# FOUR YEARS EXPERIENCE IN SPENT RESINS ENCAPSULATION WITH MOBILE UNITS OPERATED BY STMI IN EDF'S NUCLEAR PLANTS

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## ABSTRACT

The French Nuclear Program, developed since 1973 by EDF, consists of standardized 900 MW and 1300 MWe, PWR nuclear power plants. All those plants are of similar design and therefore, are particularly suited for the use of itinerant mobile equipment for the performance of intermittent tasks not directly related to electrical production.

Since 1981, STMI (EDF and CEA subsidiary for nuclear decontamination services) has operated a mobile system service for spent resins encapsulation from the EDF nuclear plants. Three mobile systems are in operation: COMET 1 and COMET 2, of STMI design, using polymerized styrene with proper additives as encapsulating material, and PRECED 1, of PEC Engineering design, based on a Dow Chemical solidification process.

To date, 25 operations have been performed on EDF's PWR plants. About 5,000, 110 liter drums have been produced, while encapsulating more than 450 cubic meters (more than 16,000 cu ft) of spent resins. During this time the mobile units have shown an excellent record of availability and reliability. Simplified devices and operation procedures make the system very efficient.

These four years of continuous operations have provided EDF and STMI with an extensive amount of performance and cost data plus directions in which to improve the system. The average waste resins volume produced under normal operation of two 900 MWe units is 10 to 15 cubic meters, resulting in 120 to 150 encapsulated drums. The expected radionuclides are mainly Co 58 and Co 60 and variable concentrations of Cesiums (134 and 137), Mn 54, Sb 124, and Ag 110m.

The shielding for the encapsulated drums has been designed for contact dose exposures not exceeding 200 mrem/hour. Average dose for an operator during the process is about 2 mrem per drum. The value above is the average for a 5 man crew during 25 working days. The encapsulation operations are conducted in accordance to a strict quality assurance and ALARA radiation safety program which complies with all the requirements of the customer (EDF) and the French Safety and Health Organizations.

## BACKGROUND AND HISTORICAL OVERVIEW

From 1973, EDF has conducted the most ambitious nuclear power plant program in the world with the following results:

- 65% of all electrical power generated in France in 1985 was nuclear--with a total of 41 stations generating 36,930 MWe.
- EDF plans to generate 80% of all French electrical power in 1990 with 56 nuclear stations totalling 55,270 MWe. Such a program could be implemented in record time and without major incidents by early standardization and growth in definite steps, with sufficient units of the same class being ordered and commissioned at the same time.

EDF's standardization policy has been projected into rad waste management techniques and equipment. EDF's Thermal Production Service, in conjunction with ANDRA (National Agency for Rad-Waste Management), are responsible to carry out those policies. Out of the various low and medium activity radwaste products from EDF's PWRs, the spent ion exchange resins require the greatest care to ensure long term stabilization for easy disposal.

These resins demineralize streams from: CVCS, BRS (boron recycle system), pool cleaning system, BDS (blowdown system), and LWS (liquid waste system). About every 12 to 18 months, depending on their location, those resins are replaced. Average waste production, for a twin 900 MWe unit plant amounts to 350 cu ft per year, with activities ranging from 30 mCi/cu ft to 30 Ci/cu ft (1 Ci/$m^3$ to 1000 Ci/$m^3$).

After several years of resin encapsulation in cement, using in-plant facilities, EDF has found that a better technical and economical solution for resin encapsulation is the use of mobile units which stabilize the waste in a thermosetting polymer matrix.

The design and operation of those mobile units has been carried out, thru this date, by two companies: PEC Engineering, which provided EDF with turn-key cement encapsulation facilities for most of the French plants and also one of the mobile polymer encapsulation units; and STMI, which provided two other mobile polymer encapsulation units and operates all three of them.

## DESCRIPTION OF THE MOBILE UNITS IN OPERATION BY STMI

In 1981 EDF requested STMI to provide encapsulation services with the aid of a mobile unit--which uses a polystyrene matrix. This unit is denominated COMET I.

In 1983 a second unit, COMET II, was manufactured. In this unit the experience gained with COMET I operation helped improve and streamline the process, making for a faster and safer operation. Later, COMET I was upgraded to the COMET II level.

At the end of 1983, EDF formed a joint venture between EDF, PEC and STMI, which was requested to design, manufacture and promote a more universal encapsulation method which will allow evaporator concentrate waste and other liquid waste solidification as well as spent resins. This unit, called PRECED, uses the Dow Chemical process for polymer matrix encapsulation and is operated by STMI.

STMI has operated the two COMET units without interruptions for the last four years. These units have processed more than 16,000 cu ft of spent bead resins and created 5,000 drums, possibly a world record.

