed, taking into consideration the estimated life of the Nuclear Power Plant.
- Special Analyses: other analyses are performed taking into consideration additional concepts:
  - material fragility analysis to determine protection against brittle fracture.
  - Dynamic analysis, to determine tube bundle vibrations.
  - Seismic analysis, to determine seismic effects.

Table II shows the above described mechanical project analysis, design data, analytic methods and failure criteria. The analyses must demonstrate a security level such as to guarantee steam generator operational performances during the life of the Nuclear Power Plant.

As previously indicated, the analyses described above concern the "mechanical project", while the "thermohydraulic project" is the responsibility of the Nuclear Power Plant technicians.

SUMMARY COMMENTS

This article should conclude by adding some general comments summarizing our experiences in manufacturing these components. The first is the enormous impact of the "learning curve" on the productivity rate and delivery period reductions. The second one is the high quality achieved in the components manufactured. This quality has given ENSA a leading position among world suppliers. This position has been achieved the to the special circumstances lived by ENSA already explained, but also owing to the special attention paid to the implementation and development of the product assurance techniques.

The last comment concerns the knowledge passed on to the Services Market by the Services Division through their activities performed at Power Plant Sites. The Services Division performs maintenance operations using tested procedures and technology for welding, tooling, equipment, nondestructive techniques, robotic applications, mack-ups, etc. that are mainly supported by experience obtained at the shop.

The above is a partial summary of the experiences accumulated by ar Spanish supplier that was created to manufacture nuclear components and thus increase the Spanish level of participation in the construction of Nuclear Plants and develop the technical skill to undertake future programs with the quality and schedules required by the market.