## COMET Units Description

The COMET encapsulation unit consists of the COMET machine itself; storage vessels and a premixing system; service facilities; associated miscellaneous equipment such as resins, feeding pump, transfer platform for the drums; and the DIANE waste characterization system. The COMET unit installed dimensions, while operating in a nuclear power plant are: 26' x 9' 3" x 10' height (8 m x 2.8 m x 3.10 m) and it weighs 40,000 pounds (22 metric tons). It includes the following elements:

- A working platform with control board for semi-automatic operation.
- An auxiliary cabin (air compressor, fire extinguishing system, vacuum pump, and refrigeration unit.
- A controlled temperature cabin for encapsulating mixture preparation. It includes a vacuum vessel, a mixing vessel and a catalyst metering system.
- A shielded (6" lead) vessel for spent resin metering allowing accurate level control of both resin and carrier water.
- A shielded pathway for safe transfer of the resin from the metering to the encapsulation vessel.

It is also possible to perform all chemical operations at the storage and premixing trailer if they are requested to be outside the controlled area. In this case flexible connections are used between the trailer and the COMET unit.

## COMET Unit Operation

Spent resins are pumped from storage vessels inside the plant by means of a transfer pump equipped with a porthole on the suction pipe. A video camera monitors the flow thru the pipe allowing the operator to minimize the chances of clogging or damaging the pump by foreign materials.

The pump stops automatically when the proper resin level is achieved. All material transfer afterwards is done using vacuum as the moving force, thus minimizing external contamination.

The resins are transferred to the encapsulating liner and vacuum dried until their average water content is the same as in the original commercial form. Free water which could be present before final encapsulation, has been found to be less than 100 ml.

The chemical mixture consisting of styrene copolymer, tensioactive material and catalyst is transferred through the bottom of the liner using a dynamic vacuum. This procedure ensures total impregnation of the resin beads without any mixing process. In this procedure, the resin fills the voids between the beads without increasing the total volume of the final encapsulated product.

The drums produced to date have been 110 liters liners containing 95 liters of resin. This process, as des-cribed, has been thoroughly qualified and tested to characterize the limits of application, as requested by EDF. A qualification and testing program has been established and is under progress to increase the final volume of the liner up to 200 liters (175 liters of resin). The final results are expected by July 1986.

Qualification tests to verify compliance with the fundamental safety rules set by SCSIN (French Industry Department) and the required specifications set by ANDRA for the LaManche Storage Site, are under way. Preliminary results indicate that the final product, as produced up to date, should comply with this set of new regulations.

The encapsulation process using the COMET machine allows for eight drums per shift. In typical operation, an STMI crew produces between 18 and 20 drums in a two shift day. The final hardening of the matrix is dependent on ambient temperature and takes between two to ten days.

## Packaging

The metallic liners used for EDF are enclosed in concrete containers which may have additional shielding as required. The COMET machine is also capable of operating using recoverable metallic shields which can be used for transportation. The concrete enclosures used by EDF enclose the metallic liner completely except for pipe connections which are capped after the encapsulation process.

Four different types of shielding for the package have been designed by STMI (based on the accumulated experience) to take into account the different waste activity levels encountered at EDF plants.

- B0 corresponds to a volumetric activity up to 400 mCi/ft$^3$ (0-18 Ci/m$^3$) equivalent Co 60
- B1 corresponds to a volumetric activity 400-1100 mCi/ft$^3$ (18-40 Ci/m$^3$)equivalent Co 60
- B2 corresponds to a volumetric activity 1100-2800 mCi/ft$^3$ (40-100 Ci/m$^3$) equivalent Co 60
- B3 corresponds to a volumetric activity 2800-400 mCi/ft$^3$ (100-300 Ci/m$^3$) equivalent Co 60

## Waste Activity Measurement -- DIANE Unit

In order to characterize the isotopic content of the encapsulated waste, STMI has designed the DIANE system which consists of:

- A high purity germanium isotopic analysis system which includes redundant recording capabilities such as magnetic tape, an X-Y recording and line by line printing of the spectra.
- DIMAV which is a double dose rate measurement system which indicates volumic gamma activities such as Co 60 equivalent, fission products and total activity, and validates the last gamma spectrum. The DIMAV equipment allows processing 3-4 spectrums per 150 encapsulated drum, instead of 1 per drum.
- An EPSON computer which analyzes the magnetic tape acquired from the MCA and transfers the analyzed spectra via Modem to a mainframe computer to STMI headquarters, where it is analyzed for validity and authorization.

PRECED 1 Unit

The PRECED 1 unit started operations in 1985 for active materials qualification tests on an industrial scale, at the Tricastin Nuclear Power Plant.

The PRECED 1 unit consists of: the system itself, which is placed inside the encapsulation room with the aid of an electrical tow truck; a service semi-trailer, with a removable shelter which houses the monitoring and control panel; a polymer storage tank located on another semi-trailer, equipped with a centrifugal pump (total volume of tank is 22 $m^3$, i.e., 780 $ft^3$).

The PRECED system includes a five position shielded tunnel into which the liners used for resin encapsulation are introduced.

The liner, which may be sealed in a concrete container or placed into a recoverable cask, is loaded into the system (Po position) with an existing plant (10 T max load) crane used in general waste handling. Then it moves to the other positions by means of a motorized roller conveyor. Above P1 tunnel position, a spent ion exchange resins dosing vessel is fed with a membrane pump. The resins are lowered into this vessel and then transferred to the liner through a screw conveyor. The loaded resins are then weighed with the drum in order to adjust the right quantity of polymer and catalysts to be added. These resins are poured into the liner through a volumetric pump and then mixed with a non-recoverable device in order to meet an average encapsulation efficiency of 65%.

The roller coveyor then carries the liner to P2 position, where a first temperature of polymerisation checking is performed while the polymer gelifies. In P3 position, after a final polymerisation, the liner is shielded and sealed with a predetermined thickness of lead shot with additional polymer mixture. The processed liner is handled by the crane in P4 position. Thirty minutes are needed to achieve a sealed processed drum, so that an average 12 drums per eight hour shift can be performed.

As with COMET units, four different classes of shielded concrete containers, designed by PEC and STMI, allow the encapsulation of resins with the same ranges of volumic activities. In the same way, DIMAV and DIANE devices, hereabove described, are used for measuring those volumic activities.

The encapsulation process performed in PRECED 1 units, is based on Dow Chemical polymer utilization. PEC Engineering has performed a complementary qualification program, in conjunction with EDF, in order to determine the limits of applicability of this process with PRECED 1 unit. The waste characterization program, to meet both ANDRA and SCISN requirements, is now being performed.

After a first testing phase in an EDF nuclear power plant, PRECED 1 machine has been modified and optimized. Those modifications included mainly the measurements and checking devices, and the liners sealing device. The PRECED 1 unit started again in industrial operation in January 1986.

The basic dimensions of PRECED 1 are:

| | | |
|---|---|---|
| Weight: | 100,000 lbs | (46 tons) |
| On Site Dimensions: | 24' 4" | ( 7.5 m) |
| | 7' 10" | ( 2.40 m) |
| | 10' 6" H | ( 3.20 m) |
| Transport dimensions: | 40' | (12.00 m) |
| | 6' 2" | ( 2.50 m) |
| | 13' H | ( 4.0 m) |

COMPREHENSIVE PROCESSING SERVICES PERFORMED BY STMI

Personnel

STMI's teams have been increasing their efficiency in mobile waste processing operations since 1981. The project and operational team consists of:

One project management team, working in STMI's main office, in charge of organizing the operations, managing the stocks of products to be used, and drawing the final balance of any on-site operation performed. This project management team has been able to draw some conclusions which enabled EDF's services to optimize their equipment and their procedures. Additionally, the hereabove improvements in both COMET and PRECED units have been performed by this management team, who also generated the safety report, the operation procedures and the quality assurance program.

The operating teams, in charge of running and maintaining the equipment. Each team consists of five operators: one site operator--team leader; two senior technicians in charge of operating the control panel and the DIANE measurement device; and two operators for chemical preparation and drum handling.

A Cost Effective Service

Transportation: road transportation trailers are all in compliance with French regulations transportation sizes.

Shipment: the packages have been designed in compliance with shipping requirements so that the dose-rate can always be kept below 200 mrem/hr close to the concrete container or the cask, and below 10 mrem/hr at a 2 m (6' 6") distance.

Measurement equipment: DIMAV and DIANE devices give a large benefit in reducing the number of gamma spectrums to be performed and validating them in a short time.

REGULATORY AND SAFETY COMPLIANCE

COMET and PRECED documents include a safety report, including both design and operation aspects, showing their compliance with safety requirements from EDF services and SCSIN for operations in nuclear plants.

The encapsulation matrix comply with French regulations in the following aspects: mechanical resistance; integrated gamma exposure; thermal degradation; and leachability.

OPERATION RESULTS

Spent resins from different demineralizers are transfered into two 9 $m^3$ (315 $ft^3$) storage tanks in the auxiliary building. Those vessels correspond to a twin 900 MWe power plant. One operation can include one, two or three auxiliary buildings, depending on the site.

To date, STMI has achieved its 30th operation with an encapsulation mobile unit, which corresponds to the 48th auxiliary building. About 500 $m^3$ (i.e., more than 17,500 $ft^3$) have been encapsulated.

In 32 auxiliary buildings operations, corresponding to about 400 $m^3$ (i.e., 13,100 $ft^3$), STMI has encapsulated:

- 2,300 $ft^3$ (65 $m^3$) of spent resins coming from 76 chemical volumetric control systems demineralizers

- 61,800 $ft^3$ (175 $m^3$) of spent resins coming from 117 BRS demineralizers
- 2,100 $ft^3$ (60 $m^3$) of spent resins coming from 40 (pool treatment) demineralizers
- 180 $ft^3$ (5 $m^3$) of spent resins coming from 3 BDS demineralizers
- about 3,500 $ft^3$ (100 $m^3$) of spent resins coming from 32 LWS demineralizers.

STMI has been able to draw conclusions about the average distribution of those resins depending on their origin, their activity range and their isotopic content.

The average volumic distribution range corresponding to 3762 encapsulated drums in 21 operations (34 auxiliary buildings) is given below:

| Equivalent Co 60 Volume Activity | | Number of Liners | % |
|---|---|---|---|
| (0-400 mCi/$ft^3$) | 0 - 20 Ci/$m^3$ | 1835 | 49 |
| (400-1100 mCi/$ft^3$) | 20 - 40 Ci/$m^3$ | 27 | 1 |
| (1100-2800 mCi/$ft^3$) | 40 - 100 Ci/$m^3$ | 1515 | 40 |
| (2800-8500 mCi/$ft^3$) | 100 - 300 Ci/$m^3$ | 385 | 10 |
| | | 3762 | 100 |

Those 3,800 drums represent more than 22,000 Ci (810 TBq), and have the following average isotopic distribution:

| | |
|---|---|
| Mn 54 | 4% |
| Co 58 | 45% |
| Co 60 | 36% |
| Ag 110 m | 2% |
| Sb 124 | 3% |
| Cs 134 | 4% |
| Cs 137 | 6% |

This distribution is an average range taking into account the statistics depending on resin origin, their storage time in the plant, and the age of the plant.

The medium activity per drum falls between 0.01 Ci and 30 Ci (0,370 GBq and 1110 GBq) with a medium value of 8 Ci per drum (296 GBq). With such a range, STMI's operators have always been looking for using the less important shielded container, according to transport and storage regulations. For this purpose, the encapsulated activity is monitored with DIMAV device, which also indicates which concrete container must be used. This allows STMI to provide a more cost-effective service to EDF.

The total dose exposure to STMI personnel, both operators and trainees, for 21 operations in which 3,648 drums have been processed is 45,979 mrem. This represents an average 12.6 man mrem/processed drum, or 2.1 mrem per operator and per drum. This integrated dose exposure is due 65% to normal operations and 35% to incidental operations as an average. Those incidents, essentially the clogging of the inlet pipe of the pump by foreign materials, took place in the first operations and can be reduced now by both improving the operating procedures and monitoring the inlet pipe by the porthole equipped with a video system. For this purpose STMI improved the pump skid by designing a rinsing system for any portion of the pumping circuit, operated by remote controlled electrovalves.

STMI could meet such a relatively low exposure because of the care given by its operators to follow the operating procedures and the Q.A. manual corresponding to these operations. Using this same care, the improvements brought by STMI to the design of the machines and the operating procedures, so that the improvements in EDF's plants on STMI's suggestions, have also been a fact of dose reduction for STMI's personnel.

Thus, the experience feedback from the first years of operation allowed STMI's Technical Division:

To design COMET 2 machine with some improvements compared to COMET 1, and to modify COMET 1 with those same improvements. The main purpose of these modifications was to have a better functional layout of different equipment, more accessible equipment in case of an incident or for maintenance, for more safety and personnel radioprotection in some operations, and a better distribution of the shieldings.

To design and operate DIMAV and DIANE industrial measuring devices which enable money savings for both EDF and STMI.

To provide STMI's feedback experience to PEC Engineering in the design of PRECED 1 unit, mostly in safety, radioprotection and easier operation. Thus, STMI, in conjunction with PEC Engineering, could also provide experienced improvements for the modifications of PRECED 1 unit after its first operation.

And last, to supply EDF's design and production services with experienced reports which enabled them to modify the connecting in-plant systems to the machines, in 900 MWe power plants, or to design optimized ones for the 1300 MWe power plants.

In conclusion, the spent resins encapsulation operation in EDF plants with mobile units has now reached its adult age. Moreover, the close cooperation between STMI and EDF, always allows new improvements in design and operations.